Selection of Pasture Forage and Harvested Forage Types

The North American beef herd has been transformed over the past 40 to 50 years, and we now have high-performance, fast-growing meat animals with improved genetic potential and increased nutrient demands, nevertheless, the industry continues to use traditional pasture forage and harvested forage management technology developed for the old-style low-performance cow.

Modern, high-performance cattle are larger and heavier, gain weight more rapidly, produce more milk, and deposit less fat on their bodies than old-style cattle. The greater size of modern animals increases their nutrient demand, and their higher production levels increase the demand further so that the additional quantities of required nutrients are not simply proportionate to the animals' greater size.

A high-performance cow that has medium milk production and is 20% larger than an old-style animal requires 24% more energy and 33% more crude protein per year than the old-style animal. A high-performance cow requires 20% more energy and 24% more crude protein during the period from mid November to late April. She also requires 27% more energy and 41% more crude protein per day during the lactation period from early May to mid November (table 56). A high-performance cow that has high milk production requires 43% more energy and 72% more crude protein per day during the lactation period than the old-style cow (table 57).

The basic components of the traditional forage management practices have not changed in decades. Forage dry matter quantities are still used as the measure when producers make major pasture and harvested forage management decisions. Pasture stocking rates are determined from estimates of herbage dry matter production. Harvested forages are cut at the time when the greatest dry matter weight can be captured and hay is traded on the dry matter weight basis per bale or ton. Traditional forage management practices inhibit the modern beef animal from performing at its genetic capability, and the result is profit margins below potential. High-performance livestock do not have the fat reserves that old-style animals produced and could draw on when forage quality was insufficient. Periods with nutrient deficiency limit modern beef animals' production. Modern cattle perform at greater efficiency when their nutritional demands are met during each production period.

Results

Evaluation of pasture forage types and harvested forage types that meet nutrient and dry matter requirements of modern range cows during each of their production periods is complicated. The various pasture forage types and harvested forage types have complex differences in their management practices, production costs per acre, plant growth stages at time of grazing or haying, quantity of forage dry matter harvested per acre, and weight of nutrients captured per acre. These differences affect animal weight performance and influence forage feed costs making comparisons of forage types and management practices difficult.

Evaluation and selection of forage types should be based on systematic comparisons of quantitative information for the multiple factors that influence forage feed costs and returns after feed costs during each production period. The quantifiable factors that should be included in the evaluations of forage types are harvested or grazed forage dry matter weight per acre, captured crude protein weight per acre, land area per cow-calf pair, cow size, cow and calf weight performance, land rent costs, equipment and labor costs, seed costs, production costs per acre, forage dry matter costs, crude protein costs per pound, supplemental roughage or crude protein costs, total forage feed costs, forage feed costs per day, calf weight gain costs per pound, market value of calf weight, returns after feed costs per cow-calf pair, and returns after feed costs per acre.

All of these quantified factors are necessary for thorough comparisons of forage types, however, not all of the factors have equal diagnostic value in selection of low cost forage types or in identification of forage types that efficiently capture high value from the land natural resources. The quantitative values for land rent costs, equipment and labor costs, seed costs, production costs per acre, and forage dry matter costs influence livestock feed costs but do not directly regulate forage feed costs and consequently do not have diagnostic value in selection of low cost forage types. The quantitative values for crude protein costs per pound, calf weight gain costs during the periods the calf is at the side of the cow, and forage feed costs per day including the supplemental roughage or crude protein costs directly affects livestock feed costs and are the three most important factors with diagnostic value in selection of low cost forage types. The quantitative values for size of land area per cow-calf pair, and returns after feed costs per acre are the two most important factors with diagnostic value in identification of forage types that efficiently capture high value from the land natural resources.

Production costs per acre for harvested forage types include land rent costs, seed costs, and equipment and labor costs to plant and harvest a forage type. Production costs per acre for pasture forage types include land rent costs plus any custom farm work costs. Production costs per acre for harvested forage types are greater than production costs for pasture forage types. However, neither production costs for harvested forage types or production costs for pasture forage types accurately reflects the respective forage feed 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 these variations are not proportional with the production costs for harvested forage types and pasture forage types. None of the individual costs that compose the production costs per acre should be the criterion on which selection of forage types are based.

A comparison between a harvested forage type with high production costs and a pasture forage type with low production costs demonstrates that forage production costs do not directly regulate forage feed costs. During the 45-day early lactation production period from mid March to late April, forage barley hay cut at the milk stage had high production costs of $68.21 per acre and reserved native rangeland pasture had low production costs of $8.76 per acre. Forage barley hay produced 4733 pounds of dry matter and captured 606 pounds of crude protein per acre. Reserved native rangeland pasture had 125 pounds of forage dry matter and captured 11.5 pounds of crude protein per acre. The forage dry matter and crude protein requirements for a 1200 lb cow with a calf were provided from 0.20 acres of forage barley hay cut early and on 10.8 acres of reserved native rangeland pasture. The forage feed costs including total forage and supplemental roughage costs were $18.23 per production period, or $0.41 per day for the forage barley hay and the forage feed costs including total pasture forage costs were $94.64 per production period, or $2.10 per day for the reserved native rangeland pasture. Even though the production costs per acre for the reserved native rangeland pasture were a small fraction of the production costs per acre for the forage barley hay, the forage feed costs per day were more than five times greater on the reserved native rangeland pasture than the forage feed costs for the forage barley hay.

Cost of forage dry matter per ton is commonly used to compare different harvested forage types, but cost per ton of pasture forage dry matter consumed by grazing livestock is generally not considered by livestock producers when comparing costs of different management strategies. Many traditional late season grazing treatments would not be used if the pasture forage dry matter costs were known. The cost per ton of forage dry matter reflects the relationship between pasture rent per acre or production costs per acre and the quantity of forage dry matter consumed by grazing livestock or harvested for hay. Forage dry matter, however, does not have a real economic value because dry matter is not incorporated into the beef weight produced. The forage dry matter is simply the carrier of the nutrients it contains. The cost of forage dry matter per ton, or per pound, does not directly regulate the forage feed costs per day of forage types that meet cow daily dry matter requirements because forage dry matter costs do not respond proportionally to the variation in quantities of nutrients contained within the dry matter. The nutrient content of a forage type determines the quantity of forage dry matter needed to meet cow daily nutrient requirements.

A comparison between a hay that costs $50.00/ton and a hay that costs $70.00/ton fed during the 90-day third trimester to 1200 lb cows that require 24 lbs DM/day and 1.87 lbs CP/day demonstrates that the forage dry matter costs are not directly related to the forage feed costs.

The hay that costs $50.00/ton has a crude protein content of 6.0%. The $50.00/ton hay would be fed at 24.0 lbs DM/day to provide 1.44 lbs CP/day. The forage would cost $54.00 per production period. The crude protein content of this hay is below the dietary requirements of a cow in the third trimester. An additional 0.43 lbs of crude protein supplement per day would need to be provided, at a cost of $11.61 per period. Total forage and supplement costs would be $65.61 per period, or $0.73 per day.

The hay that costs $70.00/ton has a crude protein content of 16.0%. The $70.00/ton hay would be fed at 11.69 lbs DM/day to provide 1.87 lbs CP/day. The forage would cost $36.82 per production period. An additional 12.31 lbs of roughage supplement per day would need to be provided, at a cost of $19.39 per period. Total forage and supplement costs would be $56.21 per period, or $0.62 per day. The hay that has the lower forage dry matter cost per ton does not have the lower forage feed cost per day.

Cost per pound of crude protein is an important indicator of forage feed costs per day. Crude protein cost per pound is related to the production cost per acre and the weight per acre of crude protein captured by grazing or haying. The proportion of produced crude protein weight captured by grazing or haying is a measure of the management strategy's efficiency. The efficiency of crude protein capture is reflected in the cost per pound of crude protein; the greater the efficiency, the lower the cost. The cost per pound of crude protein in feedstuffs directly regulates the forage feed costs per day of forage types that met cow daily crude protein requirements. Forage feed costs per day equals (lbs forage CP/d X cost/lb) plus (lbs supplemental CP/d X cost/lb) or forage feed costs per day equals (lbs forage CP/d X cost/lb) plus (lbs supplemental roughage/d X cost/lb).

A hay that contains 6.0% crude protein and costs $50.00/ton has crude protein costs of $0.42/lb. A hay that contains 16.0% crude protein and costs $70.00/ton has crude protein costs of $0.22/lb. The $50.00/ton hay would be fed to 1200 lb cows at 24.0 lbs DM/day during the third trimester and provide 1.44 lbs CP/day. An additional 0.43 lbs of crude protein supplement per day would need to be provided. The 1.44 lbs of forage crude protein costs $0.42/lb and $0.60/day; the 0.43 lbs of supplemental crude protein costs $0.30/lb and $0.13/day, with a total crude protein cost of $0.73 per day which equals the forage feed costs per day for the $50.00/ton hay with 6.0% crude protein. The $70.00/ton hay would be fed to 1200 lb cows at 11.69 lbs DM/day during the third trimester and provide 1.87 lbs CP/day. An additional 12.31 lbs of roughage supplement per day would need to be provided. The 1.87 lbs of forage crude protein costs $0.22/lb and $0.41/day; the 12.31 lbs of supplemental roughage costs $0.0175/lb and $0.21/day, with a total crude protein and supplemental roughage cost of $0.62/day which equals the forage feed costs per day for the $70.00/ton hay with 16.0% crude protein. The hay that has the lower crude protein cost per pound has the lower forage feed cost per day.

Calf weight gain costs per pound is an important diagnostic value for the evaluation of forage feed costs and comparisons of forage types. The cost per pound of calf accumulated weight is the culmination of a management strategy's positive and negative effects on forage plant production and cow and calf weight performance. Costs per pound of calf weight gain is the combined land rent costs, production per acre costs, forage dry matter costs, crude protein costs, land area per cow-calf pair costs, supplemental roughage or crude protein costs, and forage feed costs. The efficiency of a management strategy's capture of produced forage crude protein affects the cost per pound of accumulated calf weight. The forage type with the more biologically effective management strategy and that captures crude protein more efficiently will have the lower cost per pound of calf weight.

Forage feed costs per day is an important diagnostic value for the evaluation of total feed costs and comparisons of forage types. The forage costs include production costs per acre, forage dry matter costs, and crude protein costs. Forage costs are the combined costs for livestock feed that is produced on the land base assigned to a cow-calf pair during each production period. During periods in which the quantity or quality of the produced feedstuffs falls below the quantity or quality of the dietary requirements of the cow, additional roughage or crude protein from other sources need to be supplemented. The costs of supplemental roughage or crude protein plus the forage costs are the forage feed costs for a cow-calf pair for a production period. The number of days in a production period determine the forage feed costs per day.

Increasing value captured from the land natural resources requires a major paradigm shift from the traditional convention that considers the animal as the source of income and that manages the land to produce forage dry matter for livestock feed. The forage nutrients produced on the land sustain the growth in weight of livestock. Forage dry matter is simply the carrier of the nutrients it contains. Following removal of the nutrients, forage dry matter is deposited back on the land. The weight of the calf is the commodity sold at market but the calf weight is not the original source of the wealth. The renewable forage nutrients produced on the land are the original source of new wealth generated in the beef production industry. Generation of greater wealth requires the capture of greater crude protein weight per acre and its conversion into greater calf weight per acre.

Size of the land area per cow-calf pair and the returns after feed costs per acre are important diagnostic values for the comparisons of forage types and for the identification of forage types and management strategies that generate greater new wealth from the land resources. Land area per cow-calf pair is determined by the acreage required to provide adequate quantities of forage dry matter and crude protein during a production period. The greater the quantity of crude protein weight captured from a land base, the smaller the land area required by a cow-calf pair. Land area costs make up 50% to 100% of the forage feed costs for pasture forage types and from 10% to 50% for harvested forage types. Reducing land area per cow-calf pair lowers forage feed costs. Reducing land area requires increasing crude protein production per acre and improving the efficiency of crude protein capture. The capture of greater crude protein weight per acre and its conversion into greater weight of beef produced per acre reduces the cost per pound of calf accumulated weight and increases the returns after feed costs per acre resulting in the generation of greater new wealth captured from the land resources.

A low market value for calf weight must be used during the evaluations of forage types for the purpose of being able to select forage types that provide positive returns after feed costs during the entire cattle cycle. Forage types that have forage feed costs of $0.62 or less per day, calf weight gain costs of $0.42 or less per pound during periods the calf is at the side of the cow, and crude protein costs of $0.25 or less per pound yield positive profit margins and efficiently capture high value from the land natural resources during low periods in the market when calf weight is valued at $0.70 per pound at weaning time.

The forage types that meet the low market selection criterion and efficiently capture high value from the land natural resources during the dry gestation production period from mid November to mid December are crested wheatgrass hay cut early, forage barley hay cut early or late, oat forage hay cut early or late, pea forage hay cut late, and forage lentil hay cut late (table 58).

The forage types that meet the low market selection criterion and efficiently capture high value from the land natural resources during the third trimester production period from mid December to mid March are crested wheatgrass hay cut early, forage barley hay cut early, oat forage hay cut early or late, pea forage hay cut late, and forage lentil hay cut late (table 59).

The forage types that meet the low market selection criterion and efficiently capture high value from the land natural resources during the early lactation production period from mid March to late April are crested wheatgrass hay cut early, forage barley hay cut early, oat forage hay cut early, pea forage hay cut late, and forage lentil hay cut late (table 60).

The forage types that meet the low market selection criterion and efficiently capture high value from the land natural resources during the spring lactation production period from early May to late May are crested wheatgrass unfertilized pasture, crested wheatgrass fertilized pasture, crested wheatgrass hay cut early, forage barley hay cut early, oat forage hay cut early, pea forage hay cut late, and forage lentil hay cut late (table 61).

The forage types that meet the low market selection criterion and efficiently capture high value from the land natural resources during the summer lactation production period from early June to mid October are twice-over rotation native rangeland pasture system, crested wheatgrass hay cut early, forage barley hay cut early, oat forage hay cut early, pea forage hay cut late, and forage lentil hay cut late (table 62).

The forage types that meet the low market selection criterion and efficiently capture high value from the land natural resources during the fall lactation production period from mid October to mid November are Altai wildrye pasture, spring seeded winter cereal pasture, crested wheatgrass hay cut early, forage barley hay cut early, oat forage hay cut early, pea forage hay cut late, and forage lentil hay cut late (table 63).

The forage types that do not meet the selection criterion and have high forage feed costs per day, high calf weight gain costs per pound, high crude protein costs per pound and/or low or negative returns after feed costs per acre were also identified during the evaluations.

The pasture forage types with high costs and negative returns after feed costs per acre are: spring seeded winter cereal pasture grazed during the dry gestation production period following weaning of the calf, standing corn pasture grazed during the dry gestation or third trimester production periods, reserved native rangeland pastures traditionally managed with grazing occurring during the dry gestation, third trimester, or early lactation production periods, and native rangeland pastures with grazing occurring during the fall lactation production period and managed traditionally as repeated seasonal, 6.0-month seasonlong, 5.5-month seasonlong, deferred grazing, and 4.5-month seasonlong started in mid June.

The pasture forage types with high costs and low returns after feed costs per acre are: native rangeland pastures managed traditionally as 6.0-month seasonlong with grazing starting in May before the grass plants develop three and a half new leaves during the spring lactation production period, and native rangeland pastures with grazing occurring during the summer lactation production period and managed traditionally as 6.0-month seasonlong, deferred grazing, and 4.5-month seasonlong started in early June.

The harvested forage types that are cut at plant growth stages with greater forage dry matter yield have lower returns after feed costs per acre than the same forage type cut at plant growth stages with greater crude protein yield. Crested wheatgrass hay cut at the mature growth stage has lower returns after feed costs per acre than crested wheatgrass hay cut at the boot stage. Forage barley and oat forage hays cut late at the hard dough stage have lower returns after feed costs per acre than forage barley and oat forage hays cut early at the milk stage. Pea forage and forage lentil hays cut early have lower returns after feed costs per acre than pea forage and forage lentil hays cut late. Oat and pea forage grown as a mixture and cut at compromised plant growth stages has higher costs and lower returns after feed costs per acre than when oat forage and pea forage hays are grown separately and harvested at their respective optimum plant growth stages.

The harvested forage types that require supplemental crude protein because of harvest at plant growth stages that yield greater forage dry matter weight have lower returns after feed costs per acre than the same forage type not requiring supplemental crude protein because of harvest at plant growth stages that yield greater crude protein weight. Crested wheatgrass hay cut at the mature growth stage requires supplemental crude protein during all of the production periods except the dry gestation production period and has lower returns after feed costs per acre than crested wheatgrass hay cut at the boot stage. Oat forage hay cut late at the hard dough stage requires supplemental crude protein during all production periods except the dry gestation and third trimester production periods and has lower returns after feed costs per acre than oat forage hay cut early at the milk stage. Forage barley hay cut late at the hard dough stage requires supplemental crude protein during the early lactation production period and has lower returns after feed costs per acre than forage barley hay cut early at the milk stage.

Discussion

Reduction of forage feed costs for pasture forage types can be accomplished by implementation of biologically effective grazing management that places priority on meeting the biological requirements of the plants and enhances the biogeochemical cycles in the ecosystem and that has grazing periods at the plant growth stages that capture the greatest weight of crude protein per acre. During the long history of coevolution with grazing animals, grass plants developed biological processes that help the plants withstand and recover from defoliation (Manske 2007). 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. Grazing that removes a small amount of leaf area (25% to 33%) from the grass plant between the three and a half new leaf stage and flowering stage can trigger these beneficial responses.

There is a mutually beneficial relationship between the grass plant's root system and soil organisms. The narrow zone of soil around the roots of perennial grassland plants, the rhizosphere, contains bacteria, protozoa, nematodes, mites, springtails, and endomycorrhizal fungi. The grass plant's roots release carbon compounds, including sugars, to these rhizosphere organisms, and the organisms release mineral nitrogen that the plant's roots absorb. The endomycorrhizal 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 three and a half new leaf stage and the flowering stage can increase the quantity 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.

Most young grass plants in grassland ecosystems start not as seedlings but as vegetative tillers that grow from axillary buds on the crowns of an established plant. These vegetative tillers make up the majority of the plant population because they have a competitive advantage over seedlings. Tillers initially draw support from the root systems of parent tillers, while seedlings must rely on their own less-developed structures.

Tiller development from axillary buds is regulated by lead tillers, through a process called lead tiller dominance. The lead tillers produce an inhibitory hormone that prevents the growth hormone from activating growth within axillary buds. Grazing that removes a small amount of young leaf tissue from the aboveground portion of lead tillers after the three and a half new leaf stage and before the flowering stage reduces the amount of the inhibitory hormone in the plant. With that inhibitory hormone reduced, the growth hormones stimulate vegetative reproduction, and secondary tillers develop from the previous year's axillary buds.

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 these growth characteristics have greater demands for water than grasses with strong lead tillers and cease growth processes during minor water deficiency periods.

Beneficial grass plant response to grazing depends on the timing of defoliation. Grazing grass plants prior to the third-leaf stage negatively affects grass growth. Early seasonal growth of grass plants depends on carbohydrates stored in the roots, rhizomes, and stem bases, and prematurely grazed plants are unable to replenish adequate amounts of carbohydrates to support active growth. Starting grazing after the three and a half new leaf stage and before the flowering stage allows plants to establish sufficient leaf area to produce adequate photosynthetic assimilates to meet leaf growth requirements and allows all leaf bud primordia in the apical meristem to develop into leaf buds.

If no defoliation occurs before the flowering stage, as on a deferred grazing strategy, the lead tiller inhibits vegetative tiller development until the inhibitory hormone production naturally declines during the flowering stage. This hormone reduction permits one axillary bud to grow and develop into a secondary tiller, which in turn produces inhibitory hormones that prevent growth of the other six to eight axillary crown buds. These dormant axillary buds are never activated and become senescent with the lead tiller. The lack of defoliation of lead tillers prior to the flowering stage diminishes recruitment of vegetative tillers, leading to decreased plant density and reduced rhizosphere organism activity; this reduction results in decreased conversion of soil organic nitrogen into inorganic nitrogen. No evidence has been found to suggest that grazing the lead tiller after it has reached the flowering stage has beneficial stimulatory effects on vegetative tiller development or rhizosphere organism activity.

The twice-over rotation grazing management system applies defoliation treatment to grass plants at the appropriate phenological growth stages to stimulate the defoliation resistance mechanisms and the activity of the symbiotic rhizosphere microorganisms. The coordinated defoliation improves plant health and stimulates biological and ecological processes within grass plants and the ecosystem so that beneficial changes to plant growth, soil organisms, and biogeochemical cycles in the ecosystem result. During the first grazing period, grasses are between the three and a half new leaf stage and flowering stage, the stages of plant development at which grazing stimulates the defoliation resistance mechanisms that increase tillering from axillary buds and enhance rhizosphere organism activity increasing the conversion of soil organic nitrogen into inorganic nitrogen. Increased vegetative reproduction by tillering contributes to the development of greater plant basal cover and to the production of greater grass herbage weight; increased activity of the soil organisms in the rhizosphere supplies the plant with greater quantities of nutrients to support additional growth.

Grazing native rangeland pastures during May is expensive, costing even more than feeding mature crested wheatgrass hay during the same period. Rangeland plants are not physiologically ready for grazing prior to the three and a half new leaf stage, and grazing prior to plant readiness causes a reduction in herbage biomass production of 45% to 75%. Delaying grazing on native rangeland until grass plants have reached the three and a half new leaf stage, in early June, requires the use of another forage type for earlier grazing. Some domesticated perennial cool-season grasses like crested wheatgrass and smooth bromegrass reach the three and a half new leaf stage three to five weeks earlier than native cool-season grasses and are dependable during May as early season spring pasture forage. The start of the grazing season on domesticated grass pastures is restricted to very late April or early May because no perennial grass in the Northern Plains reaches the three and a half new leaf stage before late April.

Unfertilized crested wheatgrass pastures provide forage at reasonable costs during May and early to mid June, but during the third week in June the crude protein content drops below the requirements for lactating cows. Fertilized crested wheatgrass pastures provide forage at reasonable costs during May. Fertilization of crested wheatgrass pastures (applied during the first week of April) increased the amount of herbage biomass during May. The cost per ton for forage dry matter on fertilized pastures was about the same as the cost per ton for dry matter on unfertilized pastures, even though the cost of the fertilizer more than doubled the production costs per acre. Fertilization shortened by several weeks the effective period of use of domesticated grass spring complementary pastures by grazing livestock.

Grazed native rangeland pastures provide forage dry matter and crude protein at lower costs during the summer lactation production period from early June to mid October than during other times of the year. Cow and calf weight performance generally did not differ among native rangeland grazing strategies during the early grazing period of June to mid July, but during the latter portion of the grazing period, starting mid July or early August, animal weight performance on the traditional management strategies decreased successively as the grazing period progressed. Cows and calves on the twice-over rotation management strategy gained weight during the entire grazing period. Nutritional quality of native rangeland grasses decreases rapidly following the seed development stage, and the quality falls below 9.6% crude protein around mid July to early August on traditionally managed pastures. This large decrease in nutritional quality below 9.6% crude protein does not occur on the twice-over rotation strategy because of the stimulation of vegetative reproduction and secondary tiller development resulting from light defoliation on each of the three to six native rangeland pastures for 7 to 17 days during the first grazing period between early June and mid July when grass plants are between the three and a half new leaf stage and flowering stage. Manipulation of secondary tiller growth extends improved livestock weight performance for two to two and a half months until late September or mid October. The biology of native grass plants does not permit extending this improved weight performance longer. Nutritional quality of herbage on native rangeland grazed after mid October is insufficient to meet requirements of lactating cows.

Pasture forage types that meet the nutritional requirements of lactating cows after mid October include Altai and Russian wildryes. The wildryes are the only perennial grasses that retain nutrient quality in the aboveground portions of the plant after mid October until about mid November. No perennial grass in the Northern Plains retains sufficient nutritional quality to dependably meet the nutritional requirements of lactating cows later than mid November.

Grazing native rangeland during the fall and winter is commonly accepted as a low-cost, innocuous practice; however, costs of forage dry matter and crude protein on native rangeland during fall and winter are extremely high, and fall and winter grazing has the potential to degrade grassland ecosystems. The cost of grazing native rangeland during the fall and winter is high because the weight of the herbage on late-season pasture is only about half of the mid summer herbage weight and grazing livestock therefore require about twice as many acres per month in the fall and winter as they do during the summer. The nutritional quality of mature herbage during fall and winter is about half of the herbage nutrient content during summer; the crude protein content of mature native range forage is below the requirements of cows during the dry gestation, third trimester, and early lactation production periods and crude protein supplementation is needed.

Grazing mature rangeland during the fall and winter can have negative economic consequences beyond the fall and winter because the practice 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. Very few perennial grasses grow from seed in established grasslands. Perennial grasses start growth of next year's plants in late summer or early fall, during winter hardening, the process of physiological preparation for the winter season. 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.

Fall tillers grow from axillary buds on the crowns of perennial grass species between mid August and the end of the active growing season and remain viable over the winter. These fall tillers continue growth as lead tillers the following spring, producing a high proportion of that season's herbage. After the lead tillers have flowered, secondary tillers can grow from axillary buds.

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 aboveground structures are translocated to belowground structures. The translocation of cell contents reduces the nutritional quality and the weight of the herbage. The nutritional quality of mature herbage during fall decreases to about 4.8% crude protein. The weight of the herbage is about 40% to 60% of the herbage weight during mid summer. Secondary tillers that have not entered the sexually reproductive stage and fall tillers will overwinter. These tillers retain 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 leaves of 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. Winter 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 tillers 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. It is suspected 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 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. During the early portion of the growing season, overwintering tillers will have both carryover leaves and new current year's leaves. 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 photosynthetic products that, in combination with remaining stored carbohydrates, 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 graminoids during the succeeding growing season range from 17% to 43%, 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 and winter 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. Management strategies coordinated with the biological requirements of grass plants promote vigorous growth of tiller leaves and efficient capture of produced forage dry matter and crude protein. These characteristics result in considerable reductions in pasture forage costs for cows and calves.

Feeding low cost harvested forages is an economically and ecologically sound alternative to grazing livestock on fall and winter reserved native range pasture. Harvested forages are usually viewed as expensive feeds because the production costs per acre are greater than pasture forage production costs per acre and 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.

Reduction of forage feed costs for harvested forage types can be accomplished by harvesting the forage type at the plant growth stages that capture the greatest weight of crude protein per acre. The weight of crude protein harvested per acre is related to the percent crude protein content and the weight of the forage dry matter at the time of cutting. The percent crude protein content and dry matter weight of forage plants both increase during early growth stages and then decrease as the growing season progresses and plants mature. These changes are reflected in the growth curves for the two factors. The percent crude protein content curve and the dry matter weight curve for a forage type are quite different from each other throughout the growing season. The various types of forage plants have crude protein and forage dry matter curves with different shapes. The greatest percent crude protein occurs during very early plant growth stages, and then the quality level declines as the plants develop. Percent crude protein content declines at a greater rate in grasses than in legumes. The weight of the forage dry matter per acre increases during the early growth stages until the maximum plant height is reached, and then the dry matter weight decreases as the plants dry during senescence and cell contents are translocated from aboveground plant parts to the crown belowground. The rate of growth to peak dry matter weight is greater in grasses than in legumes.

Generally, the lowest cost livestock forage feed from harvested forage types is the hay with the lowest cost per pound of crude protein, which results by harvesting at the plant growth stage when the forage types yields the greatest weight of crude protein per acre. The greatest weight of crude protein per acre does not occur at the peak percent crude protein or at the peak dry matter weight per acre.

The greatest crude protein weight per acre occurs at the flowering growth stage for grass plants, including perennial grasses and annual cereal grasses. The cost per pound of crude protein is lower for perennial grasses and annual cereal forages when plants are cut early, between the boot stage and the early milk stage. Crested wheatgrass hay cut at the boot stage had lower costs per pound of crude protein than crested wheatgrass hay cut at a mature stage of growth. Forage barley hay and oat forage hay cut early, at the milk stage, had lower costs per pound of crude protein than their respective forage types cut later, at the hard dough stage.

The greatest crude protein weight per acre occurs for legumes at a later growth stage, when the plants are at full growth but before the leaves start drying from senescence. The cost per pound of crude protein is lower for annual legume forages when plants are cut one time during a late full growth stage. Early cut forage lentil hay and early cut pea forage hay were cut prior to the plant growth stage with the greatest amount of crude protein per acre, so these hays had greater costs per pound of crude protein than the same legume forage types cut at later plant growth stages.

The modern beef animal is different than the old style cattle. Traditional forage type management practices developed for the old style cattle focus on forage dry matter yield and do not meet the dietary needs of modern livestock resulting in high forage feed costs and low or negative returns after feed costs per acre. Forage types that provide low cost feed for modern beef cows and have high returns after feed costs per acre are managed for high crude protein yield per acre. The quantity of crude protein captured per acre as livestock feed is the factor that has the greatest influence on the costs of pasture forage and harvested forage and on the amount of new wealth generated from the land natural resources.

Table 56. Difference in nutrient requirements between an old style 1000 lb range cow and an average production 1200 lb range cow.

Intake nutrient requirements for "Old Style" 1000 lb range cow, data from NRC 1996.

		Dry Gestation	Third Trimester	Early Lactation	Nongrowing Season	Lactation Spring, Summer, Fall	12-month Period
Dry Matter	lb/d	21.0	21.0	21.6	21.21	22.3	21.78
Energy (TDN)	lb/d	9.64	10.98	12.05	11.01	11.98	11.54
Crude Protein	lb/d	1.30	1.64	1.88	1.64	1.78	1.72

Intake nutrient requirements for 1200 lb range cow with average milk production, data from NRC 1996.

		Dry Gestation	Third Trimester	Early Lactation	Nongrowing Season	Lactation Spring, Summer, Fall	12-month Period
Dry Matter	lb/d	24.0	24.0	27.0	24.81	27.0	26.0
Energy (TDN)	lb/d	11.02	12.62	15.85	13.18	15.23	14.29
Crude Protein	lb/d	1.49	1.87	2.73	2.03	2.51	2.29

Percent greater nutrient requirements for average production 1200 lb cow than for old style 1000 lb cow.

		Dry Gestation	Third Trimester	Early Lactation	Nongrowing Season	Lactation Spring, Summer, Fall	12-month Period
Dry Matter	%	14.29	14.29	25.00	16.97	21.08	19.38
Energy (TDN)	%	14.32	14.94	31.54	19.71	27.13	23.83
Crude Protein	%	14.62	14.02	45.21	23.78	41.01	33.14

Table 57. Difference in nutrient requirements between an old style 1000 lb range cow and a high production 1200 lb range cow.

Intake nutrient requirements for "Old Style" 1000 lb range cow, data from NRC 1996.

		Dry Gestation	Third Trimester	Early Lactation	Nongrowing Season	Lactation Spring, Summer, Fall	12-month Period
Dry Matter	lb/d	21.0	21.0	21.6	21.21	22.3	21.78
Energy (TDN)	lb/d	9.64	10.98	12.05	11.01	11.98	11.54
Crude Protein	lb/d	1.30	1.64	1.88	1.64	1.78	1.72

Intake nutrient requirements for 1200 lb range cow with high milk production, data from NRC 1996.

		Dry Gestation	Third Trimester	Early Lactation	Nongrowing Season	Lactation Spring, Summer, Fall	12-month Period
Dry Matter	lb/d	24.1	24.2	29.2	25.53	29.08	27.45
Energy (TDN)	lb/d	11.07	12.73	18.0	13.83	17.17	15.64
Crude Protein	lb/d	1.50	1.90	3.36	2.22	3.06	2.67

Percent greater nutrient requirements for high production 1200 lb cow than for old style 1000 lb cow.

		Dry Gestation	Third Trimester	Early Lactation	Nongrowing Season	Lactation Spring, Summer, Fall	12-month Period
Dry Matter	%	14.76	15.24	35.19	20.37	30.40	26.03
Energy (TDN)	%	14.83	15.94	49.38	25.61	43.32	35.53
Crude Protein	%	15.38	15.85	78.72	35.37	71.91	55.23

Table 58. Summary of costs and returns after feed costs per acre for forage types used during the 32-day dry gestation production period.

Forage Types	Forage Feed Costs $/day	Calf Weight Costs $/lb	Crude Protein Costs $/lb	Land Area ac/c-cpr	Returns After Feed Costs $/acre
Pasture Forage Types					
Native Rangeland Repeated Seasonal	1.48	1.90	1.01	5.33	-5.59
Cropland Aftermath	0.44	0.57	0.74 est.	7.10	0.46
Spring Seeded Winter Cereal	0.73	0.94	0.24 est.	0.56	-10.66
Standing Corn	1.23	1.58	0.77 est.	0.25	-87.76
Harvested Forage Types					
Crested Wheat, mature	0.42	0.54	0.28	0.47	8.47
Crested Wheat, early	**0.45**	**0.58**	**0.14**	**0.26**	**11.69**
Forage Barley, early	**0.38**	**0.49**	**0.11**	**0.08**	**66.50**
Forage Barley, late	**0.36**	**0.46**	**0.15**	**0.10**	**60.30**
Oat Forage, early	**0.38**	**0.49**	**0.13**	**0.09**	**57.78**
Oat Forage, late	**0.34**	**0.43**	**0.17**	**0.11**	**60.91**
Pea Forage, early	0.50	0.64	0.15	0.09	15.33
Pea Forage, late	**0.43**	**0.55**	**0.13**	**0.07**	**52.71**
Forage Lentil, early	0.55	0.71	0.17	0.13	-1.46
Forage Lentil, late	**0.43**	**0.56**	**0.13**	**0.09**	**39.78**
Oat-Pea Forage	0.43	0.55	0.16	0.07	51.71

Bolded forage types meet the selection criterion and efficiently capture high value from the land natural resources.

Table 59. Summary of costs and returns after feed costs per acre for forage types used during the 90-day third trimester production period.

Forage Types	Forage Feed Costs $/day	Calf Weight Costs $/lb	Crude Protein Costs $/lb	Land Area ac/c-cpr	Returns After Feed Costs $/acre
Pasture Forage Types					
Native Rangeland Repeated Seasonal	1.94	2.49	1.26	18.62	-6.75
Standing Corn	1.23	1.58	0.77 est.	0.70	-87.74
Harvested Forage Types					
Crested Wheat, mature	0.52	0.67	0.28	1.35	1.50
Crested Wheat, early	**0.45**	**0.58**	**0.14**	**0.89**	**9.19**
Forage Barley, early	**0.38**	**0.48**	**0.11**	**0.27**	**56.30**
Forage Barley, late	0.35	0.46	0.15	0.36	47.58
Oat Forage, early	**0.37**	**0.48**	**0.13**	**0.31**	**49.45**
Oat Forage, late	**0.32**	**0.41**	**0.17**	**0.38**	**53.32**
Pea Forage, early	0.53	0.68	0.15	0.32	5.16
Pea Forage, late	**0.43**	**0.56**	**0.13**	**0.25**	**40.52**
Forage Lentil, early	0.59	0.76	0.17	0.46	-8.70
Forage Lentil, late	**0.44**	**0.56**	**0.13**	**0.30**	**32.20**
Oat-Pea Forage	0.44	0.56	0.16	0.26	37.23

Bolded forage types meet the selection criterion and efficiently capture high value from the land natural resources.

Table 60. Summary of costs and returns after feed costs per acre for forage types used during the 45-day early lactation production period.

Forage Types	Forage Feed Costs $/day	Calf Weight Costs $/lb	Crude Protein Costs $/lb	Land Area ac/c-cpr	Returns After Feed Costs $/acre
Pasture Forage Types					
Native Rangeland Repeated Seasonal	2.10	1.17	0.76	10.80	-3.51
Harvested Forage Types					
Crested Wheat, mature	0.78	0.41	0.28	0.76	32.82
Crested Wheat, early	**0.52**	**0.28**	**0.14**	**0.65**	**55.88**
Forage Barley, early	**0.41**	**0.21**	**0.11**	**0.20**	**208.10**
Forage Barley, late	0.45	0.23	0.15	0.24	165.92
Oat Forage, early	**0.41**	**0.21**	**0.13**	**0.23**	**180.43**
Oat Forage, late	0.54	0.29	0.17	0.21	168.76
Pea Forage, early	0.63	0.33	0.15	0.23	136.87
Pea Forage, late	**0.49**	**0.26**	**0.13**	**0.18**	**210.00**
Forage Lentil, early	0.71	0.38	0.17	0.34	81.56
Forage Lentil, late	**0.50**	**0.26**	**0.13**	**0.22**	**170.36**
Oat-Pea Forage	0.50	0.26	0.16	0.19	196.32

Bolded forage types meet the selection criterion and efficiently capture high value from the land natural resources.

Table 61. Summary of costs and returns after feed costs per acre for forage types used during the 31-day spring lactation production period.

Forage Types	Forage Feed Costs $/day	Calf Weight Costs $/lb	Crude Protein Costs $/lb	Land Area ac/c-cpr	Returns After Feed Costs $/acre
Pasture Forage Types					
Native Rangeland					
Repeated Seasonal	1.35	0.75	0.28	4.77	-0.58
6.0-m Seasonlong (16d)	1.15	0.64	0.24 est.	2.10	0.83
Crested Wheatgrass					
Unfertilized	**0.52**	**0.27**	**0.11**	**1.88**	**13.29**
Unfertilized (76d)	0.48	0.27	0.13 est.	4.16	14.13
Fertilized	**0.51**	**0.24**	**0.10 est.**	**0.75**	**41.82**
Harvested Forage Types					
Crested Wheat, mature	0.71	0.35	0.28	0.58	37.14
Crested Wheat, early	**0.57**	**0.29**	**0.14**	**0.41**	**62.61**
Forage Barley, early	**0.47**	**0.23**	**0.11**	**0.13**	**222.46**
Forage Barley, late	0.43	0.21	0.15	0.16	188.50
Oat Forage, early	**0.47**	**0.24**	**0.13**	**0.14**	**205.14**
Oat Forage, late	0.45	0.22	0.17	0.16	180.12
Pea Forage, early	0.67	0.34	0.15	0.15	150.40
Pea Forage, late	**0.55**	**0.28**	**0.13**	**0.12**	**219.42**
Forage Lentil, early	0.75	0.38	0.17	0.34	58.91
Forage Lentil, late	**0.56**	**0.28**	**0.13**	**0.14**	**186.93**
Oat-Pea Forage	0.55	0.28	0.16	0.12	218.75

Bolded forage types meet the selection criterion and efficiently capture high value from the land natural resources.

Table 62. Summary of costs and returns after feed costs per acre for forage types used during the 137-day summer lactation production period.

Forage Types	Forage Feed Costs $/day	Calf Weight Costs $/lb	Crude Protein Costs $/lb	Land Area ac/c-cpr	Returns After Feed Costs $/acre
Pasture Forage Types					
Native Rangeland Repeated Seasonal	0.72	0.40	0.25	11.32	6.54
6.0-m Seasonlong	1.16	0.56	0.52 est.	18.10	2.18
4.5-m Seasonlong	0.81	0.39	0.37 est.	12.70	7.02
Deferred Grazing (92d)	0.63	0.30	0.28 est.	6.70	11.83
Twice-over Rotation	**0.58**	**0.26**	**0.20 est.**	**9.00**	**14.79**
Harvested Forage Types					
Crested Wheat, mature	0.71	0.35	0.28	2.57	37.05
Crested Wheat, early	**0.57**	**0.29**	**0.14**	**1.82**	**62.32**
Forage Barley, early	**0.47**	**0.23**	**0.11**	**0.56**	**228.20**
Forage Barley, late	0.43	0.21	0.15	0.73	182.56
Oat Forage, early	**0.47**	**0.24**	**0.13**	**0.64**	**198.33**
Oat Forage, late	0.45	0.22	0.17	0.73	178.85
Pea Forage, early	0.67	0.34	0.15	0.65	153.38
Pea Forage, late	**0.55**	**0.28**	**0.13**	**0.51**	**228.20**
Forage Lentil, early	0.75	0.38	0.17	0.95	93.20
Forage Lentil, late	**0.56**	**0.28**	**0.13**	**0.60**	**192.77**
Oat-Pea Forage	0.55	0.28	0.16	0.53	218.77

Bolded forage types meet the selection criterion and efficiently capture high value from the land natural resources.

Table 63. Summary of costs and returns after feed costs per acre for forage types used during the 30-day fall lactation production period.

Forage Types	Forage Feed Costs $/day	Calf Weight Costs $/lb	Crude Protein Costs $/lb	Land Area ac/c-cpr	Returns After Feed Costs $/acre
Pasture Forage Types					
Native Rangeland					
Repeated Seasonal	1.71	0.95	0.92	4.60	-2.91
6.0-m Seasonlong	1.18	1.99	0.82 est.	4.04	-5.69
5.5-m Seasonlong	0.74	0.80	0.51 est.	2.53	-1.12
Deferred Grazing	0.65	0.85	0.44 est.	2.18	-1.51
4.5-m Seasonlong (15d)	0.95	0.70	0.75 est.	1.63	-0.03
Altai Wildrye	**0.40**	**0.23**	**0.16 est.**	**1.39**	**17.81**
Cropland Aftermath	0.44	1.05	0.74 est.	6.63	-0.67
Spring Seeded Winter Cereal	**0.66**	**0.33**	**0.18 est.**	**0.47**	**47.45**
Harvested Forage Types					
Crested Wheat, mature	0.71	0.35	0.28	0.56	37.07
Crested Wheat, early	**0.57**	**0.29**	**0.14**	**0.40**	**62.10**
Forage Barley, early	**0.47**	**0.23**	**0.11**	**0.12**	**233.17**
Forage Barley, late	0.43	0.21	0.15	0.16	182.38
Oat Forage, early	**0.47**	**0.24**	**0.13**	**0.14**	**198.50**
Oat Forage, late	0.45	0.22	0.17	0.16	178.69
Pea Forage, early	0.67	0.34	0.15	0.14	155.78
Pea Forage, late	**0.55**	**0.28**	**0.13**	**0.11**	**231.64**
Forage Lentil, early	0.75	0.38	0.17	0.21	92.33
Forage Lentil, late	**0.56**	**0.28**	**0.13**	**0.13**	**194.85**
Oat-Pea Forage	0.55	0.28	0.16	0.12	211.67

Bolded forage types meet the selection criterion and efficiently capture high value from the land natural resources.