Domesticated Graminivores: An Indispensable Biotic Component of the Northern Mixed Grass Prairie

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Prairie ecosystems are complex; exceedingly more complex than the most complicated machines ever built by humans. The long-standing standard process to understand complex systems is to initially investigate the separate component parts. The gained knowledge of each part combined with the synergistic effects resulting when the parts work together provide the information needed to develop an understanding of the whole ecosystem. This classical concept of biological systems was developed by the Greek philosopher/scientist Aristotle (384-322 BC) who taught that "the whole is greater than the sum of its parts".

The goals of this study were developed by Dr. Warren C. Whitman (c. 1950) and Dr. Harold Goetz (1963) which were to gain quantitative knowledge of each component part and to provide a pathway essential for the understanding of the whole prairie ecosystem that would result in the development and establishment of scientific standards for proper management of native rangelands of the Northern Plains. The introduction to this study can be found in report DREC 16-1093 (Manske 2016).

Grass vegetation, rhizosphere organisms, and domesticated graminivores are indispensable biotic components of a functional rangeland ecosystem. Grazing graminivores depend on grass plants for nutritious forage. Grass plants depend on rhizosphere organisms for mineralization of essential elements from the soil organic matter. Rhizosphere organisms, which are achlorophyllous, depend on grass plants for short carbon chain energy that is exudated through the roots of lead tillers at vegetative growth stages following partial defoliation by grazing graminivores. Grass plants produce double the leaf biomass than is needed for photosynthesis in order to attract the vital partial defoliation by grazing graminivores on which they depend.

The three indispensable biotic components of rangeland ecosystems: Grass Vegetation, Rhizosphere Organisms, and Domesticated Graminivores will each be quantitatively described in separate companion reports. This report will provide quantitative knowledge of grazing domesticated graminivores as indispensable biotic components of grassland ecosystems.

Indispensable Graminivores

Grazing large graminivores on a fully functional grassland ecosystem can be perpetually sustainable with biologically effective management that activates the ecosystem biogeochemical processes and the grass plant physiological mechanisms to function at potential levels. When these processes and mechanisms function above threshold levels, capture and replenishment of input essential elements occurs at greater quantities than the amount of output essential elements. Soil organisms and grass plants use the essential elements in the inorganic form to synthesize vital organic compounds of carbohydrates, proteins, and nucleic acids. Grass plants produce double the quantity of leaf biomass than needed for normal plant growth and maintenance (Crider 1955, Coyne et al. 1995). All of the aboveground herbage biomass produced by perennial grasses in a growing season represents about 33% of the total biomass produced. About 67% of the annual perennial grass biomass is produced belowground. About 50% of the aboveground biomass is expendable by the grass plant (Crider 1955). About half of the expendable leaf material is removed as senescent leaves that are broken from the plant and fall to the ground as litter, or removed as leaf material by wildlife, grasshoppers, and other small animals. About half of the expendable leaf material, or 25% of the aboveground grass biomass can be consumed by grazing graminivores (Manske 2012a).

Graminivores grazing grass plants acquire energy, protein, macrominerals, and microminerals from the forage they consume. Perennial grass leaf material consists of both digestible nutrients and nondigestible plant structural components. Adequate quantities of crude protein and energy are available to the graminivores during early June through mid October from the growing forage grass plants on fully functional ecosystems. About 15% of the nutrients contained in the consumed grass leaf material is extracted by stocker heifers and steers and retained for growth. About 30% of the nutrients contained in the consumed grass leaf material is extracted by lactating cows, with a portion retained by the cow for production, and the remainder of the extracted nutrients passed on the her calf for growth (Russelle 1992, Gibson 2009).

All of the nondigestible dry matter and most of the nutrients consumed by grazing graminivores are deposited on the ground as manure in a couple of days. Most of the consumed nutrients extracted and used by graminivores for maintenance are returned to the ecosystem in the feces and urine. None of the herbage biomass dry matter produced during a growing season is removed by graminivores from the grassland ecosystem. All of the essential elements contained in the belowground biomass and contained in the nonconsumed aboveground biomass stay in the ecosystem. Nearly all of the essential elements used in the annual production of grass herbage biomass and soil organism biomass are retained and recycled in the ecosystem.

Some essential elements are lost or removed from the ecosystem as annual output. The metabolic process of respiration of soil organisms, grass plants, graminivores, and other fauna results in a loss of some essential elements as carbon dioxide, water vapor, and heat energy. Some essential elements are removed from the ecosystem as weight biomass produced by insects and wildlife. The essential elements transferred from grass plants to grazing graminivores and used for growth are removed from the ecosystem (Gibson 2009). If the grassland ecosystem is burned, almost all of the essential elements in the aboveground herbage are volatized, and if the soil is dry, some of the belowground essential elements are also lost (Russelle 1992).

Grassland ecosystems degrade when the losses of essential elements is greater than the capture of replacement essential elements. Conversely, grassland ecosystems aggrade when the capture of essential elements is greater than the losses (McGill and Cole 1981). A large biomass of soil microbes and healthy grass plants is required to aggrade grassland ecosystems (Coleman et al. 1983, Schimel, Coleman, and Horton 1985, Cheng and Johnson 1998). When the ecosystem biogeochemical processes and the grass plant physiological mechanisms are functioning at potential levels, a grazed grassland ecosystem is perpetually sustainable (Manske 2013).

1983-2005 Study of Graminivore Weight Performance

Management Treatments

A 23 year study separated into two sections, with the first portion from 1983 to 1994 and the second portion from 1995 to 2005, evaluated cow and calf weight performance on spring, summer, and fall pastures managed by two distinctly different concepts. The traditional concept managed the land for its use as forage for livestock. The biologically effective concept managed the land as an ecosystem that considers the biological requirements of the grass plants, soil microbes, and the livestock.

Spring Complementary Pastures

The traditional spring complementary pasture was unfertilized crested wheatgrass. During 1983 to 1988, the livestock managed by the traditional concept grazed unfertilized crested wheatgrass pastures during May to mid June, however, weight performance data were not collected. During 1989 to 1994, cow and calf pairs grazed one unfertilized pasture of 18 acres (replicated two times) at 2.45 ac/AUM for 28 days (2.25 ac/AU) from mid May to mid June. During 1995 to 2005, cow and calf pairs grazed one unfertilized pasture of 15 acres (replicated three times) at 2.33 ac/AUM for 28 days (2.14 ac/AU) from early May to early June (Appendix tables 6-10).

The biologically effective spring complementary pasture was crested wheatgrass. During 1983 to 1994, cow and calf pairs grazed one pasture of 13 ac fertilized with 50 lbs N/ac during early April (replicated two times) at 0.85 ac/AUM for 21 days from mid May to early June. During 1995 to 2005, cow and calf pairs grazed one unfertilized pasture of 26.5 acres split into equal halves with each portion used for 2 alternating 7 day periods in a switchback plan (replicated two times) at 1.25 ac/AUM for 28 days from early May to early June (Appendix tables 1-5).

Summer Pastures

The traditional summer pasture was native rangeland. During 1983 to 1987, cow and calf pairs grazed one native rangeland pasture seasonlong (replicated two times) at 6 cows per 80 acres with 13.33 ac/AU for 134 days from mid June to late October. During 1988 to 1990 a dry period, cow and calf pairs grazed one native rangeland pasture seasonlong (replicated three times) at 7 cows per 80 acres with 11.43 ac/AU for 85 days from mid June to mid September. During 1991 to 1994, cow and calf pairs grazed one native rangeland pasture seasonlong (replicated two times) at 7 cows per 80 acres with 11.43 ac/AU for 127 days from mid June to late October. During 1995 to 1997, cow and calf pairs grazed one native rangeland pasture seasonlong (replicated three times) at 7 cows per 80 acres with 11.43 ac/AU for 131 days from early June to mid October. During 1998 to 2001, cow and calf pairs grazed one native rangeland pasture seasonlong (replicated three times) at 7 cows per 80 acres with 11.43 ac/AU for 134 days from early June to mid October. During 2002 to 2005, cow and calf pairs grazed one native rangeland pasture seasonlong (replicated two times) at 7 cows per 80 acres with 12.22 ac/AU for 135 days from early June to mid October (Appendix tables 16-20).

The biologically effective summer pastures were native rangeland. During 1983 to 1987, cow and calf pairs grazed three native rangeland pastures with twice-over rotation (replicated two times) at 8 cows per 80 acres with 10.22 ac/AU for 138 days from early June to mid October. During 1988 to 1990 a dry period, cow and calf pairs grazed three native rangeland pastures with twice-over rotation (replicated two times) at 8 cows per 80 acres with 10.22 ac/AU for 100 days from early June to mid September. During 1991 to 1994, cow and calf pairs grazed three native rangeland pastures with twice-over rotation (replicated two times) at 8 cows per 80 acres with 10.22 ac/AU for 121 days from early June to early October. During 1995 to 1997, cow and calf pairs grazed three native rangeland pastures with twice-over rotation (replicated two times) at 8 cows per 80 acres with 10.22 ac/AU for 130 days from early June to mid October. During 1998 to 2001, cow and calf pairs grazed three native rangeland pastures with twice-over rotation (replicated two times) at 8 cows per 80 acres with 10.22 ac/AU for 131 days from early June to mid October. During 2002 to 2005, cow and calf pairs grazed three native rangeland pastures with twice-over rotation (replicated two times) at 8 cows per 80 acres with 10.59 ac/AU for 135 days from early June to mid October (Appendix tables 11-15).

Fall Complementary Pastures

The traditional fall complementary pasture was cropland aftermath consisting primarily of annual cereal residue of oat or barley stubble with some senescent grass on the headlands and waterways. During 1983 to 1998, cow and calf pairs grazed cereal residue forage (replicated two times) at 6.63 ac/AU for 30 days from mid October to mid November (Appendix tables 26-27).

The biologically effective fall complementary pastures were Altai wildrye and spring seeded winter cereal (fall or winter rye). During 1984 to 2002, cow and calf pairs grazed one pasture of Altai wildrye (replicated two times) at 1.39 ac/AU for 30 days from mid October to mid November (Appendix tables 21-23). During 2003 to 2005, cow and calf pairs grazed 4 pastures of spring seeded winter cereal with a fresh pasture made available every 7 to 8 days stocked at 0.47 ac/AU for 30 days from mid October to mid November (Appendix tables 24-25).

Domesticated Graminivores

Commercial cow-calf pairs were evaluated during this study. During 1983 to 1994, commercial Angus-Hereford cows with Charolais sired calves were used. Cows were assigned to separate herd pools for each grazing treatment. Before spring turn out, cow-calf pairs were sorted by cow age, and calf age with 50% steers and heifers. During 1995 to 2005, commercial crossbred cattle were used on all grazing treatments. Before spring turn out, cow-calf pairs were sorted by cow age, and calf age with 50% steers and heifers. Calves were born during March and early April with the average birth date of 16 March and the average birth weight of 95 pounds during the entire study period.

Precipitation

The precipitation in inches and percent of long-term mean for perennial plant growing season months, April to October, and growing season months with water deficiency conditions are reported in the study introduction (Manske 2016). The 12 year period of 1983 to 1994 had a total of 72 growing season months, 31 months (43.1%) had water deficiency conditions, 14.5 months (20.1%) had high precipitation greater than 125% of LTM, and 26.5 months (36.8%) had normal precipitation greater than 75% and less than 125% of LTM. The 11 year period of 1995 to 2005 had a total of 66 growing season months, 15.5 months (23.4%) had water deficiency conditions, 27.5 months (41.7%) had high precipitation greater than 125% of LTM, and 23.0 months (34.8%) had normal precipitation greater than 75% and less than 125% of LTM.

Procedure

Individual cows and calves were weighed on and off each treatment pasture, at 15-day intervals during the early portion of the grazing season from early May to mid July, and at 30-day intervals during the latter portion of the grazing season from mid July to mid November. Total accumulated weight gain per head, gain per day, and gain per acre were determined.

Pasture costs were determined using pasture rent value of $8.76 per acre calculated from the mean rent values of the 15 counties in southwestern North Dakota reported for 1993 and 1994 (ND Ag Statistics). Total pasture costs and costs per day were determined. Grazing cropland aftermath cost was determined to be $2.00 per acre.

Market value per pound of calf pasture accumulated live weight gain was determined from the low market value of $0.70 per pound occurring during 1993 and 1994.

Net returns per cow-calf pair were determined by subtracting pasture costs from calf pasture weight gain value. Net returns per acre were determined by dividing the net returns per cow-calf pair by the number of acres used per Animal Unit (AU) per production period.

One treatment of crested wheatgrass was fertilized annually with 50 pounds of nitrogen per acre at an average cost of $12.50 per acre used during 1983 to 1994. Land rent plus fertilizer cost was $21.26 per acre.

Results

At the start of this study, the consensus of the experienced range scientists of the Northern Mixed Grass Prairie was that grazing readiness of native rangeland started on 15 June based on the research by Campbell (1952) and Rogler et al. (1962), and as reported together by Manske (2008b). As a result, the grazing starting dates of the traditional seasonlong treatments during 1983 to 1994 were mid June. The first year (1983) of the biologically effective twice-over rotation treatment on native rangeland also started grazing in mid June. With some persuasion, for the purpose of new research, the grazing starting dates of the biologically effective twice-over rotation treatment were moved to early June during 1984 to 2005. The starting date of the spring turn out to the traditional crested wheatgrass complementary pastures was thought to be around mid May, based on decades of previous research, which was the starting date used during 1983 to 1994. The duration of the grazing period on crested wheatgrass complementary pastures was also still undetermined at that time. Moving the grazing start date of the crested wheatgrass complementary pastures from mid May to early May was not accomplished until after 1994. During 1995 to 2005, the grazing start date for crested wheatgrass pastures was early May and the grazing start date for native rangeland pastures was early June for both the management practices of the traditional and biologically effective concepts. Perennial grass tillers are physiologically capable of tolerating partial defoliation after they have developed 3.5 new leaves. The major native cool season grasses reach the 3.5 new leaf stage around early June. Crested wheatgrass tillers reach the 3.5 new leaf stage on 22 April but do not have adequate herbage weight until early May to start the grazing period. Perennial grass phenological growth stages are determined by the length of daylight and occur at the same time (plus or minus 1 or 2 days) year after year.

In the past, a great deal of emphasis has been given to the dry matter intake requirements of beef cattle. During lactation, a 1000 lb cow requires 24 lbs of dry matter per day, a 1200 lb cow requires 27 lbs, and a 1400 lb cow requires 30 lbs per day (NRC 1996). When these lactating cows are grazing, the dry matter allocation is increased 2 lbs/day for the 1000 lb cow, and 3 lbs/day for the 1200 lb and 1400 lb cows (Manske 2012b). However, none of the cow and calf weight gain while grazing grass forage comes from the ingested dry matter, the weight gain comes mainly from the quantity of energy and crude protein extracted from the dry matter carrier while it passes through the digestive system of the livestock. The energy content of grass forage usually does not decrease below the cows requirements during the growing season of the Northern Mixed Grass Prairie. The crude protein content of grass lead tillers decreases below the cows requirements during mid to late July. At this point, cows are unable to maintain weight gain and milk production. Weight gain decreases first, then the quantity of milk production decreases. When the cows lose weight, the milk production decreases greatly and calf weight gains drop below 2.50 lbs/day. The reduction of crude protein content of grass forage below the cows requirements in late July can be avoided by activation of sufficient quantities of vegetative tillers developed from axillary buds with partial defoliation by graminivores that removes 25% to 33% of the leaf material from grass lead tillers at phenological growth between the three and a half new leaf stage and the flower (anthesis) stage during early June to mid July, which prevents cow weight lose and milk production reduction between mid July and late September or mid October (Manske 1999, 2011).

Spring Complementary Pastures

Crested wheatgrass is an excellent spring (May) complementary pasture. Crested wheatgrass was introduced into North America from Eurasia during the early 1900's. Early leaf greenup starts in mid April. The tillers have three and a half new leaves around 22 April which is four to five weeks earlier than native cool season grasses. The quantity of available herbage weight is insufficient for grazing until 1 May and provides superior quality forage to the end of May or to the first couple of days in June. The crude protein content from early May to early June ranges from 19.0% to 12.1%. Cows with calves one month old on 1 May perform very well while grazing crested wheatgrass (Manske 2017b).

During 1983 to 1994, cow and calf weight performance on a crested wheatgrass pasture fertilized with 50 lbs N/ac stocked at 0.85 ac/AUM was evaluated (Appendix tables 1-5). During 1989 to 1994, cow and calf weight performance on a crested wheatgrass unfertilized pasture stocked at 2.45 ac/AUM was evaluated (Appendix tables 6-10). On the fertilized pasture, calf weight gain was 2.37 lbs per day, 78.82 lbs per acre, and accumulated weight was 66.83 lbs per head. Cow weight gain was 2.57 lbs per day, 92.81 lbs per acre, and accumulated weight gain was 50.87 lbs per head (table 1). On the unfertilized pasture, calf weight gain was 2.34 lbs per day, 28.08 lbs per acre, and accumulated weight was 66.21 lbs per head. Cow weight gain was 0.93 lbs per day, 11.83 lbs per acre, and accumulated weight was 27.84 lbs per head (table 1). The calf gain per day and total weight gain per head were similar on both treatments, while the calf weight gain per acre was 50.74 lbs (180.7%) greater on the fertilized pasture. The cow weight gain on the fertilized pasture was greater than that on the unfertilized pasture. The cow weight gain on the fertilized pasture was 1.64 lbs per day greater, 23.03 lbs greater total weight per head, and impressively was 80.98 lbs per acre (684.5%) greater (table 1). The dollar value captured was greater on the fertilized pasture, the pasture cost was $9.01 lower, pasture weight gain value was $0.43 greater, net return per cow-calf pair was $8.43 greater, and net return per acre was $28.14 (258.2%) greater (table 2). During the 12 year period of 1983 to 1994, the basal cover of fertilized crested wheatgrass increased (50.0%) from 21.5% to 32.2%, with a decrease to 19.1% during the dry period of 1988 to 1990.

Most of the old crested wheatgrass acreage was abandoned cropland plots that had been plowed rangeland in order to fulfill the compliance requirements of the Homestead Acts of both the United States and Canada. Most of these parcels are located within units that consist of other types of plant cover, like rangeland. These old crested wheatgrass stands developed symbiotic relationships with soil microbes sometime between 25 to 35 years after they were seeded, and if they have been properly managed, those soil microbes should still be active. Fertilization of these old crested wheatgrass areas will greatly decrease the soil microbes. The old crested wheatgrass stands with soil microbes should be managed without fertilizer. The younger crested wheatgrass stands have usually been seeded into wornout cropland without the benefit of copious quantities of barnyard manure applied during the years before seeding. These younger stands of crested wheatgrass may be deficient of essential nutrients. Fertilization of these younger deficient crested wheatgrass pastures can work biologically and economically if 50 lbs N/ac were to be applied one month before the start of grazing, which would be early April. Fertilization applied at later dates results in greatly reduced herbage biomass. It takes a long time period for the fertilizer treatment to effect grass growth. Also the calves need to be on the ground one month before the start of grazing crested wheatgrass; calves less than one month old cannot gain much more than 1.25 lbs/day, which would leave little profit after the fertilizer bill was paid. The older calves make this work economically. Also remember that if the fertilizer treatment is stopped, not many soil microbes remain, and it will take more than 25 to 35 years to regain a soil microbe population.

Fertilizing perennial grasses does not increase herbage production during an entire growing season. Herbage production that would have occurred during one period is moved to overlap the herbage production during an earlier period. Fertilization synchronizes grass tiller development to occur during a short period of time. When crested wheatgrass is fertilized during early April, the increased synchronized tiller growth occurs during May. The vegetative tillers that would have developed during June and July, developed during May and only a few secondary tillers remain to develop a low biomass during that June, with a few fall tillers developing during July and August. The herbage growth from early June to late July was 647.97 lbs (table 3).

During 1995 to 2005, cow and calf weight performance on a crested wheatgrass two pasture switchback stocked at 1.25 ac/AUM (Appendix tables 1-5) was compared to that on an unfertilized pasture stocked at 2.33 ac/AUM (Appendix tables 6-10). On the switchback pastures, calf weight gain was 2.61 lbs per day, 66.60 lbs per acre, and accumulated weight was 76.45 lbs per head. Cow weight gain was 2.60 lbs per day, 65.49 lbs per acre, and accumulated weight was 75.43 lbs per head (table 1). On the unfertilized pasture, calf weight gain was 2.57 lbs per day, 32.93 lbs per acre, and accumulated weight was 72.67 lbs per head. Cow weight gain was 2.05 lbs per day, 26.67 lbs per acre, and accumulated weight was 59.15 lbs per head (table 1). The cow and calf weight gain on the switchback pastures was greater than those on the unfertilized pasture. The calves weight gain was 0.04 lbs per day greater, 3.78 lbs total weight gain per head greater, and 33.67 lbs per acre (102.2%) greater. The cow weight gain was 0.55 lbs per day greater, 16.28 lbs total weight gain per head greater, and 38.82 lbs per acre (145.6%) greater (table 1). The dollar value captured was greater on the switchback pastures, the pasture cost was $9.33 lower, pasture weight gain value was $2.65 greater, net return per cow-calf pair was $11.96 greater, and net return per acre was $23.66 (165.2%) greater (table 2). During the 11 year period of 1995 to 2005, the basal cover of crested wheatgrass on the unfertilized pasture decreased (5.7%) from 21.4% to 20.2%, and the basal cover of crested wheatgrass on the switchback pastures increased (36.6%) from 19.8% to 27.1%.

The cow and calf weight gains per head and per day on the unfertilized pasture were acceptable, however, the weight gains per acre were low for crested wheatgrass standards. Grazing of the one unfertilized pasture for 28 to 30 days during May does not activate the internal grass growth mechanisms. The herbage growth from early June to late July was only 384.83 lbs (table 3).

The cow and calf weight gains per head and per day on the switchback pastures were a little greater than those on the unfertilized pasture, importantly, the cow and calf weight gains per acre were 145.6% and 102.2% greater than those on the unfertilized pasture, respectively. The two pasture switchback spring crested wheatgrass system activated all of the internal grass growth mechanisms yielding greater grass biomass production, greater grass basal cover, and greater development of secondary tillers and fall tillers resulting in greater cow and calf weight gains per head and per day, and remarkably greater weight gains per acre. The herbage growth from early June to late July was 757.62 lbs, with a July peak at 1796.59 lbs (table 3).

Crested wheatgrass meadows are excellent spring complementary pastures during May. Crested wheatgrass is physiologically ready for grazing and the herbage biomass quantity is sufficient for grazing to start in early May. Spring grazing of crested wheatgrass during May synchronizes cattle requirements closely with the herbage production curves and the nutritional quality curves of the grass forage and is an ideal match coordinating grass phenological growth stages with partial defoliation by large grazing graminivores to activate beneficial plant mechanisms and ecological processes. Crested wheatgrass lead tillers contain 19.0% crude protein in early May. A healthy dense stand of crested wheatgrass is capable of producing rapid rates of growth of herbage biomass with most years producing 300 lbs/ac/day while lead tillers are at vegetative growth stages. By mid May, the lead tillers contain 16.2% crude protein when the flower stalks start developing. Some of the advanced lead tillers reach the flower stage by 28 May containing 13.5% crude protein. The rate of growth slows. The crude protein content is at 12.1% during early June. The remaining lead tillers usually reach the flower stage by 10 June. High animal weight gains per head and per day, and incredible weight gains per acre can be achieved without fertilizer by using a two pasture switchback treatment where each of the two pastures are grazed for two alternating periods of 7 to 8 days for a total of 28 to 32 days from early May to late May or to a couple of the first days of June. The calves need to be one month old on 1 May at the start of grazing in order for them to be able to put on high rates of weight gain per day. A minimum of 500 lbs to 1000 lbs of live herbage weight per acre must remain at the end of grazing, more is better. Also, crested wheatgrass pastures should only have one use per growing season.

Crested wheatgrass plants are hardy but cannot fully recover from double heavy use during one growing season. The stand deteriorates with great reductions in basal cover and herbage production. Double use of crested wheatgrass meadows that removes most of the standing dead vegetation has the potential to cause serious mineral deficiencies in the grazing cows blood. Mature lactating cows can develop milk fever or grass tetany while grazing lush spring crested wheatgrass vegetation that contains little standing dead grass. Milk fever is caused by a blood deficiency of calcium (Ca) and grass tetany is caused by a blood deficiency of magnesium (Mg.). Crested wheatgrass live herbage, however, is rarely deficient in calcium or magnesium during the growing season. A cows blood serum deficiency of calcium or magnesium is not caused by consuming crested wheatgrass forage deficient in those minerals. Absorption of most minerals from the forage is by passive transport (diffusion) across the intestinal wall; some calcium is transported with a protein carrier. Only about half of the ingested minerals are absorbed through the intestinal wall into the cows blood system under normal conditions. During the early spring, the rate of forage passage through the cows digestive tract is accelerated when lush vegetation that is high in water and crude protein is consumed without adequate quantities of standing dead vegetation; greatly reducing the quantity of dietary minerals absorbed through the intestinal wall and potentially resulting in deficiencies of calcium or magnesium in the cows blood. Cattle grazing crested wheatgrass pastures containing sufficient amounts of dry standing carryover residual vegetation can maintain normal slow rates of forage passage through the digestive tract and normal rates of mineral diffusion; which in effect, prevents the occurrence of mineral deficiencies in the blood and thus preventing the development of milk fever or grass tetany in cows grazing crested wheatgrass spring (May) complementary pastures.

The grazing start date of spring crested wheatgrass complementary pastures was determined to be 1 May and duration of the grazing period was confirmed to extend to late May or to the first couple of days in June during this study.

In the west river region of the Northern Mixed Grass Prairie, the optimum stocking rate for a one unfertilized spring crested wheatgrass pasture in very good condition was determined to be 2.33 ac/AUM and the optimim stocking rate for a two pasture spring crested wheatgrass switchback system in excellent condition was determined to be 1.30 ac/AUM. During the first few years this treatment was stocked way too heavy at 1.05 ac/AUM, and later 1.25 ac/AUM was tried for several years and found to still be a little too heavy.

During this study, the two pasture switchback grazing treatment was successfully adapted to management of spring (May) grazing on unfertilized crested wheatgrass pastures. This two pasture switchback treatment design is extremely detrimental when used to manage grazing on summer native rangeland pastures because the grazing periods are out of synchronization with the development of grass phenological growth stages. And the reason that it works well for one month (May) on crested wheatgrass pastures is that most of the entire grazing period occurs prior to when the lead tillers reach the flower stage. The first lead tillers to reach the flower stage is usually 28 May with most tillers at flower stage by 10 June. If grazing starts on 1 May and the two alternating grazing periods in each of the two pastures is 7 days long, the end of grazing is 28 May, and if the grazing periods are 8 days long, the end of the grazing is 2 June, while most of the forage material is still vegetative lead tillers.

Grass lead tillers grazed only during vegetative phenological growth stages permits the greater stocking rate compared to native rangeland on the same soil type. However, grazing crested wheatgrass at high stocking rates for 28 to 30 days during May requires the remainder of the growing season for the tillers to fully recover.

Crested wheatgrass meadows do not produce more than native rangeland. The total net primary production of crested wheatgrass herbage biomass during an entire growing season is about the same as that produced on native rangeland. Crested wheatgrass monocultures appear to produce greater herbage than native rangeland because ungrazed crested wheatgrass has one major growth period with most of the lead tillers growing together at a similar time and at a similar rate resulting in a high peak herbage biomass early in the growing season with little new growth occurring after mid to late June. Native rangeland, on the other hand, is a mixture of numerous cool season and warm season species with several growth periods not occurring together but spread throughout the early portion of the growing season resulting in a lower peak herbage biomass extended over a longer period of time, and producing about the same quantity of total new growth material as crested wheatgrass on the same soil type per acre during one growing season.

The ability to start grazing a month ahead of the proper grazing start date on native rangeland is the primary biological advantage of crested wheatgrass pastures and their priority use should be grazing during May as spring complementary pastures in conjunction with summer grazing native rangeland rotation systems starting in early June.

Table 1. Cow and calf weight performance grazing spring crested wheatgrass complementary pastures managed by the biologically effective concept compared to pastures managed by the traditional concept.

	Traditional Concept			Biologically Effective Concept			Biological Gain		
Crested wheatgrass	Wt Gain lbs	Gain per Day lbs	Gain per Acre lbs	Wt Gain lbs	Gain per Day lbs	Gain per Acre lbs	Wt Gain lbs	Gain per Day lbs	Gain per Acre lbs
1989-1994	One Pasture, 2.45 ac/AUM Unfertilized			One Pasture, 0.85 ac/AUM Fertilized 50 lbs N/ac					
Calf	66.21	2.34	28.08	66.83	2.37	78.82	0.62	0.03	50.74
Cow	27.84	0.93	11.83	50.87	2.57	92.81	23.03	1.64	80.98
1995-2005	One Pasture, 2.33 ac/AUM Unfertilized			Two Pasture, 1.25 ac/AUM Switchback					
Calf	72.67	2.57	32.93	76.45	2.61	66.60	3.78	0.04	33.67
Cow	59.15	2.05	26.67	75.43	2.60	65.49	16.28	0.55	38.82

Table 2. Value captured gain in dollars from spring crested wheatgrass complementary pastures managed by the biologically effective concept compared to pastures managed by the traditional concept.

	Traditional Concept				Biologically Effective Concept				Value Captured Gain			
Crested wheatgrass	Pasture Cost $	Pasture Weight Gain Value $	Net Return per C-C pr $	Net Return per Acre $	Pasture Cost $	Pasture Weight Gain Value $	Net Return per C-C pr $	Net Return per Acre $	Pasture Cost $	Pasture Weight Gain Value $	Net Return per C-C pr $	Net Return per Acre $
1989-1994	One Pasture, 2.45 ac/AUM Unfertilized				One Pasture, 0.85 ac/AUM Fertilized 50 lbs N/ac							
Cow-Calf pair	20.65	46.35	25.71	10.90	11.64	46.78	35.14	39.04	-9.01	0.43	8.43	28.14
1995-2005	One Pasture, 2.33 ac/AUM Unfertilized				Two Pasture, 1.25 ac/AUM Switchback							
Cow-Calf pair	19.38	50.87	31.50	14.32	10.05	53.52	43.46	37.98	-9.33	2.65	11.96	23.66

Table 3. Herbage biomass (lbs/ac) recovery following May grazing of crested wheatgrass spring (May) complementary pastures managed with three treatments.

Crested wheatgrass	Apr	May	Jun	Jul	Aug	Sep
1 Pasture, 0.85 ac/AUM Fertilized 50 lbs N/ac						
1983-1994						
Pregrazed	1121.76					
Grazed		518.93	789.62	1166.90	1280.07	718.82
1 Pasture, 2.33 ac/AUM Unfertilized						
1995-2005						
Pregrazed	752.16					
Grazed		797.13	1018.07	1181.96	1101.63	1019.18
2 Pasture, 1.25 ac/AUM Switchback						
1995-2005						
Pregrazed	1330.38					
Grazed		1038.97	1362.88	1796.59	1733.59	1763.57

Summer Native Rangeland Pastures

Native rangeland is the only perennial grass type that can adequately provide nutritious forage to modern lactating cows during the summer period from 1 June to mid October when the ecosystem processes and the internal grass mechanisms are fully activated with partial defoliation by graminivores that removes 25% to 33% of the leaf material from grass lead tillers at phenological growth stages between the three and a half new leaf stage and the flower stage (Manske 1999, 2011).

During 1983 to 1994, cow and calf weight performance grazing three native rangeland pastures with twice-over rotation stocked at 8 cows per 80 acres with 10.22 ac/AU (Appendix tables 11-15) was compared to that on a native rangeland pasture grazed seasonlong stocked at 6 cows per 80 acres during 1983 to 1987 and at 7 cows per 80 acres during 1988 to 1994 with 11.43 ac/AU (Appendix tables 16-20). On the twice-over system, calf weight gain was 317.98 lbs per head, 2.70 lbs per day, and 31.80 lbs per acre, and cow weight gain was 81.58 lbs per head, 0.68 lbs per day, and 8.16 lbs per acre (table 4). On the seasonlong system, calf weight gain was 265.12 lbs per head, 2.35 lbs per day, and 21.99 lbs per acre and cow weight gain was 21.80 lbs per head, 0.19 lbs per day, and 1.67 lbs per acre (table 4). The dry period of 1988 to 1990 resulted in reductions of cow and calf weight performance caused by reduced herbage production with lower nutritional quality and reduced length of the grazing period. On the twice-over system, cow weight gain was reduced 14.89 lbs and calf weight gain was reduced 39.78 lbs. On the seasonlong system, cow weight gain was reduced 6.40 lbs and calf weight gain was reduced 58.35 lbs. The cow and calf weight gain on the twice-over system was greater than those on the seasonlong system. Calf weight gain was 52.86 lbs per head greater, 0.35 lbs per day greater, and 9.81 lbs per acre greater and cow weight gain was 59.78 lbs per head greater, 0.49 lbs per day greater, and 6.49 lbs per acre greater (table 4). The dollar value captured was greater on the twice-over system than those on the seasonlong system. The pasture cost was $16.15 lower, pasture weight gain value was $37.00 greater, net return per cow-calf pair was $53.14 greater, and net return per acre was $6.41 greater (table 5).

The grazing period on the seasonlong system managed with the traditional concept was from mid June to late October. The cows daily weight gain generally lost weight during the first two weeks from mid June to early July with an average loss of 2.19 lbs per day, the cows gained weight at a decreasing rate during 2.5 months from 1 July to 15 September than lost weight for 1.5 months. The seasonlong cows gained weight during 55.6% and lost weight during 44.4% of the 4.5 month grazing period (figures 1 and 2). The seasonlong calf daily gain was below 2.50 lbs per day during the first two weeks when the cows lost weight, the calf weight gain was above 2.50 lbs per day during the 2.5 months that the cows gained weight from 1 July to 15 September and then the calf daily gain dropped below 2.50 lbs per day while the cow lost weight for 1.5 month from mid September to late October (figures 1 and 2).

The grazing period on the twice-over system managed with the biologically effective concept was from early June to mid October. During the first rotation period of 45 days from early June to mid July, the cows daily gain decreased with the vegetation decrease in crude protein, the cow daily gain leveled off when the cows grazed pastures 1 and 2 during the second period, and then halfway through grazing pasture 3 the second period, the cows lost weight. The twice-over cows gained weight during 88.9% and lost weight during 11.1% of the 4.5 month grazing period (figures 1 and 2). During the first five years of this study, the stimulation period was thought to be 60 days long from early June to late July. The cows loss of weight during the last two weeks of the grazing period showed that the stimulation period was actually only 45 days long from early June to mid July. The twice-over calf daily gain was greater than 2.50 lbs per day from 1 June to 30 September and then the calf daily gain dropped below 2.50 lbs per day for the last 2 weeks while the cow lost weight from late September to mid October (figures 1 and 2).

During the 1983 to 1994 period, the cow and calf weight performance on the traditional concept was substantially lower than those for the cow and calf pairs on the biologically effective concept. A great amount of the weight reduction was caused by the differences in the dates of the grazing periods on the traditional concept pastures. The crested wheatgrass pasture was grazed from mid May to mid June and the native pasture was grazed from mid June to late October. The crested wheatgrass pasture was grazed during two weeks in June when the crude protein content was 12% to 10% which had been traded for grazing during two weeks in early May when the crude protein content was 19% to 16%, costing the cows and calves at least 30 lbs. The native rangeland pasture was grazed during the last two weeks in October when the cows lost 26 lbs and the calves gained only 16 lbs which had been traded for grazing during the first two weeks of June when the cows could have gained 30 lbs and the calves could have gained 35 lbs.

During the 1983 to 1994 period, the grazing period on the crested wheatgrass pastures on the biologically effective concept was from mid May to early June with only 20 days of grazing instead of starting during early May with 28 or 30 days of grazing adding 18 lbs or 23 lbs to the calf weight and adding 20 lbs or 26 lbs to the cows weight.

A simple problem of having the wrong dates for the grazing period not coordinated with the grass plant herbage biomass production curves and the nutritional quality curves can cost a great quantity in cow and calf weight performance. The optimum coordinated dates for crested wheatgrass pastures is to graze from 1 May to late May or to the first couple days in June. The optimum coordinated dates for native rangeland pastures is to graze from early June to mid October. These are the grazing period dates used for both the traditional concept and the biologically effective concept pastures during the 1995 to 2005 period.

During 1995 to 2005, cow and calf weight performance grazing three native rangeland pastures with twice-over rotation stocked at 8 cows per 80 acres with 10.34 ac/AU (Appendix tables 11-15) was compared to that on a one native rangeland pasture grazed seasonlong stocked at 7 cows per 80 acres with 11.69 ac/AU (Appendix tables 16-20). On the twice-over system, calf weight gain was 380.47 lbs per head, 2.89 lbs per day, and 37.66 lbs per acre and cow weight gain was 86.92 lbs per head, 0.66 lbs per day, and 8.68 lbs per acre (table 4). On the seasonlong system, calf weight gain was 354.37 lbs per head, 2.65 lbs per day, and 30.61 lbs per acre and cow weight gain was 67.11 lbs per head, 0.50 lbs per day, and 5.91 lbs per acre (table 4). The cow and calf weight gain on the twice-over system was greater than those on the seasonlong system. Calf weight was 26.10 lbs per head greater, 0.24 lbs per day greater, and 7.05 lbs per acre greater and cow weight gain was 19.81 lbs per head greater, 0.16 lbs per day greater, and 2.77 lbs per acre greater (table 4). The dollar value captured was greater on the twice-over system than those on the seasonlong system. The pasture cost was $11.82 lower, pasture weight gain value was $15.16 greater, net return per cow-calf pair was $30.09 greater, and net return per acre was $4.37 greater (table 5).

On the seasonlong system managed with the traditional concept, cow daily gain decreased at an average rate of 47% per month from 1 June to 15 September (figure 3). Lead tillers of native cool season and warm season grasses decrease in crude protein content at an average rate of 24% and 23% per month, respectively, from 1 June to 15 September. The cow daily gain decreased 377% during 15 September to 15 October. The seasonlong cows lost weight the last month of the grazing period during 9 growing seasons (82% of the time). Calf daily gains averaged 2.79 lbs/day from 1 June to 15 September, then daily gains decreased to 2.11 lbs/day during the last month (figure 3). Cow weight accumulation occurred at about 28 lbs/month from 1 June to 15 September, then the cows lost 26 lbs during the last month, which was more than 26% of their accumulated weight. Calf weight accumulation occurred at about 81 lbs/month during the entire grazing period (figure 4).

On the twice-over system managed with the biologically effective concept, cow daily gain decreased at an average rate of 34% during the first month (June), then the rate of daily gain increased each time the cows returned to pastures 1 and 2 for the second grazing period. The small increase in daily gain is assumed to occur for more than 2 weeks when the cows returned to pasture 3 for the second grazing period, however, weight performance data has not been collected during late season interim dates. The cows lost an average of 0.51 lbs/day during the first 2 weeks of October. This loss of cow weight was the result of 4 years (36% of the time) with one month per growing season with severe water deficiency at 22% of LTM during August, September, or October causing an average cow weight loss of 1.93 lbs/day. During the other 7 years (64% of the time) the cow weight gain averaged 0.34 lbs/day during the first 2 weeks of October. Calf daily gain averaged 3.08 lbs/day from 1 June to 15 September, then daily gains decreased to 2.28 lbs/day during the last month (figure 3). Cow weight accumulation occurred at about 32 lbs/month from 1 June to 15 September, then the cows lost 17 lbs, which was about 15% of their accumulated weight. Calf weight accumulation occurred at about 88 lbs/month during the entire grazing period (figure 4).

With both the biologically effective concept and the traditional concept using the same optimum coordinated grazing period dates, the cow and calf weight performance on the traditional concept pastures moved closer to the cow and calf weight performance on the biologically effective concept. However, the twice-over rotation system has a considerable biological and economical advantage over the seasonlong system.

Grazing native rangeland for 4.5 months from 1 June to 15 October (137 days) is the ideal period for the best potential cow and calf weight performance to occur. Grazing before 1 June, when the grass lead tillers have not produced 3.5 new leaves is extremely detrimental for grass herbage biomass production with a reduction between 20% and 45% resulting in secondary problems in lost animal weight gains. Grazing after 15 October when the available quantity of crude protein is deficient, cow and calf weight gains suffer greatly and the removal by grazing of living carryover tillers greatly reduces the following growing seasons grass density and herbage biomass production.

In the west river region of the Northern Mixed Grass Prairie, the optimum stocking rate for one native rangeland pasture in very good condition managed with a seasonlong system is with 7 cows/80 acres at 11.43 ac/AU and 2.60 ac/AUM determined during this study. The optimum stocking rate for three native rangeland pastures in near excellent condition managed with a twice-over rotation system is with 8 cows/80 acres at 10.22 ac/AU and 2.30 ac/AUM determined during this study.

The period of time that the internal grass plant growth mechanisms of compensatory physiological mechanisms, vegetative reproduction by tillering, nutrient resource uptake, and water use efficiency can be activated and the external ecosystem processes carried out by the rhizosphere microorganisms can be enhanced with short chain carbon energy transported from the surpluses in grass tillers to the microbes occurs from 1 June to 15 July with grass lead tillers between the three and a half new leaf stage and the flower stage when grazing graminivores' partial defoliation removes 25% to 33% of the aboveground leaf material and when mineral nitrogen is available in the soil at the 100 lbs/ac threshold level.

Partial defoliation by grazing graminivores is the only method that the grass plant mechanisms and ecosystem processes can be activated. Fire and mowing remove too much of the leaf area and the biomass of wildlife is too low to remove 25% to 33% of the leaf material unless elk or bison can reach the biomass of the domesticated cow herd. This makes domesticated graminivores an indispensable biotic component of functional grassland ecosystems.

The biologically effective twice-over rotation strategy was perfected during this study. This grazing strategy was developed to coordinate partial defoliation events with grass phenological growth stages, meet the nutritional requirements of the grazing graminivores, meet the biological requirements of the grass plants and the rhizosphere organisms, and enhance the ecosystem biogeochemical processes and activate the internal grass plant mechanisms to function at potential levels.

Each of three native rangeland pastures of the twice-over rotation system were grazed two times during the 4.5 month period from early June to mid October. The first grazing period of 15 days occurred between 1 June and 15 July, when grass lead tillers were between the three and a half new leaf stage and the flower stage. The second grazing period of 30 days occurred after 15 July and prior to mid October, when the stimulated vegetative secondary tillers had reached their three and a half new leaf stage. The first pasture grazed each year was the last pasture grazed the previous year. A three year sequence would be ABC, CAB, and BCA.

Table 4. Cow and calf weight performance grazing summer native rangeland pastures managed by the biologically effective concept compared to pastures managed by the traditional concept.

	Traditional Concept			Biologically Effective Concept			Biological Gain		
Native Rangeland	Wt Gain lbs	Gain per Day lbs	Gain per Acre lbs	Wt Gain lbs	Gain per Day lbs	Gain per Acre lbs	Wt Gain lbs	Gain per Day lbs	Gain per Acre lbs
1983-1994	One Pasture, 12.06 ac/AU Seasonlong			Three Pastures, 10.22 ac/AU Twice-over rotation					
Calf	265.12	2.35	21.99	317.98	2.70	31.80	52.86	0.35	9.81
Cow	21.80	0.19	1.67	81.58	0.68	8.16	59.78	0.49	6.49
1995-2005	One Pasture, 11.69 ac/AU Seasonlong			Three Pastures, 10.34 ac/AU Twice-over rotation					
Calf	354.37	2.65	30.61	380.47	2.89	37.66	26.10	0.24	7.05
Cow	67.11	0.50	5.91	86.92	0.66	8.68	19.81	0.16	2.77

Table 5. Value captured gain in dollars from summer native rangeland pastures managed by the biologically effective concept compared to pastures managed by the traditional concept.

	Traditional Concept				Biologically Effective Concept				Value Captured Gain			
Native Rangeland	Pasture Cost $	Pasture Weight Gain Value $	Net Return per C-C pr $	Net Return per Acre $	Pasture Cost $	Pasture Weight Gain Value $	Net Return per C-C pr $	Net Return per Acre $	Pasture Cost $	Pasture Weight Gain Value $	Net Return per C-C pr $	Net Return per Acre $
1983-1994	One Pasture, 12.06 ac/AU Seasonlong				Three Pastures, 10.22 ac/AU Twice-over rotation							
Cow-Calf pair	105.68	185.58	79.91	6.64	89.53	222.58	133.05	13.02	-16.15	37.00	53.14	6.41
1995-2005	One Pasture, 11.69 ac/AU Seasonlong				Three Pastures, 10.34 ac/AU Twice-over rotation							
Cow-Calf pair	102.42	248.06	145.64	12.67	90.60	263.22	175.73	17.04	-11.82	15.16	30.09	4.37

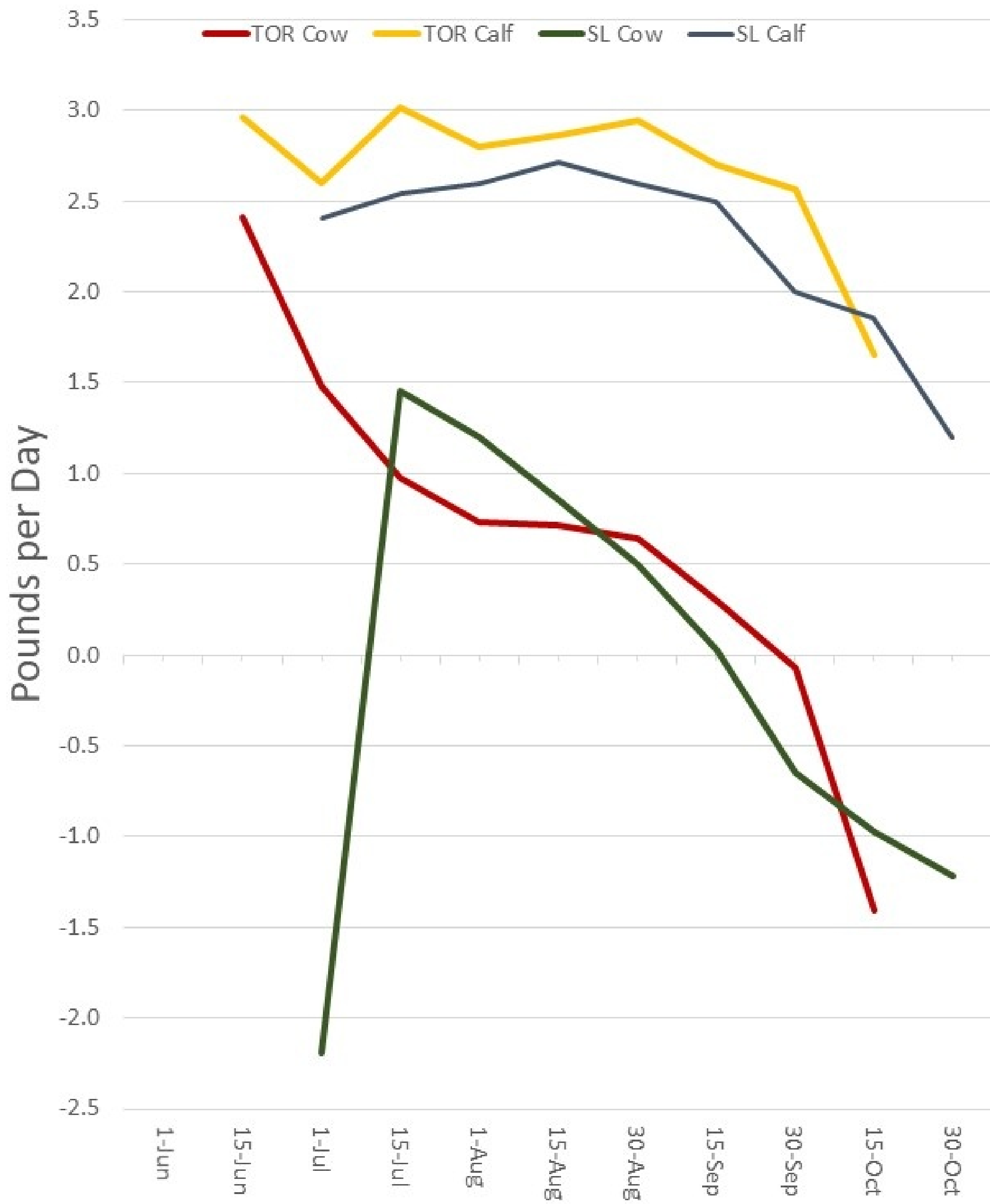

Figure 1. Cow and calf daily gain on the seasonlong and twice-over grazing systems, 1983-1994.

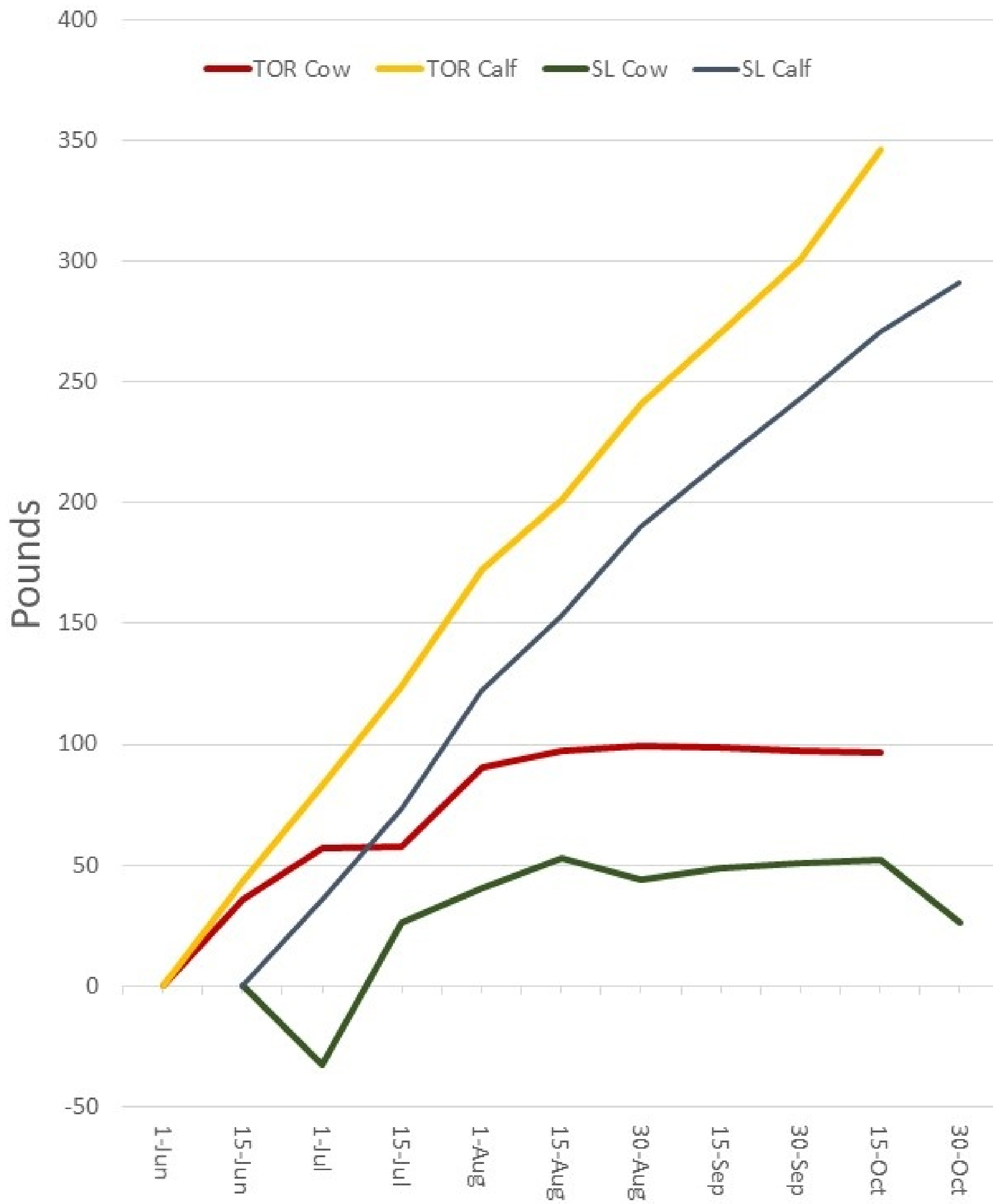

Figure 2. Cow and calf accumulated weight gain on the seasonlong and twice-over grazing systems, 1983-1994.

Figure 3. Cow and calf daily gain on the seasonlong and twice-over grazing systems, 1995-2005.

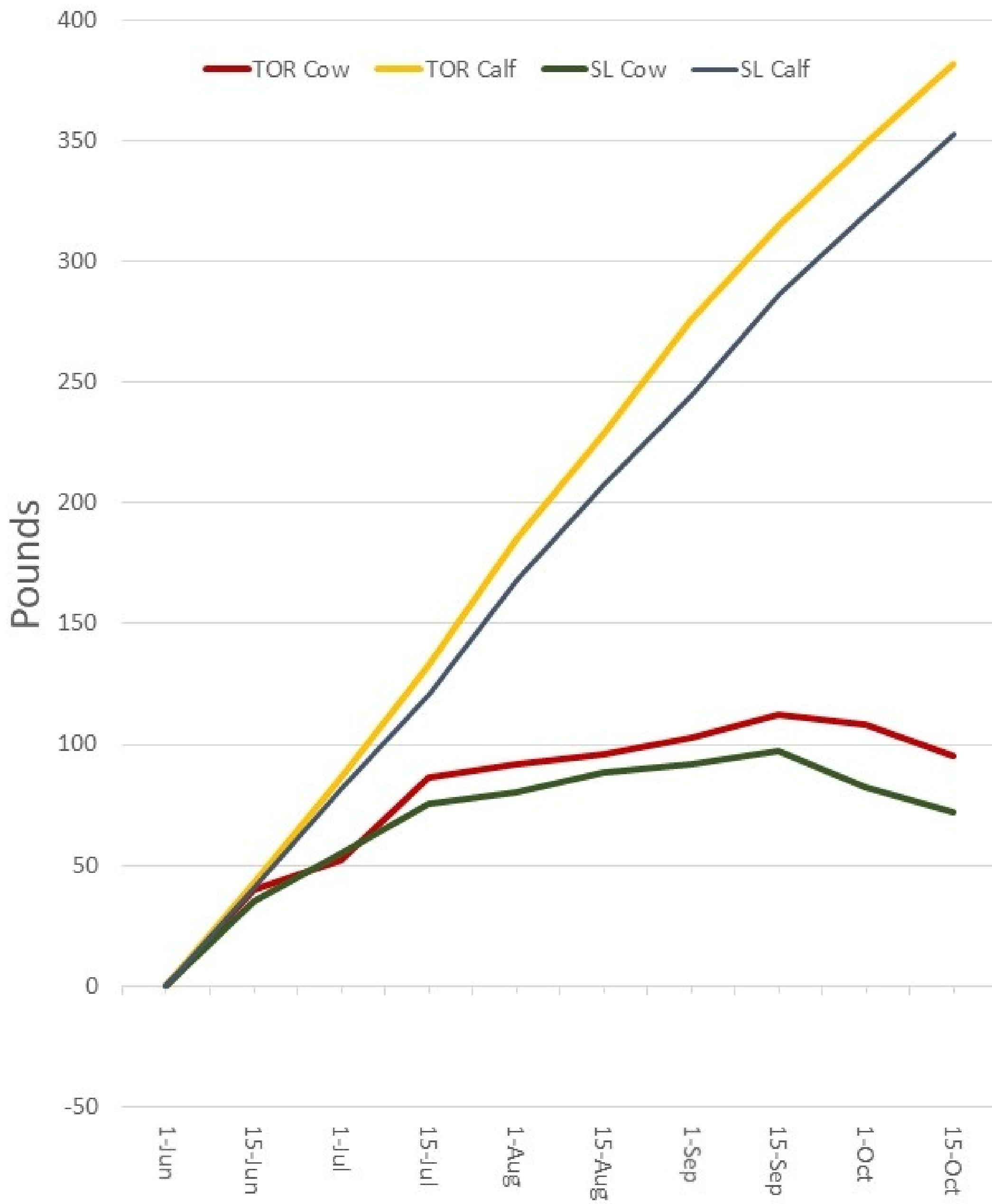

Figure 4. Cow and calf accumulated weight gain on the seasonlong and twice-over grazing systems, 1995-2005.

Fall Complementary Pastures

Native rangeland herbage has low quantity and little quality after mid October. Measured by wet chemistry, late season native rangeland herbage contains around 4.9% crude protein. The Kjeldahl method measures nitrogen content and, during the late season, almost all of this nitrogen is chemically bonded to plant structural components that are not available through rumination. Grazing native rangeland herbage after mid October results in cow average loss of weight at around 0.96 lbs/day and in reductions of calf average weight gain to about 0.91 lbs/day (Manske 2008a). The value of the calf weight gain is usually below pasture costs resulting in negative net returns per cow-calf pair and per acre. Low cash flow costs does not indicate low cost feed. Alternative forage sources that meet livestock dietary quantity and quality are needed during the fall period to capture greater wealth from the land.

Cropland aftermath has been a long-time traditional fall forage type. The nutrient content of stubble from annual cereals harvested for grain is almost nonexistent. Unless the cropland aftermath pasture contains a substantial quantity of sprouted grain, lactating cows cannot find forage that meets their crude protein requirements.

The wildryes are the only perennial grass that retains nutritional quality to meet lactating cows requirements during mid October to mid November. There are numerous species of wildryes in the world. Research at DREC has tested the grazing characteristics of Russian and Altai wildryes. The wildryes have been considered to be difficult to manage because they respond differently than other grasses to standard grassland practices. Which should indicate that the wildryes need to be managed differently than other grasses to be successful.

Annual cereal grasses are typically not used as forage plants for livestock except during emergencies. Winter cereals are usually seeded during summer but this late seeding would not produce sufficient herbage for fall grazing. Spring seeded winter cereals produce sufficient root mass and depth to survive low precipitation periods that can occur during July, August, or September and still produce sufficient herbage for grazing during mid October to mid November. Winter varieties of triticale, wheat, and rye are grown for grain. Triticale produces the greatest herbage biomass but cattle like it the least. Rye produces the lowest herbage biomass and cattle like it the best. Wheat is in the middle. Winter barley does not survive the Northern Plains winters and would not have the problem of leaving plants that need to be sprayed with herbicides or tilled under before the next springs planting. However, because of its winter survival problem, it isn't grown for grain and seed of winter barley is not available locally and long-distance purchases are only sold by the semi load. Because rye is a more dependable crop and has the greater frost and drought resistance, plus cattle like it best, winter (fall) rye was used as the annual cereal forage.

During 1984 to 2002, cow and calf weight performance grazing Altai wildrye pastures stocked at 1.39 ac/AU for 30 days was evaluated (Appendix tables 21-23). During 2003 to 2005, cow and calf weight performance grazing 4 pastures of spring seeded winter cereal stocked at 0.47 ac/AU for 30 days was evaluated (Appendix tables 24-25). During 1983 to 1998, cow and calf weight performance grazing cropland aftermath stocked at 6.63 ac/AU for 30 days was evaluated (Appendix tables 26-27). On the Altai wildrye pastures, calf weight gain was 50.34 lbs per head, 1.82 lbs per day, and 37.12 lbs per acre, and cow weight gain was 42.60 lbs per head, 1.62 lbs per day, and 32.22 lbs per acre (table 6). On the spring seeded winter cereal pastures, calf weight gain was 60.0 lbs per head, 2.00 lbs per day, and 127.66 lbs per acre, and cow weight gain was 31.50 lbs per head, 1.05 lbs per day, and 67.02 lbs per acre (table 6). On the cropland aftermath pastures, calf weight gain was 12.57 lbs per head, 0.42 lbs per day, and 1.90 lbs per acre, and cow weight loss was 48.17 lbs per head, 1.61 lbs per day, and 7.27 lbs per acre (table 6).

The cow and calf weight gain on the Altai wildrye pastures was greater than those on the cropland aftermath pastures. Calf weight gain was 37.77 lbs per head greater, 1.40 lbs per day greater, and 35.22 lbs per acre greater. Cow weight gain was 90.77 lbs per head greater, 3.23 lbs per day greater, and 39.49 lbs per acre greater (table 6). Calf weight gain on the spring seeded winter cereal pastures was greater than those on the Altai wildrye pastures. Calf weight gain was 9.66 lbs per head greater, 0.18 lbs per day greater, and 90.54 lbs per acre greater. The dollar value captured was greater on the Altai wildrye pastures than those on the cropland aftermath pastures. The pasture cost was $1.86 lower, pasture weight gain value was $26.44 greater, net returns per cow-calf pair was $28.30 greater, and net return per acre was $18.98 greater (table 7). The dollar value captured per acre on the spring seeded winter cereal pastures was greater than those on the Altai wildrye pastures. The pasture cost was $8.30 greater, pasture weight gain value was $6.76 greater, net returns per cow-calf pair was $1.54 lower, and net return per acre was $29.14 greater (table 7).

Wildrye pastures deteriorate in 20 to 25 years after they are seeded when managed with standard grassland practices. Previous work on Basin wildrye indicated that the roots extending out past the drip line of wildrye bunch were extremely sensitive to compaction. Observations of driving a pickup or tractor in wildrye pastures killing plants have been made for Altai wildrye, leading to an erroneous conclusion that heavy cows stepping near the crown of wildrye plants were causing plant depletion. Another serious misconception about wildryes is the low herbage biomass production and low quantity of crude protein and total digestible nutrient values collected from ungrazed test plots. Grazing wildryes during the fall period from mid October to mid November changes the growth characteristics of the wildryes.

All perennial grases reproduce vegetatively by producing tillers from axillary buds. These tillers live for two growing seasons, the first year as a vegetative tiller and the second year as a reproductive seed producing tiller. The apical meristem of the major native cool season and warm season grass in the Northern Mixed Grass Prairie change from producing leaf buds to producing flower buds during the second spring when the tiller is between the three new leaf stage and the three and a half new leaf stage; this is one of the reasons grazing readiness occurs after the three and half new leaf stage. Whether or not we have been conscious of the timing of this changeover, our standard grassland management practices are based on this phenomenon. This is also the reason why our standard grassland management practices used on the wildryes causes them to deteriorate. The apical meristem of wildryes, Russian and Altai, change from producing leaf buds to producing flower buds during the second growing season in August, not in the spring like our native grasses. Partial defoliation of wildrye lead tillers during the fall period from mid October to mid November stimulates greater numbers of vegetative tillers to develop from the axillary buds. This greatly increases the herbage biomass production to be over 3000 lbs in mid October at higher quantities of crude protein and TDN permitting cows and calves to gain around 2.0 lbs/day until mid November. The differences in wildrye growth are the reason changes in management are needed. In order to perpetuate a wildrye pasture, no more than 50% of the aboveground herbage can be removed with grazing by mid November, which means about 1500 lbs of herbage must be left standing when the cattle are moved off. If 50% of the aboveground herbage is not left at the end of grazing, the stand deteriorates greatly each year. Using this new insight into the proper management of wildrye pastures, Russian and Altai wildryes should be reconsidered as viable fall perennial grass pastures (Manske 2017a).

Seeding a winter cereal like rye in the spring into fenced cropland with frost free water produces close to 2000 lbs of forage/ac feeding a 1200 lb cow with a calf for 30 days on about 0.5 acres. At low market value for accumulated calf weight of $0.70/lb, the net return per acre is around $48.00. At a market value of $1.25/lb, the net return per acre is around $118.00.

Cropland aftermath of cereal stubble is not a good source of forage for modern livestock, however, with shelter from wind and frost free water, cropland aftermath would be an excellent location to full feed harvested hay to the cow herd during the late season and the barnyard manure would automatically be delivered to the site that it would be beneficial.

Seeding forage barley in the spring into fenced cropland cut for hay at the milk stage produces over 4500 lbs of forage/ac that would feed a 1200 lb cow with a calf for 30 days during the fall from 0.12 acres plus 321 lbs of roughage. At low market value for accumulated calf weight of $0.70/lb, the net return per acre after paying $115.00 for production costs/ac would be around $233.00. At market value of $1.25/lb, the net return per acre is around $498.00 (Manske 2014). Annual cereal grass hay harvested at the proper phenological growth stage has the potential to yield high net returns per acre and should be reconsidered for use as a standard management practice.

Table 6. Cow and calf weight performance grazing fall complementary pastures managed by the biologically effective concept compared to pastures managed by the traditional concept.

Fall Pasture	Traditional Concept Wt Gain lbs	Traditional Concept Gain per Day lbs	Traditional Concept Gain per Acre lbs	Biologically Effective Concept Wt Gain lbs	Biologically Effective Concept Gain per Day lbs	Biologically Effective Concept Gain per Acre lbs	Biological Gain Wt Gain lbs	Biological Gain Gain per Day lbs	Biological Gain Gain per Acre lbs
1983-1998	One Pasture, 6.63 ac/AU Cropland Aftermath			One Pasture, 1.30 ac/AU Altai wildrye					
Calf	12.57	0.42	1.90	50.34	1.82	37.12	37.77	1.40	35.22
Cow	-48.17	-1.61	-7.27	42.60	1.62	32.22	90.77	3.23	39.49
2003-2005				Four Pasture, 0.47 ac/AU Spring Seeded Winter Cereal					
Calf				60.00	2.00	127.66	9.66	0.18	90.54
Cow				31.50	1.05	67.02	-11.10	-0.57	34.80

Table 7. Value captured gain in dollars from fall complementary pastures managed by the biologically effective concept compared to pastures managed by the traditional concept.

Fall Pastures	Traditional Concept Pasture Cost $	Traditional Concept Pasture Weight Gain Value $	Traditional Concept Net Return per C-C pr $	Traditional Concept Net Return per Acre $	Biologically Effective Concept Pasture Cost $	Biologically Effective Concept Pasture Weight Gain Value $	Biologically Effective Concept Net Return per C-C pr $	Biologically Effective Concept Net Return per Acre $	Value Captured Gain Pasture Cost $	Value Captured Gain Pasture Weight Gain Value $	Value Captured Gain Net Return per C-C pr $	Value Captured Gain Net Return per Acre $
1983-1998	One Pasture, 6.63 ac/AU Cropland Aftermath				One Pasture, 1.30 ac/AU Altai wildrye							
Cow-Calf pair	13.26	8.80	-4.46	-0.67	11.40	35.24	23.84	18.31	-1.86	26.44	28.30	18.98
2003-2005					Four Pasture, 0.47 ac/AU Spring Seeded Winter Cereal							
Cow-Calf pair					19.70	42.00	22.30	47.45	8.30	6.76	-1.54	29.14

Total System, Spring, Summer, and Fall Pastures

The total system evaluation of cow and calf weight performance connects to spring, summer, and fall pastures managed by the two distinctly different concepts.

On the Traditional concept system, cow and calf pairs grazed one crested wheatgrass pasture at the rate of 2.33 acres for 28 days during early May to late May, one seasonlong native rangeland pasture at the rate of 11.43 acres for 137 days during early June to mid October, and one cropland aftermath pasture at the rate of 6.63 acres for 30 days during mid October to mid November. The entire system was comprised of 20.39 acres grazed for 195 days (6.39 months) from early May to mid November at a total pasture cost for $133.80 per cow-calf pair, with a cost of $0.69 per day (table 8). Calf weight gain was 439.61 lbs per head, 2.25 lbs per day, and 21.65 lbs per acre (table 9). Cow weight gain was 78.09 lbs per head, 0.40 lbs per day, and 3.83 lbs per acre (table 9). The dollar value captured was $307.73 calf pasture weight gain value, $173.93 net return per cow-calf pair, $8.53 net return per acre, and $0.30 cost per lb of calf weight gain (table 9).

On the Biologically Effective concept system, cow and calf pairs grazed two switchback crested wheatgrass pastures at a rate of 1.30 acres for 28 days during early May to late May, three twice-over rotation native rangeland pastures at a rate of 10.22 acres for 137 days during early June to mid October, and one Altai wildrye pasture at a rate of 1.30 acres for 30 days from mid October to mid November. The entire system was comprised of 12.82 acres grazed for 195 day (6.39 months) from early May to mid November at a total pasture cost of $112.30 per cow-calf pair, with a cost of $0.58 per day (table 8). Calf weight gain was 507.26 lbs per head, 2.60 lbs per day, and 39.57 lbs per acre (table 9). Cow weight gain was 204.95 lbs per head, 1.05 lbs per day, and 15.99 lbs per acre (table 9). The dollar value captured was $355.08 calf pasture weight gain value, $242.78 net return per cow-calf pair, $18.94 net return per acre, and $0.22 cost per lb of calf weight gain (table 9).

The grazing periods occurred at the same time, the number days and the number of months grazed were the same on both concept systems. The Biologically Effective concept system grazed 7.57 fewer acres, at $21.50 lower cost per cow-calf pair, and at $0.11 lower cost per day (table 8). On the Biologically Effective concept system, calf weight gain was 67.65 lbs per head greater, 0.35 lbs per day greater, and 18.01 lbs per acre greater, and cow weight gain was 126.86 lbs per head greater, 0.65 lbs per day greater, and 12.16 lbs per acre greater (table 9). The dollar value captured on the Biologically Effective concept system was $47.35 greater calf pasture weight gain value, $68.85 greater net returns per cow-calf pair, $10.41 greater net return per acre, and $0.08 lower or cost per lb of calf weight gain (table 9).

Using the Traditional concept of management, 400 cow-calf pairs would require 8,156 acres of spring, summer, and fall pastures and would yield $69,572 in net returns for the cow-calf pairs. Using the Biologically Effective concept of management, 400 cow-calf pairs would require 5,128 acres of spring, summer, and fall pastures and would yield $97,112 in net returns for the cow-calf pairs. The 400 cow-calf pairs managed with the Biologically Effective concept would require 3,028 fewer (37.1%) acres and yield $27,540 greater (39.6%) net returns for the cow-calf pairs.

The Traditional concept of management does not consider the biological requirements of the grass plants and soil microbes, and does not consider the crude protein requirements of the cows. As a result, the three biotic components do not produce at their potential levels. When the biotic components of the ecosystem do not function at biological potential, a high percentage of the potential wealth from the land is not captured. In the above example, about 40% of the wealth from the land was not captured.

The Biologically Effective concept of management considers the biological requirements of the grass plants and soil microbes, and provides adequate crude protein from stimulated secondary tillers to meet the cows requirements to late September 100% of the years and to mid October 64% of the years. During the period of May on the crested wheatgrass pastures, the period of early June to mid July on the native rangeland pastures, and the period of mid October to mid November on the Altai wildrye pastures, partial defoliation by the cattle activated the compensatory physiological mechanism, vegetative reproduction by tillering, nutrient resource uptake, and water use efficiency internal grass plant growth mechanisms and enhanced the external biogeochemical ecosystem processes performed by the rhizosphere microbes. The activation of all these mechanisms and processes was accomplished by the grazing graminivores with partial defoliation of grass tillers at specific phenological growth stages. When these mechanisms and processes function at biological potentials, the three biotic components of the ecosystem can function at their biological potentials producing greater wealth captured from the properly managed renewable land resources. In the above example, the Biologically Effective concept system captured 140% of the wealth from the land that the Traditional concept system captured.

Table 8. Grazing period, stocking rate, and pasture cost on the Biologically Effective concept system compared to those on the Traditional concept system.

Concept System	Grazing Period	# Days	# Months	Acres per C-C pr	Pasture Cost $	Cost per day $
Traditional	early May-mid Nov	195	6.39	20.39	133.80	0.69
Biologically Effective	early May-mid Nov	195	6.39	12.82	112.30	0.58
Difference	Same	same	same	-7.57	-21.50	-0.11

Table 9. Total cow and calf weight performance and net returns on the Biologically Effective concept system compared to those on the Traditional concept system.

Concept System	Total wt gain lbs	Gain per day lbs	Gain per Acre lbs	Pasture weight gain Value $	Net Return per c-c pr $	Net Return per Acre $	Cost/lb Calf Weight Gain $
Traditional							
Calf	439.61	2.25	21.56	307.73	173.93	8.53	0.30
Cow	78.09	0.40	3.83				
Biologically Effective							
Calf	507.26	2.60	39.57	355.08	242.78	18.94	0.22
Cow	204.95	1.05	15.99				
Difference							
Calf	67.65	0.35	18.01	47.35	68.85	10.41	-0.08
Cow	126.86	0.65	12.16				

Discussion

Grazing graminivores perform two indispensable functions for grassland ecosystems. Graminivores activate the four major internal grass plant growth mechanisms and enhance rhizosphere activity and increase biomass to perform the ecosystem biogeochemical processes, and remove the 50% surplus grass biomass produced by grass plants each growing season.

Grass growth can occur without partial defoliation by graminivores, however, total herbage biomass production is greatly suppressed without the activation of the internal grass growth mechanisms of compensatory physiological mechanisms, vegetative reproduction by tillering, nutrient resource uptake, and water use efficiency. When 100 lbs/ac of mineral nitrogen is available in the soil and all four growth mechanisms are fully activated, grass plants can produce 140% of the removed foliage which would not have been produced without partial defoliation. The activated vegetative reproduction mechanism produce secondary tillers that provide adequate quantities of crude protein for the cows between mid July and late September or mid October. The activated nutrient resource uptake mechanisms increases grass plant competitiveness that prevents weeds, shrubs, and trees from growing in a prairie plant community. The activated water use efficiency permits 50.4% greater grass herbage biomass production per inch of precipitation.

The rhizosphere microorganisms are achlorophyllous and do not have chlorophyll to capture energy and are deficient of energy except when partial defoliation by graminivores causes a transfer of surplus simple carbon energy from grass tillers to the rhizosphere microbes. The resulting greater biomass and activity of the soil microbes mineralize greater quantities of essential elements from the organic form which are unusable by plants into the usable mineral form, primarily nitrogen, which has to be at the threshold level of 100 lbs/ac in order for the grass growth mechanisms to function. The level of available mineral nitrogen in soil managed by the Traditional concept is usually around 50 to 60 lbs/ac which is insufficient to permit the grass growth mechanisms to function. Low soil microbe biomass and activity also prevents the capture of adequate quantities of replacement essential elements which eventually causes ecosystem deterioration.

Grass plants produce double the aboveground herbage biomass than the plants need for photosynthesis for normal growth and maintenance. This extra production has two main purposes: first it ensures the plant can continue proper functions with removal of half the herbage through grazing, and second it attracts grazing graminivores to perform the vital partial defoliation treatments on which the grass plants depend for activation of critical mechanisms. When the double production of herbage biomass is not removed annually by graminivores, it becomes detrimental by shading the young growing leaves the following growing season. In just a couple of growing seasons, the unremoved herbage causes severe reductions in desirable plant species permitting a shift in species composition to less desirable or undesirable plant species, and eventually shrubs then trees can invade the deteriorated prairie plant community as a result of removal of grazing graminivores.

There are no replacement methods that can perform the indispensable functions of grazing graminivores on a fully functional grassland ecosystem.

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