Pasture-Forage Management Strategies Following Drought Conditions

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Effects of the Precipitation Shortage during 2002

Most of western North Dakota experienced below-average herbage production on perennial grass spring pastures, native rangeland pastures, and grass and alfalfa haylands during 2002. Climatic conditions received most of the blame for these reductions, although herbage production is affected by management practices as well as by the level of precipitation in relation to normal amounts.

The majority of the state's western region was dry during the late summer and fall of 2001 and cool during the spring of 2002. The dry fall resulted in reduced fall tiller growth, with an average of fewer than 1.5 leaves per tiller. Tillers of cool-season grasses require about 2.5 fall leaves for normal herbage production the following year. Cold nights and cool days during the spring resulted in a moderate reduction in the daily grass growth rate. The combination of a dry fall and cool spring was responsible for a portion of the reduction in herbage biomass in the region.

The amount of herbage biomass reduction resulting from just the combination of restricted growth of fall tillers during the late season of 2001 and the slightly reduced rate of grass growth during the spring of 2002 was not great enough to change grazing dates or stocking rates on pastures that had been properly managed and had healthy plants. The annual development of healthy grass plants occurred within the normal range of dates during the spring of 2002, with a delay of only 3 to 7 days from the average date. However, in some areas large reductions in herbage occurred because the dry fall and cool spring magnified existing problems caused by detrimental management practices.

In addition, parts of western North Dakota received below-normal precipitation during the spring and summer of 2002. Large areas south of Interstate 94 had various levels of water stress, and several areas in south central North Dakota experienced drought or near-drought conditions. The below-normal precipitation further restricted herbage production on pastures and haylands in these areas and created additional problems.

The average peak herbage biomass in late July has a direct relationship with the long-term mean precipitation of an area. Percentages of herbage reduction in healthy plants are proportional to the levels of precipitation reduction below the normal range. When reductions in herbage production occur, adjustments in stocking rate are necessary. The required percent reduction in the stocking rate on pastures with healthy plants can be extrapolated from the percent reduction in peak herbage biomass. The percent reduction in peak herbage biomass can be estimated by a comparison between the local long-term mean precipitation received during January through July and the current year's precipitation for that period. The procedure to estimate percent reduction in stocking rate during drought conditions is presented in Appendix A.

Reductions in the January through July precipitation levels during 2002 generally ranged from 0 percent to 26 percent below normal. The following list of locations includes the long-term January through July precipitation, the 2002 January through July precipitation as a percent of the long-term seasonal mean, and the estimated percent reduction in stocking rate needed on healthy pastures in each area:
Williston (9.8 inches, 101 percent, 0 percent), Watford City (9.7 inches, 116 percent, 0 percent), Manning (10.3 inches, 139 percent, 0 percent), Dickinson (11 inches, 114 percent, 0 percent), Beulah-Hazen (11 inches, 86 percent, 0 percent), Bismarck (10.7 inches, 67 percent, 8 percent), Bowman (10.7 inches, 73 percent, 2 percent), Hettinger (10.5 inches, 54 percent, 21 percent), and Shields (11.5 inches, 49 percent, 26 percent).

Estimates of reduced herbage production in the Northern Plains during the 2002 growing season were much greater than the reductions in precipitation, ranging from 25 percent to greater than 60 percent. The additional reductions in herbage biomass were caused by the ineffectiveness of traditional management practices in meeting the biological requirements of the plants and by the resulting deterioration of plant health status. During growing seasons with below-normal precipitation, traditional management practices intensify the problems caused by water stress in plants and add to the economic hardships created by reduced precipitation levels. Plants with diminished health status are affected more severely than healthy plants during periods of below-normal precipitation, and the biological inefficiency of traditional practices leads to reduced herbage and nutrient production. In addition, because of their diminished health status, plants on pastures managed with traditional practices recover more slowly from drought conditions than healthy plants do.

The herbage reductions that result from the combination of below-average precipitation and biologically inefficient traditional management practices pressure ranches without drought forage plans into using ‘emergency’ practices that generally include grazing grass residue on domesticated grass spring pastures, on summer pastures, and on grass haylands. These emergency grazing practices are commonly assumed to be less costly than the purchase of additional hay because of lower cash-flow costs, but during the two or three seasons following drought growing seasons, the biological and financial costs of these practices will be evident in reduced production of herbage weight and subsequent reduction in pounds of calf per acre.

Emergency grazing practices negatively affect perennial grasses. Grasses reproduce primarily by vegetative tillering from axillary buds on the crowns of established plants. Survival of perennial grasses through the winter and their regrowth in the spring depend on the plants’ ability to store sufficient nutrients during the latter portion of the growing season.

The quantity of carbohydrates stored during the winter hardening process, which occurs between mid-August and mid-October, is closely related to the amount of active leaf material on each tiller. Emergency drought grazing practices can remove enough leaf material to diminish the quantity of carbohydrates stored. Under these conditions, some tillers may not survive until spring, and plants that do will produce tillers with reduced height and weight.

Reductions in height during the succeeding growing season can range from 17 to 43 percent. Reductions in herbage weight are related to the severity of the grazing, with most pastures producing 50 percent or less of their normal herbage weight. Ranches that implemented emergency grazing practices during 2002 should be prepared for delayed grass growth-stage development and diminished herbage production during the upcoming grazing season and for the necessary stocking rate reduction. The procedures to estimate stocking rates based on herbage weight adjusted for the effects of drought conditions are presented in Appendix B.

Selection of Forage Types to Compensate for the Shortfall in Herbage Biomass

The Quantity of Herbage Biomass Shortfall

The quantity of reduction in perennial plant herbage production during the growing seasons following a drought season depends on the type of management used during previous years and on the severity of grazing pressure during the drought season.

Perennial grass pastures managed with biologically effective grazing strategies had herbage reductions about equal to the percent reduction in precipitation below normal during the drought growing season of 2002. The herbage production on these pastures will be near normal levels during the following growing season; if a small reduction in herbage production occurs, it may not require a reduction in stocking rate.

Domesticated perennial grass pastures, native rangeland pastures, and grass and alfalfa haylands previously managed by traditional management practices had herbage biomass reductions greater than the percent reduction below average precipitation during the drought growing season of 2002. Perennial plants on these pastures and haylands will require one to two years to recover. Herbage biomass production will be below normal during the recovery period, and a reduction in stocking rate will be necessary.

Perennial grass pastures and haylands used for emergency grazing during the drought growing season of 2002 will require two to four years to recover. Herbage biomass production will be below normal during the recovery period. Grass growth-stage development will be delayed by two to six weeks during the first recovery season, depending on the time of year of the emergency grazing and on its severity.

The quantity of the herbage biomass shortfall will be the difference between the amount of estimated forage produced on perennial grass pastures (from the procedures in Appendix B) and the total amount required by the cow herd. Modern fast-growing, high-performance cattle are genetically different from the old-style cattle and have higher nutrient requirements. Modern cattle have higher rates of weight gain, produce greater quantities of milk, are larger and weigh more, and deposit less fat on their bodies. Because of the higher production level and reduced body fat, the modern animal performs best when all of the required quantities of nutrients are provided throughout the production year. The procedure to estimate the nutrient requirements of cows is presented in Appendix C.

Forage Dry Matter and Crude Protein Costs

Producers facing herbage reductions and a shortfall in herbage biomass will need additional sources of forage. Numerous types of annual forage plants can provide the forage required by livestock during the time perennial plants need to recover from drought stress and emergency-grazing pressure.

Annual forage pastures can be grazed. Seeded annual cereals like oats, forage barley, or foxtail millet can be successfully grazed between the fourth- or fifth-leaf stage and the flowering stage and can be used for additional early and mid-season grazing. Spring-seeded winter cereals like winter rye, winter wheat, or winter triticale can serve as forage for additional late-season grazing.

Perennial grass and annual cereal and legume types harvested as hay can fill the forage needs created by the shortfall in herbage biomass. Selection of forage types that provide low-cost livestock forage can be made based on the cost per pound of crude protein or from the total feed cost or cost per day during the spring, summer, and fall portions of the lactation production period. A recent study evaluated these costs for several harvested-forage types, and the results are summarized below. Costs for perennial grass and annual cereal and legume hays are shown in Tables 1 and 2. Forage-feed costs during the spring, summer, and fall portions of the lactation production periods are shown in Tables 3-5.

The cost of harvested forage is affected by the efficiency of the harvest strategy and by the quantity of nutrients captured relative to the potential quantity of nutrients produced. Forage management treatments and forage types can be evaluated accurately by comparisons based on the costs per unit of nutrient.

Perennial grass hay has been the major harvested-forage type used as feed for beef cows in the Northern Plains. Traditionally, crested wheatgrass and smooth bromegrass--domesticated perennial grass hays--are cut late, after the seed heads have developed and plants have reached maximum height. This practice yields about the year's potential amount of forage dry matter per acre, about 300 pounds per acre more dry matter than harvesting at the boot stage does. However, the quantity of crude protein captured per acre in mature hay was only a little more than half the quantity of crude protein captured per acre in hay cut at the boot stage. Forage dry matter costs were $34.80 per ton for mature hay and $40.80 per ton for hay cut at the boot stage. Crude protein costs were $0.28 per pound for mature hay and $0.14 per pound for early cut hay. Mature domesticated perennial grass hay is expensive livestock feed because it has high costs per pound of crude protein.

Annual cereal hays of forage barley and oat forage cut at the milk stage or hard dough stage had high production costs that ranged from $68 to $75 per acre. However, the forage dry matter costs and crude protein costs were relatively low. Forage dry matter costs ranged between $26 and $30 per ton, and crude protein costs ranged between $0.11 and $0.17 per pound. The early cut annual cereal hays captured greater pounds of crude protein per acre than the late-cut hays, and the cost per pound of crude protein was lower for the early cut annual cereal hays.

Annual legume hays of pea forage and forage lentil cut at early and late plant growth stages and oat-pea forage had high production costs that ranged from $60 to $96 per acre. The forage dry matter costs ranged from $37 to $72 per ton. The late-cut annual legume hays had lower dry matter costs than the early cut legume hays. Crude protein costs were relatively low for all annual legume hays and ranged from $0.13 to $0.17 per pound. Late-cut annual legume hays captured greater pounds of crude protein per acre and had lower crude protein costs than the early cut annual legume hays.

Table 1. Forage dry matter biomass and crude protein yield and costs for crested wheatgrass hay cut at two growth stages.

	Costs/acre								
	Land Rent	Custom Work	Baling Costs	Production Costs $/ac	Forage Biomass Yield lb/ac	Forage Biomass Costs $/ton	Crude Protein %	Crude Protein Yield lb/ac	Crude Protein Costs $/lb
Crested Wheatgrass									
Mature	14.22	5.31	8.58	28.11	1600	34.80	6.4	102	0.28
Boot stage	14.22	5.31	6.97	26.50	1300	40.80	14.5	189	0.14

Table 2. Forage dry matter biomass and crude protein yield and costs for annual cereal and annual legume hays.

	Costs/acre									
	Land Rent	Custom Work	Seed Costs	Baling Costs	Production Costs $/ac	Forage Biomass Yield lb/ac	Forage Biomass Costs $/ton	Crude Protein %	Crude Protein Yield lb/ac	Crude Protein Costs $/lb
Forage Barley Milk	22.07	16.08	4.69	25.37	68.21	4733	28.80	13.0	606	0.11
Forage Barley Hard Do.	22.07	16.08	4.69	27.51	70.35	5133	27.40	9.2	468	0.15
Oat Forage Milk	22.07	16.08	6.00	25.02	69.17	4667	29.60	11.5	535	0.13
Oat Forage Hard Do.	22.07	16.08	6.00	30.38	74.53	5667	26.40	7.8	435	0.17
Pea Forage Early	22.07	16.08	23.80	15.01	79.96	2800	55.00	18.9	526	0.15
Pea Forage Late	22.07	16.08	23.80	24.92	86.87	4650	37.40	14.4	685	0.13
Forage Lentil Early	22.07	16.08	12.60	8.94	59.69	1667	71.60	21.8	361	0.17
Forage Lentil Late	22.07	16.08	12.60	20.73	71.48	3867	37.00	14.7	567	0.13
Oat-pea Forage Hay	22.07	16.08	29.80	27.57	95.52	5143	37.20	12.5	611	0.16

Total Harvested-Forage Feed Costs

Total forage-feed costs during the 31-day spring portion of the lactation production period ranged between $13.24 per period, or $0.43 per day, and $28.97 per period, or $0.93 per day. Mature crested wheatgrass hay was expensive at $0.93 per day and had the highest harvested-forage hay costs. Early cut pea forage hay and early cut forage lentil hay were expensive forages, with costs greater than $20.00 per period or $0.65 per day. The other harvested-forage types had costs lower than $18.00 per period or $0.58 per day. Late-cut forage barley hay, early cut forage barley hay, and early cut oat forage hay had the lowest costs, at less than $15.00 per period or $0.48 per day.

Total forage-feed costs during the 137-day summer portion of the lactation production period ranged between $58.53 per period, or $0.43 per day, and $128.04 per period, or $0.93 per day. Mature crested wheatgrass hay was expensive at $0.93 per day and had the highest harvested-forage hay costs. Early cut pea forage hay and early cut forage lentil hay were expensive forages, with costs greater than $90.00 per period or $0.65 per day. The other harvested-forage types had costs lower than $80.00 per period or $0.58 per day. Late-cut forage barley hay, early cut forage barley hay, and early cut oat forage hay had the lowest costs, at less than $65.00 per period or $0.48 per day.

Total forage-feed costs during the 30-day fall portion of the lactation production period ranged between $12.82 per period, or $0.43 per day, and $28.02 per period, or $0.93 per day. Mature crested wheatgrass hay was expensive at $0.93 per day and had the highest harvested-forage hay costs. Early cut pea forage hay and early cut forage lentil hay were expensive forages, with costs greater than $20.00 per period or $0.65 per day. The other harvested-forage types had costs lower than $18.00 per period or $0.58 per day. Forage barley hay and early cut oat forage hay had the lowest costs, at less than $14.50 per period or $0.48 per day.

Some harvested forages had high livestock feed costs because the quantity of nutrients captured per acre was relatively small. Several harvested forages had low livestock feed costs because the quantity of nutrients efficiently captured per acre was high in relation to the forage production costs. Mature crested wheatgrass hay had the highest harvested-forage hay costs, and forage barley hay and early cut oat forage hay had the lowest harvested-forage hay costs.

Evaluation of Harvested-Forage Costs

Production costs per acre for harvested forages were greater than pasture rent per acre. Production costs per acre for annual cereal and annual legume hays were considerably greater than those for perennial grass hay. However, neither production costs per acre nor pasture rent per acre accurately reflects livestock production costs because forage dry matter weight per acre and nutrient weight per acre captured through grazing or haying vary with forage type and plant growth stage, and the variations are not proportional to these per-acre costs.

The costs per unit of forage dry matter reflect the relationships between the pasture rent per acre or production costs per acre and the amount of dry matter consumed by grazing livestock or harvested for hay. Forage dry matter costs per unit of weight do not accurately reflect livestock production costs because of the variable quantity of nutrients contained within the dry matter and the resulting differences in the amount of dry matter needed to provide adequate quantities of nutrients for livestock.

Cost per unit of nutrient is an important indicator of livestock pasture-forage costs. Nutrient cost per unit of weight is related to the forage dry matter cost and the quantity of nutrients per unit of forage weight. Crude protein costs for early cut perennial grass hay and annual cereal hays were lower than crude protein costs for the same forage types cut late. Crude protein costs for late-cut annual legume hays were lower than crude protein costs for the same forage types cut early.

Land area per animal unit has not been traditionally recognized as an important factor in beef production costs. Land area required to produce one month of forage from harvested forages was relatively small. Crested wheatgrass hay cut at a mature plant stage required the larger land area, and forage barley cut at the milk stage, pea forage cut late, and oat-pea hay required the smaller land areas. With greater amounts of the produced nutrients captured from a land base, the land area required by an animal unit becomes smaller and the pasture-forage production costs become lower.

Table 3. Forage-feed costs during the spring portion of the lactation production period.

	Land Area ac/pp	Forage Dry Matter $/ton	Crude Protein $/lb	Forage Cost $/pp	Supplement Cost $/pp	Total Feed Cost $/pp	Cost per Day $/d
Crested Wheatgrass Mature	0.58	34.80	0.28	21.70	7.27	28.97	0.93
Crested Wheatgrass Boot Stage	0.41	40.80	0.14	10.85	6.88	17.73	0.57
Forage Barley Milk	0.13	28.80	0.11	8.68	5.80	14.48	0.47
Forage Barley Hard Do.	0.16	27.40	0.15	11.78	1.46	13.24	0.43
Oat Forage Milk	0.14	29.60	0.13	10.23	4.45	14.68	0.47
Oat Forage Hard Do.	0.16	26.40	0.17	13.33	3.72	17.05	0.55
Pea Forage Early	0.15	55.00	0.15	11.78	9.06	20.84	0.67
Pea Forage Late	0.12	37.40	0.13	10.23	6.84	17.07	0.55
Forage Lentil Early	0.34	71.60	0.17	13.33	10.04	23.37	0.75
Forage Lentil Late	0.14	37.00	0.13	10.23	7.00	17.23	0.56
Oat-Pea Forage Hay	0.12	37.20	0.16	11.78	5.37	17.15	0.55

Table 4. Forage-feed costs during the summer portion of the lactation production period.

	Land Area ac/pp	Forage Dry Matter $/ton	Crude Protein $/lb	Forage Cost $/pp	Supplement Cost $/pp	Total Feed Cost $/pp	Cost per Day $/d
Crested Wheatgrass Mature	2.57	34.80	0.28	95.90	32.14	128.04	0.93
Crested Wheatgrass Boot Stage	1.82	40.80	0.14	47.95	30.42	78.37	0.57
Forage Barley Milk	0.56	28.80	0.11	38.36	25.65	64.01	0.47
Forage Barley Hard Do.	0.73	27.40	0.15	56.06	6.47	58.53	0.43
Oat Forage Milk	0.64	29.60	0.13	45.21	19.66	64.87	0.47
Oat Forage Hard Do.	0.73	26.40	0.17	58.91	16.44	75.35	0.55
Pea Forage Early	0.65	55.00	0.15	52.06	40.04	92.10	0.67
Pea Forage Late	0.51	37.40	0.13	45.21	30.21	75.42	0.55
Forage Lentil Early	0.95	71.60	0.17	58.91	44.35	103.26	0.75
Forage Lentil Late	0.60	37.00	0.13	45.21	30.93	76.14	0.56
Oat-Pea Forage Hay	0.53	37.20	0.16	52.06	23.74	75.80	0.55

Table 5. Forage-feed costs during the fall portion of the lactation production period.

	Land Area ac/pp	Forage Dry Matter $/ton	Crude Protein $/lb	Forage Cost $/pp	Supplement Cost $/pp	Total Feed Cost $/pp	Cost per Day $/d
Crested Wheatgrass Mature	0.56	34.80	0.28	21.00	7.02	28.02	0.93
Crested Wheatgrass Boot Stage	0.40	40.80	0.14	10.50	6.66	17.16	0.57
Forage Barley Milk	0.12	28.80	0.11	8.40	5.62	14.02	0.47
Forage Barley Hard Do.	0.16	27.40	0.15	11.40	1.42	12.82	0.43
Oat Forage Milk	0.14	29.60	0.13	9.90	4.31	14.21	0.47
Oat Forage Hard Do.	0.16	26.40	0.17	12.90	3.60	16.50	0.55
Pea Forage Early	0.14	55.00	0.15	11.40	8.79	20.19	0.67
Pea Forage Late	0.11	37.40	0.13	9.90	6.62	16.52	0.55
Forage Lentil Early	0.21	71.60	0.17	12.90	9.71	22.61	0.75
Forage Lentil Late	0.13	37.00	0.13	9.90	6.77	16.67	0.56
Oat-Pea Forage Hay	0.12	37.20	0.16	11.40	5.20	16.60	0.55

Forage costs per day and per production period for early cut crested wheatgrass hay were about half the forage costs for mature-cut crested wheatgrass hay. The forage costs for early cut annual cereal hays were lower than the forage costs for late-cut annual cereal hays. The forage costs for late-cut annual legume hays were lower than the forage costs for early cut annual legume hays. The forage costs for oat-pea hay were similar to the forage costs for late-cut annual cereal hays and early cut legume hays.

Perennial grass hays yield greater pounds of crude protein per acre when harvested during early developmental stages, around the boot stage to flowering stage. Annual cereal hays yield greater pounds of crude protein per acre when harvested during early developmental stages, around the flowering stage to late milk stage. Annual legume hays generally yield greater pounds of crude protein per acre when harvested during the middle and late stages of development. Cereal-legume mixed hays have generally not produced greater quantities of forage dry matter or pounds of crude protein per acre than have annual cereals or annual legumes seeded separately, because of the differences in the optimum times to harvest annual cereals and annual legumes. Cutting forage hays at their optimum harvest times reduces livestock forage costs per day and per production period because the cost per pound of crude protein is lower when greater pounds of crude protein per acre are captured during harvest.

Harvested forages are usually viewed as expensive feeds because the production costs per acre are greater than pasture rent per acre and because a high percentage of the harvested-forage production costs consist of labor and equipment costs. Some harvested forages are expensive, but not all harvested forages are high-cost feeds. Harvested forages cut at plant stages that yield great amounts of dry matter and low amounts of crude protein per acre have high costs per unit of nutrient and are generally expensive forages that increase livestock production costs. However, harvested forages cut at plant stages that yield great amounts of crude protein per acre have lower costs per unit of nutrient and are relatively low-cost forages that help reduce livestock production costs. The cost of harvested forage is affected by the efficiency of the harvest strategy and by the quantity of nutrients captured relative to the potential quantity of nutrients produced. Early crested wheatgrass, early forage barley, early oat forage, late pea forage, late forage lentil, and oat-pea forage have crude protein costs below $0.25/lb and total feed costs below $0.62/day. These harvested forages can provide the low-cost livestock feed needed to compensate for the shortfall in herbage biomass production that occurs on traditionally managed perennial grass pastures during the period plants require to recover from drought conditions.

Development of Biologically Effective Grazing Management to Reduce the Effects of Future Drought Conditions

Effective Grazing Management Beneficially Manipulates Grass Plant Growth

Grasses have developed specialized growth characteristics and biological processes in response to a long history of grazing. Producers can manipulate these processes to enhance grass herbage production and reduce pasture and forage costs.

Unlike plants such as trees, shrubs, and forbs, which grow with the youngest cells at the shoot tips, grass plants have the oldest cells at the leaf tip. Grazing animals can remove portions of a grass leaf without stopping the growth of the shoot. Leaves may continue to grow from existing buds and from new leaf buds developed in the shoot's apical meristem, or growing point. The apical meristem remains close to the ground and below the reach of the grazing animal when the shoot is in the vegetative, or non-flowering, phase. This growth structure makes grasses well adapted to grazing.

Grass plants consist of tillers, which have shoots and roots. Each shoot is made up of units with four parts:

1. a leaf, consisting of a blade and sheath, with a collar separating the two structures;
2. a node, the point of leaf attachment to the stem;
3. an internode, the length of stem between two nodes; and
4. an axillary bud, the area of tissue that can develop into a new shoot.

The crown of a grass plant is the lower portion of a shoot and has at least two nodes that can produce roots. Before flower development, the shoot consists of several closely spaced nodes. The node at the top, or apex, of the stem is the location of the shoot's apical meristem, an area of new cell formation. The cells in this area can develop into either leaf buds or flower buds, depending on the stage of the shoot. Leaves form on alternating sides of the shoot, with the oldest leaf outermost and each new leaf growing upward, protected by the surrounding sheaths of the lower leaves. The leaf grows as the cells' size and weight increase, beginning with cells at the tip of the blade.

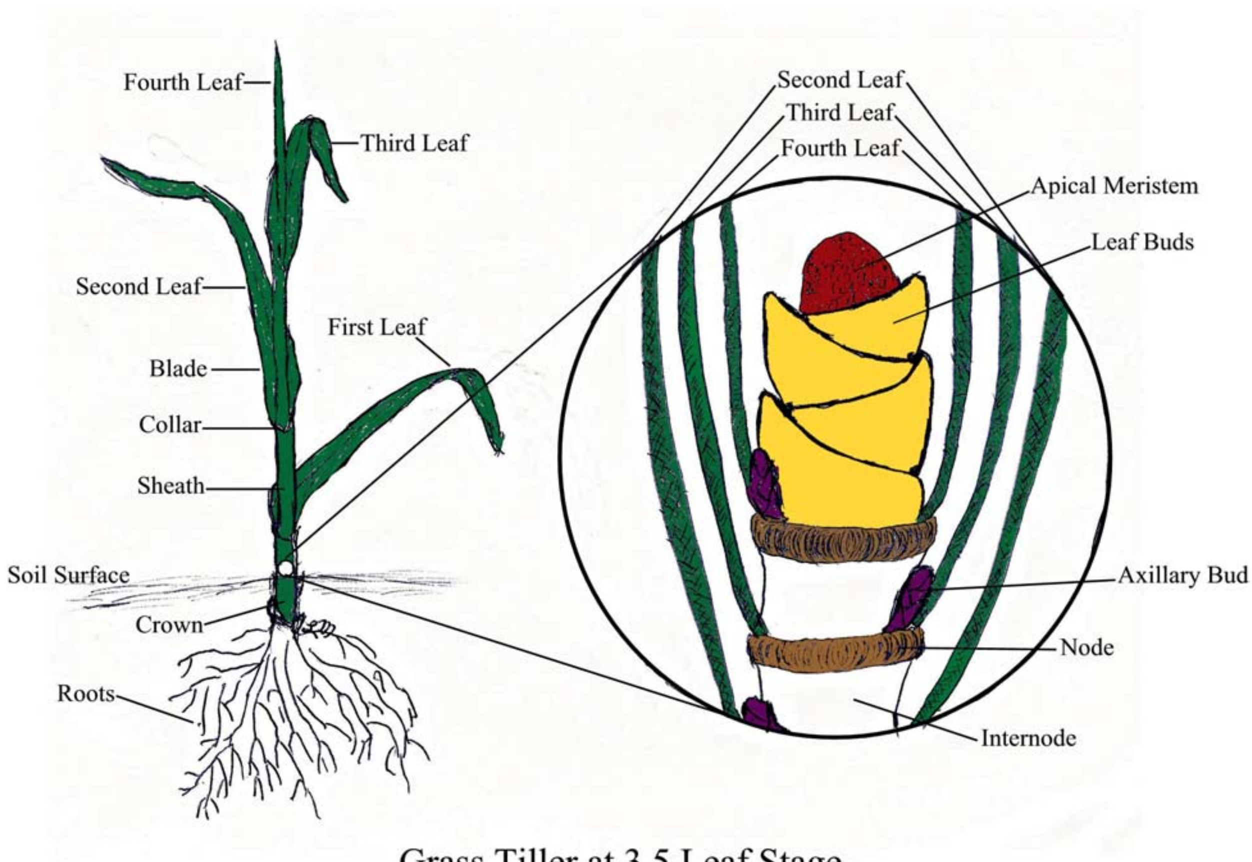
Even with this specialized form, grass plants can be damaged if too much material is removed by grazing or if grazing occurs too early or too late in the season. Grazing that deprives the shoot of sufficient leaf area to support the tiller or that removes leaf buds or the apical meristem has the potential to stop the growth of the shoot and limit herbage production for the season.

The grass shoot's production of three to three and a half new leaves during the growing season is important. When the shoot reaches the third-leaf stage, the apical meristem begins to produce flower buds rather than leaf buds, although previously formed leaf buds continue to grow and develop. Defoliation of leaf material before the shoot has reached this stage can disrupt the formation of leaf buds and leaves for the shoot, weaken the plant, and diminish the plant's ability to produce herbage. Most native cool-season grasses reach the third-leaf stage around early June, and most native warm-season grasses follow in about two weeks.

Defoliation of the shoot that has reached the third-leaf stage can stimulate the natural biological processes grass plants have developed in response to grazing. These processes include stimulation of vegetative reproduction, the growth of new tillers from the grazed shoot's axillary buds. Properly timed grazing that removes only a small portion of the leaf activates beneficial processes that can result in a 30 to 45 percent increase in herbage production.

Changes in day length trigger the shoot to begin flowering, the process of sexual reproduction. The first external sign of flower stalk development is the swelling of the sheath that encloses the flower head. This stage of grass plant development, referred to as the "boot" stage, marks the shoot's transition from the vegetative to the reproductive stage. Most cool-season plants enter the reproductive stage before June 21, the longest day of the year, and most warm-season plants enter the reproductive stage after June 21. Flowering, fertilization, and the formation of seeds soon follow.

Plants need not produce viable seed each year for a grassland to remain healthy. In North American prairies, the primary form of grass reproduction is vegetative, and defoliation management designed to enhance sexual reproduction through seed production does little to improve the prairie ecosystem and increase herbage production. Strategies that defer grazing until after seeds have developed are neither biologically nor economically sound.



Grass Tiller at 3.5 Leaf Stage

The nutritional quality of the grass diminishes sharply after the flowering stage. On pastures managed to produce grass seed, the growth of secondary tillers has not been stimulated by grazing between the third-leaf and the flowering stage, so the quantity and quality of herbage produced are lower than the quantity and quality of herbage produced on rotation pastures. Deferring grazing to allow seed production decreases livestock returns. The energy and resources directed toward sexual propagation could be better directed into vegetative tiller production.

Implementing grazing management strategies that begin grazing after plants reach the third-leaf stage and that coordinate rotation grazing periods with grass growth stages can improve plant health and activate beneficial plant processes. These biologically effective management strategies result in increased herbage production and, in turn, in reduced pasture and forage costs.

Delaying Grazing until after Plants Reach the Third-Leaf Stage Allows for Greater Herbage Production

Turning livestock onto native range too early in the spring damages plants and limits herbage production by removing leaf area from grass that has not recovered from winter dormancy. This practice reduces the forage available to livestock later in the season and decreases profits.

Grass cannot withstand defoliation before reaching the third-leaf stage, when plants have produced sufficient foliage to support growth. The arrival of plants at the third-leaf stage is the most reliable indicator of when grazing may safely begin. The date on which the third new leaf stage is reached varies by plant type. Most native range cool-season grasses are ready for grazing in early June, and warm-season species are ready for grazing in mid June.

Research shows that starting grazing on native range in early May results in a loss of 75 percent of the potential herbage and that starting grazing in mid May results in a loss of 45 to 60 percent of the potential herbage. These reductions in herbage production lead to reductions in stocking rate, calf average daily gain, calf gain per acre, net returns per cow-calf pair, and net returns per acre. Delaying grazing until early June on rotation grazing systems or until mid June on seasonlong treatments allows for greater growth of the potential herbage production and produces greater economic returns for the cow-calf operation.

Cool-season domesticated grasses can serve as alternative spring forage sources until native range grasses are ready for grazing. Like native range, complementary spring domesticated grass pastures should be grazed only after plants arrive at the third-leaf stage. No perennial grasses develop the third new leaf before late April, but domesticated grass species such as crested wheatgrass and smooth bromegrass reach the third-leaf stage three to five weeks earlier than cool-season native species. Pastures of domesticated grasses can support grazing livestock from early May until grazing on native range can begin safely in early June.

Allowing livestock to graze native range early in the season may seem less costly than feeding livestock harvested hay, but the lower cow-calf gain that results from reductions in native range forage production ultimately yields lower net returns for a cow-calf operation. Coordinating grazing with grass growth stages to meet the biological requirements of grass plants and livestock helps to protect rangeland health and increase profits for beef producers.

Coordinating Grazing Periods with Plant Growth Stages Enhances Grass Growth

Coordinating grazing with grass growth stages to meet the biological requirements of grass plants can enhance plant growth. Carefully timed grazing can stimulate beneficial activity of soil organisms and vegetative reproduction by tillering of grasses. Stimulation of these biological responses can improve the health of grassland ecosystems and increase herbage production.

Grass plants evolved 20 million years ago with early herbivores that are now extinct. During this time, grasses developed biological processes that help the plants withstand and recover from defoliation. This complex of processes, called defoliation resistance mechanisms, accelerates both the growth rate of the grazed plant and its development of foliage and roots. Two biological processes of primary concern to grassland managers are the increased beneficial activity of soil organisms and the stimulation of vegetative reproduction by secondary tiller development from axillary buds.

Plant response to defoliation depends on the amount of material removed and the growth stage of the plant. Removing too much leaf area or grazing too early or too late in the seasonal development of the plant diminishes the plant's ability to recover. Grazing that removes a small amount of leaf area from the grass plant between the third-leaf stage and flowering stage can trigger the beneficial responses.

There is a mutually beneficial relationship between the grass plant's root system and soil organisms. Properly timed grazing can enhance that relationship. The rhizosphere--the narrow zone of soil around the roots of perennial grassland plants--contains bacteria, protozoa, nematodes, mites, springtails, and mycorrhizal fungi. The grass plant's roots release carbon compounds, including sugars, to these organisms, and the organisms release mineral nitrogen that the plant's roots absorb. The mycorrhizal fungi also provide phosphorus, other mineral nutrients, and water that the plant needs for growth. Activity of the soil microorganisms increases with the availability of carbon compounds in the rhizosphere, and the elevated microorganism activity results in an increase in nitrogen available to the grass plant.

Grazing lead tillers between the third-leaf stage and the flowering stage can increase the amount of carbon compounds the defoliated plant releases into the rhizosphere. The increase in nitrogen produced by elevated rates of microorganism activity allows the plant to accelerate growth and recover more quickly from defoliation. This beneficial activity does not seem to occur when grazing is conducted during the middle and late growth stages of the grass plant.

Grazing that removes a small amount of young tissue from the aboveground portion of lead tillers after the three-leaf stage and before the flowering stage reduces the amount of hormone that leaf tissue produces to control the growth of axillary buds on the plant crown. With that growth-controlling hormone reduced, vegetative reproduction is stimulated and secondary tillers develop from the previous year's axillary buds.

If no defoliation occurs, the lead tiller inhibits secondary tiller development through a process called lead tiller dominance. This biological process continues until inhibitory hormone production declines around the flowering stage. Usually only one secondary tiller develops from the potential six to eight axillary buds because this secondary tiller asserts dominance by producing inhibitory hormones.

All grass species in the Northern Plains have strong lead tiller dominance except Kentucky bluegrass and meadow bromegrass, which have low levels of inhibitory hormones and relatively higher levels of tiller development. Plants with weak lead tillers have greater demands for water than do grasses with strong lead tillers. Grasses with strong lead tillers produce one set of lead tillers and one set of secondary tillers. Lead tillers of cool-season grasses begin growth during fall, overwinter, and resume growth the following spring. Proper grazing management can increase the number of secondary tillers that develop, but the growing season length does not permit the development of a third set of tillers.

The number of sets of tillers determines the number of times each pasture in a rotation system can be grazed. Two sets of tillers permit two rotation grazing periods. Rotation systems that graze each pasture more than two times are not coordinated with grass plant growth and do not meet grass plants' biological requirements. Rotating cattle in an arbitrary sequence that is not coordinated with grass plant developmental stages and that does not meet the biological requirements of grassland plants does not produce satisfactory results.

Grassland managers can increase beneficial activity of soil organisms in the rhizosphere and activate secondary tiller development from axillary buds by implementing grazing management strategies that start after the third-leaf stage, have two grazing periods in each of three to six pastures, and coordinate grazing periods with grass growth stages.

Management during the Fall Affects Next Season's Herbage Production

Treating young fall tillers of grasses as a source of bonus late-season forage for grazing livestock can be costly. The fall tillers, which grow from the crowns of perennial grass species between mid August and the end of the active growing season, remain viable over the winter. They continue growth as lead tillers the following spring, producing a high proportion of that season's herbage. Although it's commonly accepted as an innocuous practice, fall grazing has the potential to degrade grassland ecosystems because it can remove or damage fall growth and other leaf material that the grass plant depends on to survive the winter and resume growth the next spring.

Perennial grasses are perpetuated primarily through vegetative reproduction by tillering rather than through sexual reproduction, which is the process of seed production and the uncertain growth of a seedling. Sexual reproduction is the only method by which annual grasses are perpetuated.

Perennial grasses start growth of next year's plants in late summer or early fall during winter hardening--the plants' process of preparing for winter. Warm-season grasses produce a relatively large bud but suspend additional growth until the next spring. Cool-season grasses produce tillers with one and a half to four leaves.

Very few perennial grasses grow from seed in established grasslands. Almost all young plants are tillers that have grown from axillary buds on the crowns of established plants. The tiller is the basic unit of the grass plant. The lead tillers are most conspicuous during the early and mid portions of the growing season as the tillers progress through typical growth stages. After the lead tillers have flowered, secondary tillers can grow from axillary buds.

Secondary tiller growth can be suppressed or stimulated by the timing of grazing periods. Most secondary tillers do not complete their growth cycle during one growing season. Those that have not entered the sexual reproduction stage can overwinter and complete their growth stages the following year as lead tillers. Under some environmental conditions, like severe drought, lead tillers can overwinter and resume growth the following year. Lead tillers that have overwintered progress through their growth stages at abnormal times.

During the later portion of the growing season, the grass plant population consists of mature lead tillers, secondary tillers, and fall tillers. Mature lead tillers that are near the completion of their life cycle and secondary tillers that have developed seed heads will not overwinter but will progress through a natural aging process called senescence. During this aging process, the cell components of the above-ground structures are translocated to below-ground structures. The translocation of cell contents reduces the nutritional quality and the weight of the herbage. The nutritional quality of mature herbage during fall is about 4.8 percent crude protein, which is about half the mid summer quantity. The weight of the herbage is about 40 percent to 60 percent of the herbage weight during mid summer.

Secondary tillers and fall tillers that will overwinter have active leaf material until the end of the growing season when the chlorophyll fades and the leaves lose their green color, appearing brown like the lead tillers that have completed their growth cycle. Perennial grasses remain alive and maintain physiological processes throughout the year, even during the winter. Winter dormancy for perennial grasses is not a period of total inactivity but a period of reduced biological activity. The crown, some portions of the root system, and some leaf tissue remain active by using stored carbohydrates. Survival and spring regrowth of secondary tillers and fall tillers depend on the plant's having adequate carbohydrate reserves.

The quantity of carbohydrates stored during the winter hardening process is closely related to the amount of active leaf material on each tiller. Tillers with abundant leaf area during late summer and early fall can store adequate quantities of carbohydrates to survive the winter and produce robust leaves the following spring. Generally, the greater the number of active leaves on a tiller during the fall, the more robust the plants will be the following spring.

Heavy grazing of grasslands during August to mid October removes sufficient leaf material from secondary and fall tillers that quantities of carbohydrates stored will be low. Tillers with low carbohydrate reserves may not survive until spring. Researchers suspect that fall tillers with fewer than one and a half leaves may be unable to store adequate carbohydrate reserves to survive the winter. Plants that have low carbohydrate reserves and survive the dormancy period produce tillers with reduced height and weight.

The rate at which plants respire, or use, stored carbohydrates during the winter is affected by the amount of insulation that standing plant material and snow provide from the cold winter air temperatures. The greater the amount of insulation, the more slowly the plant draws on its carbohydrate reserves. When the standing herbage on a grassland is grazed short and most of the snow is blown off, very rapid respiration can occur and deplete carbohydrate reserves before spring, causing plant death called "winter kill."

On tillers that have overwintered, the leaf portions with intact cell walls can regreen early in the spring. The leaf portions with ruptured cell walls remain brown. The surviving leaves, with their brown tops and green bases, are most obvious soon after the snow melts. When the current year's early leaf growth has been exposed for several hours to air temperatures below 28°F, it may have large dry portions and appear similar to overwintering leaves.

The green portion of the overwintered leaves provides nourishment from photosynthesis. In combination with remaining stored carbohydrates, the products of photosynthesis support the development and growth of new leaves and roots. The robustness of spring growth in plants that overwinter is dependent on the amount of surviving leaf area.

Removal of the leaf area of the overwintering tillers by grazing during fall or winter deprives developing tillers of a major source of nutrients, increases the demand on low levels of carbohydrate reserves, and results in reduced leaf production. Reductions in leaf height for the major grasses during the succeeding growing season range from 17 percent to 43 percent, and the contribution of herbage weight to the ecosystem biomass is greatly reduced.

The common assumption that grazing perennial grasses after they turn brown following a hard frost will not harm grass plants guides numerous fall grazing practices. This popular belief is not consistent with the biology of grass growth and should not be used as a foundation for grazing management decisions because of the resulting reductions in grass production and increases in pasture-forage costs the following year.

Summary of Biologically Effective Grazing Management Recommendations

Northern Plains beef producers can reduce the impacts of drought conditions and improve profit margins by implementing management strategies that place priorities on meeting the biological requirements of the plants and ecosystem processes. Effective pasture-forage management strategies that improve the quality of the natural resources and increase the value captured from the land are based on three scientific premises:

- Coordinating livestock grazing with specific plant growth stages and seasons of the year beneficially manipulates plant biological processes, stimulates soil organism activity, and enhances the biogeochemical cycles responsible for the flow of nitrogen, carbon, and water through ecosystems. This practice increases the biological effectiveness of management strategies and results in improved plant health and increased herbage production and nutrient flow in grassland ecosystems.

- Harvesting by grazing or mechanical haying of forage plants at the growth stage with the greatest nutrient weight per acre rather than the greatest dry matter weight per acre yields more nitrogen as crude protein and carbon as energy per acre. This practice improves the efficiency of nutrient capture and results in a reduced cost per pound of nutrient and in turn a reduced cost for that forage type as livestock feed.

- Meeting the daily nutritional requirements of modern high-performance livestock all year maintains animal production levels at genetic potentials. This practice improves the efficiency of nutrient conversion into saleable commodities like calf weight and results in stronger animal performance and lower annual pasture-forage costs than practices that overfeed or underfeed nutrients.

Implementing effective 12-month pasture-forage management strategies will result in increased livestock weight gain per acre, reduced livestock production costs, reduced economic impacts during dry growing seasons, increased profit margins from beef production, and an enhanced regional agricultural economy.

Developing biologically effective grazing management strategies that meet the biological requirements of the plants and enhance plant health status is the long-term solution to management-caused herbage reduction problems and will help to reduce the effects of future drought conditions. Levels of herbage reductions during drought conditions are smaller in healthy plants than in weak plants, and healthy plants recover from these conditions more rapidly. Three effective management practices that improve plant health are recommended:

- Begin grazing in the spring only after plants reach the third-leaf stage (early May for crested wheatgrass and smooth bromegrass and early June for native rangeland).

- Coordinate grazing rotation dates with grass growth stages. Plant density increases when secondary tillers are stimulated by grazing for 7 to 17 days during the period between the third-leaf and flowering growth stages (early June to mid July for native rangeland).

- Do not graze spring and summer pastures or haylands during the fall. Fall grazing decreases the carryover secondary tillers and the new fall growth tillers and reduces the amount of herbage biomass produced the following season. The common assumption that grazing perennial plants after a frost does not hurt the plants is incorrect.

Establishing forage contingency plans that decrease or eliminate dependence on emergency grazing measures will also help reduce the effects of growing seasons with below-normal precipitation. One contingency plan suggests that producers annually put up as hay the amount of harvested forage needed that year and put up an additional 10 to 20 percent as haylage. Putting up haylage preserves forage quality for many years and creates a supply for growing seasons in which precipitation levels are below normal and herbage production is inadequate.

Growing seasons with drought conditions should not be considered emergency situations. Drought growing seasons occur with an average frequency of two in every 12 years in the Northern Plains, and ranches with drought forage plans face herbage reductions 16 percent of the time. However, ranches without drought forage plans will experience reduced herbage production with a greater frequency than this. These ranches must contend with herbage reductions not only in the years with below-normal precipitation but also in the following two- to three-year periods of grassland recovery from the stress of emergency grazing. Consequently, for 33 to 50 percent of the years that ranches operate without a drought forage plan, they will have below-normal herbage production and the amount of forage produced will not be adequate to feed a fully stocked cow herd. Grazing management strategies that enhance plant health should be implemented and plans for a contingency supply of forage should be developed before the next growing season with drought conditions.

Dry falls, water stress during growing season months, and summer drought are not abnormal climatic conditions in the Northern Plains. Plant health status, which is affected by management practices, can magnify or diminish the negative effects these reoccurring environmental conditions have on herbage production. During periods of below-normal precipitation, required stocking rate reductions on pastures with healthy plants will reflect forage reductions caused only by the precipitation shortage; required stocking rate reductions on pastures with poor health status will reflect forage reductions caused both by the precipitation shortage and by management practices that are not biologically effective. Management strategies that sustain high levels of plant health help to ensure that the problems accompanying below-normal precipitation are minor incidents rather than catastrophes.

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Appendix A

Procedure to Estimate Percent Reduction in Stocking Rate during Drought Conditions

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Stocking rates are affected by the amount of herbage biomass plants produce. During periods of below-normal precipitation, decreased herbage production may necessitate adjustments in stocking rates. The required percent reduction in the stocking rate can be estimated from the percent reduction in peak herbage biomass in healthy plants.

Effective grazing management can help minimize herbage reductions during periods of below-normal precipitation because herbage production is affected by both the type of management practices used and the level of precipitation in relation to normal amounts. The quantity of herbage biomass produced is related to plant size and plant density. These two characteristics are directly affected by the level of plant health, which is determined by the biological effectiveness of the management strategy used.

Management practices that do not meet the biological requirements of the plants slow plant processes. The resulting deterioration in the level of plant health is manifested as decreased plant density and diminished plant size that lead to reduced herbage production during periods with normal precipitation. Herbage reduction percentages caused by detrimental grazing management practices such as grazing before the third-leaf stage, grazing seasonlong, or grazing during the fall usually vary between 40 and 60 percent below the potential herbage biomass. The greatest reductions in herbage production observed in western North Dakota have occurred on domesticated grass spring pastures that were hayed during the summer and/or grazed during the fall, on native rangeland summer pastures that were grazed during the fall, and on domesticated grass and alfalfa haylands that were hayed late and/or grazed during the fall.

Herbage weight of perennial plants increases from early season through May, June, and July until peak herbage biomass, which occurs during the last couple weeks of July. Herbage weight then decreases as plants age and dry. The amount of herbage biomass produced by healthy plants is related to precipitation levels during January through July, which affect plant size and plant density.

Herbage reduction percentages caused by low precipitation are usually proportional to the levels of precipitation below the normal range. An estimate of the amount of herbage reduction low precipitation causes in healthy plants can be determined by a comparison between the local long-term mean precipitation received during January through July and the current year's precipitation for that period. The range of normal precipitation is plus or minus 25 percent of the long-term mean.

The procedure to estimate percent reduction in peak herbage biomass caused by below-normal precipitation requires just three simple calculations: first, the monthly precipitation for January through July is totaled to give the current seasonal precipitation; then, this precipitation amount is divided by the local long-term January through July precipitation amount to determine the current seasonal precipitation as a percentage of the long-term mean precipitation; next, that percentage is subtracted from 75 percent, which is the low-normal long-term precipitation value.

The resulting estimated percentage of reduction that below-normal precipitation has caused in peak herbage biomass provides a guideline for the percent reduction in stocking rate needed for the remainder of the grazing season--until mid October--on pastures that have been properly managed and have healthy plants. For example, if the January through July seasonal precipitation amount is 65 percent of the long-term mean, the estimated 10 percent reduction from normal herbage biomass would suggest a 10 percent reduction in stocking rate--assuming the proper stocking rate was being used. This method does not determine the amount for stocking rate adjustments required on pastures managed by practices that diminish the health status of plants below potential levels.

The long-term mean monthly precipitation amounts for numerous locations are available on the National Weather Service (NOAA) web site for North Dakota (www5.ncdc.noaa.gov/climatenormals/clim81/NDnorm.pdf). For the current season's precipitation, amounts collected at individual ranches and marked on the calendar can be used if a complete January through July data set is available. Another source for the current season's precipitation amounts for many locations is the NDAWN web site (http://ndawn.ndsu.nodak.edu). These data start in April because NDAWN does not collect data for precipitation that occurs as snow. The precipitation amounts for January through March and the amount of precipitation that falls as snow during other periods must be obtained from other sources. Current season's precipitation data that include snow moisture amounts are available on the National Weather Service site (www.crh.noaa.gov/bis/OtherHydro.htm Click on "text" for the desired month's precipitation data).

If the percentages of reduction in herbage biomass produced on domesticated grass spring pastures, native rangeland pastures, or grass and alfalfa haylands are greater than the estimated percentage of herbage reduction reached by the comparison between the long-term and current seasonal precipitation amounts, the health of the plants is below the potential level because management practices have not met the plant biological requirements. When management practices meet the biological requirements of the plants and the level of plant health is high, the percentages in herbage biomass reduction that occur during periods of below-normal precipitation are about equal to the percent reduction in precipitation. These herbage biomass reduction percentages are smaller and less problematic than reduction percentages on areas with diminished plant health.

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Table 1. Examples from three locations to illustrate the procedure to estimate percent reduction in peak herbage biomass in healthy plants as a result of below-normal January through July seasonal precipitation.

	Bowman		Hettinger		Pretty Rock	
	Long-term	2002	Long-term	2002	Long-term	2002
Jan	0.49	0.62	0.30	0.37	0.33	0.47
Feb	0.48	0.33	0.32	0.12	0.41	0.20
Mar	0.73	0.69	0.60	0.62	0.86	0.72
Apr	1.32	1.23	1.59	1.14	1.89	1.03
May	2.53	0.56	2.54	0.80	2.64	0.55
Jun	3.07	2.94	2.95	1.24	3.02	0.89
Jul	2.03	1.43	2.16	1.36	2.34	1.91
Total	10.65	7.80	10.46	5.65	11.49	5.77
% of Long-term		73.24		54.02		50.22
75% - % of Long-term		1.76%		20.98%		24.78%
% reduction of peak herbage biomass in healthy plants		2%		21%		25%
% stocking rate reduction on pastures with healthy plants		2%		21%		25%

Appendix B

A Method of Determining Stocking Rate Based on Monthly Standing Herbage Biomass Adjusted for the Effects of Drought Conditions

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Stocking rate is the number of animals (animal unit) for which a grassland unit (acre) can provide adequate forage for a specified length of time (month). Stocking rate depends on the amount of herbage biomass available to grazing animals, the time of year, the type of grazing system used, and the amount of forage consumed by livestock per month. Stocking rate is commonly presented as acres per animal unit month (AUM) or its reciprocal, AUM's per acre.

Forage dry matter intake of grazing animals is affected by the size of the cow. Large cows consume more forage than medium- and standard-sized cows. A more accurate estimate of daily or monthly forage demand of livestock on grazinglands can be determined with the metabolic weight of the animal than with its live weight. Metabolic weight is live weight to the 0.75 power. A 1000-pound cow with a calf is the standard, which is defined as 1.00 animal unit (AU) and has a daily dry matter allocation of 26 pounds of pasture forage. The metabolic weight of a 1200-pound cow with a calf is 1.147 animal unit equivalent (AUE), which has a daily dry matter allocation of 30 pounds of pasture forage. The metabolic weight of a 1400-pound cow with a calf is 1.287 animal unit equivalent (AUE), which has a daily dry matter allocation of 33 pounds of pasture forage. The amount of forage dry matter consumed in one month by one animal unit, a 1000-pound cow with a calf, is an animal unit month (AUM). The daily dry matter allocation for a cow with a calf on pasture is different from the daily dry matter requirement for just the cow during the same production periods. During the grazing season from May through November, the length of the average month is 30.5 days.

The mathematical process used to determine stocking rate from herbage biomass is presented in Table 1. The amount of herbage available during the grazing season is the average value of the mean monthly standing herbage biomass values for the grazing-season months. The mean monthly standing herbage biomass should be determined by clipping and weighing the dry herbage from each pasture and averaging the weights over several years. If these values are not available, the generalized values for western North Dakota native range (Table 2) can be substituted. The general monthly herbage values on the herbage weight curve in Table 2 are averages of herbage production on well-managed pastures during years with normal precipitation.

Each of the monthly herbage biomass values needs to be adjusted to reflect the differing effect of various grazing treatments on the quantity of herbage biomass produced. Time of year and intensity of defoliation vary with different grazing treatments; these variations affect plant biological mechanisms and result in the production of different amounts of herbage. The percentages of the potential amount of herbage biomass produced on various grazing treatments are summarized in Table 2. The monthly herbage biomass values for the months of the grazing season can be adjusted for differences in herbage biomass on specific grazing treatments by multiplying monthly herbage weight by the percentage of potential herbage produced on a particular grazing treatment.

Each of the monthly herbage biomass values also needs to be adjusted during the perennial plant recovery period to reflect the percentage of herbage weight reduction that resulted from the effects of drought conditions. The percent reduction that results from the effects of drought conditions can be determined by a comparison of normal-year herbage biomass and drought-year or recovery-year herbage biomass. If these data are not available, estimations based on several years of experience can be used. The estimate of percent herbage reduction needs to be converted to percent of herbage biomass produced. The percent of herbage produced is determined by subtracting the percent reduction in herbage from 100%. The monthly normal-year herbage biomass values adjusted for the effects of grazing system are multiplied by percent of herbage produced to adjust for the effects of drought conditions.

The average monthly herbage biomass is determined by adding the adjusted monthly herbage biomass for the months of the grazing season and dividing the sum by the number of grazing-season months.

Not all of the average herbage biomass for the planned months of the grazing season is consumable forage. Perennial plants must retain a portion of the leaf material to conduct photosynthesis and provide carbohydrates and other products necessary to sustain healthy and productive growth. The amount of leaf material the plant must retain ranges from 40% to 60%, depending on grassland type (40% on the shortgrass, 50% on the midgrass, and 60% on the tallgrass prairies). When specific values for percent proper utilization are not known for the grassland type, an average value of 50% may be used. This value implies that the plant retains half the herbage and half the herbage is available for utilization.

Not all standing herbage available for proper utilization is ingested by grazing animals. Grazing livestock consume only about 50% of herbage available for utilization. The remainder of the utilized herbage is broken from the plant, soiled by animal waste, consumed by insects and wildlife, and lost to other natural processes. Data to allow comparison of forage-harvest efficiency on different grazing systems are not available. However, the quantity of herbage ingested by livestock would be expected to increase with improvement in efficiency of harvest from some grazing systems.

The differences in daily dry matter intake for cows of different weights are used to adjust stocking rates for cow size. The standard 1000-lb cow requires 26 lbs of dry matter per day. The dry matter intake for lighter or heavier cows can be determined by multiplying 26 lbs by the animal unit equivalent (Table 3), which is based on the metabolic weight of the cow.

For determination of stocking rate, the available monthly forage for intake value adjusted for grazing system and drought conditions is divided by the amount of dry matter per cow per month--the daily amount of dry matter per cow adjusted for cow size multiplied by the number of days per average month (30.5 days). This stocking rate is presented as AUM's per acre. The reciprocal can be determined by dividing that number into 1 to give acres per AUM. This is the number of acres required to provide forage for one month for a cow with a calf.

The number of cows to turn onto the grazing system is determined by dividing the total number of acres in the pastures of a grazing system by the acres per AUM value and dividing this total number of AUM's by the number of months of the grazing season. The number of cows that can graze the pastures subtracted from the total number of cows in the herd will show the forage shortfall.

The stocking rate value determined by this mathematical process is based on the average monthly standing herbage biomass for the grazing-season months and has been adjusted for percentage utilization, percentage forage intake, grazing system, cow size, and the effects of drought conditions.

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Table 1. Process to determine stocking rate from monthly herbage biomass adjusted for drought conditions

Adjustment for grazing treatment

Monthly herbage biomass value X % of potential herbage produced on appropriate grazing treatment

Adjustment for effects of drought conditions

Monthly herbage biomass value adjusted for grazing treatment X (100 % - % herbage reduction)

Average monthly herbage biomass

Sum of adjusted monthly herbage biomass for the months of the grazing season

÷ number of grazing season months

Adjustment for size of cow

26 lbs daily dry matter intake X Animal Unit Equivalent for appropriate cow size (from Table 3).

Stocking Rate

Average monthly herbage biomass adjusted for grazing treatment and for drought conditions

X % proper utilization (50%)

X % consumed (50%)

= lbs of available monthly forage

÷ dry matter per AUM (26 lbs X AUE X 30.5 days)

= AUM/ac

reciprocal
1.0 ÷ AUM/ac = ac/AUM

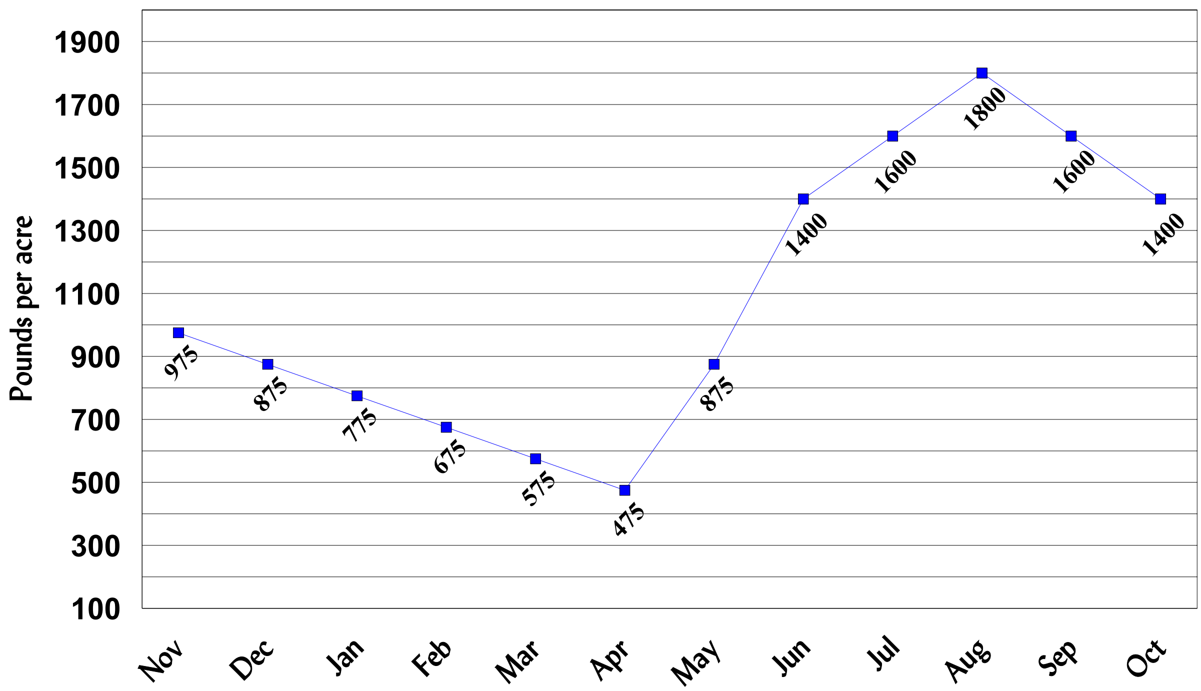
The number of cows that can graze the available forage

Total number of acres in grazing system

÷ acres/AUM

÷ number of grazing season months

Table 2. Generalized Standing Herbage Biomass for Well-Managed Native Rangeland during Normal Precipitation Years



Seasonlong	start 1 May	30% of Potential Herbage
6.0 Seasonlong	start 15 May	50% of Potential Herbage
4.5 Seasonlong	start 15 Jun	70% of Potential Herbage
4.0 Deferred	start 15 Jul	90% of Potential Herbage
4.5 Short Duration	start 15 Jun	95% of Potential Herbage
4.5 Twice Over	start 1 Jun	100% of Potential Herbage

Table 3. Animal Unit Equivalent (AUE) based on metabolic weight (live animal weight $^{0.75}$).

Animal Live Weight (lbs)	Animal Unit Equivalent $y^{x\ 0.75}$ (% of 1000 lbs)
600	0.682
650	0.724
700	0.765
750	0.806
800	0.846
850	0.885
900	0.924
950	0.962
1000	**1.000**
1100	1.074
1200	1.147
1300	1.217
1400	1.287
1500	1.355
1600	1.423
1700	1.489
1800	1.554
1900	1.618
2000	1.682
2200	1.806
2400	1.928
2600	2.048
2800	2.165
3000	2.280

Appendix C

Procedure to Determine 12-Month Nutrient Requirements for Cows with Different Calf Birth Dates

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Beef cows require energy, protein, minerals, vitamins, and water. The daily quantities of each nutrient required by the cow depend on the size of cow, level of milk production, and production period (dry gestation, 3rd trimester, early lactation, lactation). The quantities of nutrients required by cows for 12 months depend on the month in which calf birth occurs. Calf birth date affects the time of year during which the production periods occur and the length of the production periods. The length of the production periods and the time of the year during which they occur determine the type of forage available during any given production period and the amount of forage needed from pasture or from harvested forage.

The 12-month quantities of dry matter, energy (TDN), crude protein, calcium, and phosphorus required by cows having average milk production but different weights and different calf birth months can be determined with the procedures presented in this report, the worksheet provided, and the information provided about the daily nutrient requirements (Table 1) and the length in days of the production periods and forage types for calf birth dates for 4 months (Table 2). A separate worksheet for each cow-size category and month of calf birth will need to be completed. An example worksheet for 1200-pound cows with calf birth dates in March is provided to illustrate the procedures.

In the appropriate spaces near the top of the worksheet, record the cow weight and calf birth month. On the appropriate line in the top section of the worksheet, place the number of days for the production periods and forage types corresponding to the selected calf birth month. These figures can be found in Table 2, which was developed to have low numbers of acres per cow per year and to implement management strategies that graze domesticated grass and native range pastures at the proper time of year. Domesticated grasses reach grazing readiness about a month earlier than native range and can be grazed starting in early May. Native range is ready to be grazed starting in early June. With the use of rotation grazing systems based on grass phenology, the nutritional quality of native range can be manipulated to match requirements of lactating cows until mid October. Domesticated grass pastures of wildrye types can provide adequate nutrients for lactating cows until mid November. Harvested-forage rations will provide adequate nutrient levels during the remainder of the year.

Check the values for the days at the right side of the worksheet to ensure that the total number of days on ration and days on pasture equals 365.

Locate the daily nutrient requirements in pounds for the various production periods from the appropriate cow-weight category on Table 1, and record these requirements in pounds on the middle section of the worksheet.

To determine the number of pounds of nutrients required for each production period and forage type, multiply the pounds of nutrients required per day by the number of days in the period and for the available forage type. Record these values in the appropriate spaces on the bottom section of the worksheet. Combine the nutrient quantity values for ration-forage and pasture-forage types. Then add the total values for ration forage to the total values for pasture forage to determine the total quantity of required nutrients for a 12-month period for the selected cow weight and calf birth month. Record these values in the bottom right section of the worksheet.

The quantity of nutrients required by a cow for 12 months is variable and depends on cow weight and calf birth month. The quantity of nutrients provided from harvested forage in rations and from pasture forages varies with calf birth month because different forage types are available during production periods that occur at different times of the year.

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Table 1. Intake nutrient requirements in pounds per day for beef cows with average milk production during four production periods (data from NRC 1996).

	Dry Gestation	3^{rd} Trimester	Early Lactation	Lactation
1000 lb cows				
Dry matter	21	21	24	24
Energy (TDN)	9.64	10.98	14.30	13.73
Crude protein	1.30	1.64	2.52	2.30
Calcium	0.03	0.05	0.07	0.06
Phosphorus	0.02	0.03	0.05	0.04
1200 lb cows				
Dry matter	24	24	27	27
Energy (TDN)	11.02	12.62	15.85	15.23
Crude protein	1.49	1.87	2.73	2.51
Calcium	0.04	0.06	0.08	0.07
Phosphorus	0.03	0.04	0.05	0.05
1400 lb cows				
Dry matter	27	27	30	30
Energy (TDN)	12.42	14.28	17.40	16.71
Crude protein	1.67	2.13	2.94	2.70
Calcium	0.04	0.07	0.08	0.08
Phosphorus	0.03	0.05	0.06	0.05

Data compiled from National Research Council. 1996. Nutrient requirements of beef cattle, 7 th rev. ed. National Academy Press, Washington, DC.

Table 2. Twelve-month range cow production period sequences for calf birth dates in January to April.

12-Months	Calf Birth Month			
	January	February	March	April
late Nov	RATION (cont')	RATION	Dry Gestation	RATION
Dec	3rd Trimester 3.0m, 90d	3rd Trimester 3.0m, 90d	1.0m, 32d RATION	Dry Gestation 2.0m, 62d
Jan	Calf Birth		3rd Trimester 3.0m, 90d	
Feb	Early Lactation 1.0m, 32d	Calf Birth		3rd Trimester 3.0m, 90d
Mar	Lactation 2.5m, 75d	Early Lactation 1.0m, 32d	Calf Birth	
Apr		Lactation 1.5m, 45d	Early Lactation 1.5m, 45d	Calf Birth
May				Early Lactation 0.5m, 15d
Jun	PASTURE Lactation (spring) 1.0m, 31d	PASTURE Lactation (spring) 1.0m, 31d	PASTURE Lactation (spring) 1.0m, 31d	PASTURE Lactation (spring) 1.0m, 31d
Jul	Lactation (summer) 4.5m, 137d	Lactation (summer) 4.5m, 137d	Lactation (summer) 4.5m, 137d	Lactation (summer) 4.5m, 137d
Aug				
Sep				
Oct	Calf age-9m Calf Weaning			
early Nov	RATION 3rd Trimester 3.0m, 90d	Lactation (fall) 1.0m, 30d Calf age-9m Calf Weaning	Lactation (fall) 1.0m, 30d Calf age-8m Calf Weaning	Lactation (fall) 1.0m, 30d Calf age-7m Calf Weaning

Worksheet to determine 12-month nutrient requirements for cows of different sizes and with different calf birth dates.

Cow size (weight)____________

Calf birth month _____________

Production Periods	Dry Gestation		3rd Trimester		Early Lactation		Lactation					
Forage Type	Ration	Pasture	Ration	Pasture	Ration	Pasture	Ration	Pasture		# Days Ration	# Days Pasture	# Days 12 months
Number Days from Chart												

Requirements lbs/day from Table 1.

Dry matter								
Energy (TDN)								
Crude Protein								
Calcium								
Phosphorus								

Nutrient lbs/day X #days = Nutrient lbs/period

Totals for periods										Totals for Ration	Totals for Pasture	Totals for 12 months
Dry matter												
Energy (TDN)												
Crude Protein												
Calcium												
Phosphorus												

Worksheet to determine 12-month nutrient requirements for cows of different sizes and with different calf birth dates.

Cow size (weight) 1200 lbs

Calf birth month March

Production Periods	Dry Gestation		3rd Trimester		Early Lactation		Lactation					
Forage Type	Ration	Pasture	Ration	Pasture	Ration	Pasture	Ration	Pasture		# Days Ration	# Days Pasture	# Days 12 months
Number Days from Chart		32	90		45			198		135	230	365
Requirements lbs/day from Table 1.												
Dry matter		24	24		27			27				
Energy (TDN)		11.02	12.62		15.85			15.23				
Crude Protein		1.49	1.87		2.73			2.51				
Calcium		0.04	0.06		0.08			0.07				
Phosphorus		0.03	0.04		0.05			0.05				
Nutrient lbs/day X #days = Nutrient lbs/period												
Totals for periods										Totals for Ration	Totals for Pasture	Totals for 12 months
Dry matter		768	2160		1215			5346		3375	6114	9489
Energy (TDN)		352.64	1135.80		713.25			3015.54		1849.05	3368.18	5217.23
Crude Protein		47.68	168.30		122.85			496.98		291.15	544.66	835.80
Calcium		1.28	5.40		3.60			13.86		9.00	15.14	24.14
Phosphorus		0.96	3.60		2.25			9.90		5.85	10.86	16.71