Evaluation and Development of Forage Management Strategies for Range Cows

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Evaluation and Development of Twelve-Month Pasture and Harvested Forage Management Strategies for Range Cows Based on Capture of New Wealth from the Land Natural Resources

3rd Edition

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Biologically Efficient 12-Month Pasture and Harvested Forage Management Strategies for Range Cows

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Biologically efficient 12-month livestock forage management strategies improve profit margins for beef production and enhance the regional agricultural economy by increasing value captured from land natural resources.

Major efforts of the beef production industry at correcting the problems of high production costs and low profit margins have been on improving animal performance. Complex tools and techniques have been developed for beef producers to evaluate individual animal performance and to predict future performance. As a result, the North American beef herd has been transformed into high-performance, fast-growing meat animals with improved genetic potential and increased nutrient demands. 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. After 40 to 50 years of improvements in animal performance, high production costs and low profit margins continue to be problems for the beef production industry.

These problems persist as a result of the mismatch of forage nutrients required and forage nutrients available between modern, high-performance cattle and traditional low-performance old-style livestock forage management practices. Forage management systems were not improved simultaneously with beef cow performance. Traditional forage management practices are antagonistic to plant growth mechanisms and ecosystem processes, inefficient at nutrient capture and conversion, and deficient at providing adequate forage quality for modern livestock at low cost.

The beef production industry is intrinsicly resistant to accepting and making changes to these traditional forage management practices. Beef producers tenaciously perpetuate the use of the same basic concepts and technologies of pasture and harvested forage management that were developed by their forefathers during the early stages of the beef industry for the old-style low-performance cattle. Most beef producers follow traditional management principles unquestioningly and do not know if a particular pasture or harvested forage management practice used on a specific parcel of land yields an income or is an expense. Beef production is the last meat industry to evaluate feed costs and to make feed management decisions from the cost per unit of dry matter. The swine, poultry, and dairy industries have switched to efficient feed management systems that evaluate feed costs from the cost per unit of the nutrients.

Traditional livestock forage management practices assume the source of income to be from the sale of the animals. Pasture forage and harvested forage, and labor and equipment are considered to be costs of production. Profits result when the sale value of livestock weight is greater than the paid production costs. Reduction of livestock production costs requires reduction of the labor and equipment costs, and the pasture forage and harvested forage costs. Efforts at reducing the high production costs tend to use feeds with low forage dry matter costs and low nutrient content. Traditional beef cow forage feed rations are deficient in crude protein for 29% to 45% of the days per year. Modern cattle on traditional forage management practices developed for old-style cattle have reduced production efficiencies that depress cow and calf weight performance below genetic potentials causing reduced value received at market and reduced profits.

Traditional forage management concepts that consider livestock weight as the source of income inhibit, and often prohibit, using the land resources and the labor and equipment resources efficiently to the detriment of livestock production. The land resources that produce pasture forage and harvested forage and the labor and equipment resources that perform the work are essential components of forage management strategies and these resources need to be used efficiently for livestock production to be profitable.

Efficient forage management concepts that consider the land natural resources as the source of new wealth generated by livestock agriculture and regard the renewable forage plant nutrients as the primary unit of production that are converted into animal weight commodities and then sold at market provide an almost unlimited combination of possibilities for efficient resource use that result in widening the margins between production costs and market value of the produced commodities. Production from the land resources, production from the livestock resources, and production by the labor and equipment resources all contribute to the production of saleable commodities. Profits result when the costs of the resource inputs are lower than the market value of the resulting commodities produced. Profits increase with increased biological efficiencies of resource use.

Evaluation of the efficiencies of livestock forage management strategies is complicated because the various pasture forage types and harvested forage types have complex differences. 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 because variations of these production costs are not proportional with the forage dry matter weight per acre and do not respond proportionally to the variations in quantities of nutrients contained within the dry matter.

The quantitative values for crude protein costs per pound, calf weight gain costs per pound, and forage feed costs per day directly affect 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 value from the land natural resources.

The fundamental problem with traditional livestock forage management concepts is that the land resources are managed from the perspective of their use. Management for a use narrowly considers only the few elements directly related with the specific portions of the resource expended and neglects to address the needs of the other individual components that makeup the ecosystems. The renewable natural resources (rangelands, grasslands, croplands, forestlands, and fisheries) have all been managed traditionally for their use. Rangelands are touted to be managed for multiple uses. These renewable resources are no longer able to maintain current production at potential levels as a result of the management caused declining ecosystem processes. Small cities and towns that depend on farming, grazing, logging, and fishing for their economic base are declining in a symptomatic response to the decrease in resource productivity.

Renewable natural resources are complex ecosystems with several trophic layers of living organisms that have individual biological requirements and nonliving components that have changeable characteristics. It is imperative for future progress that management of renewable natural resources be directed away from placing priority on the use and to be focused towards meeting the requirements of all the living and nonliving components of the ecosystems for the purpose of improving ecosystem processes and maintaining production at sustainable levels. In order to achieve continued ecosystem production of new wealth at potential sustainable levels, the rangeland, grassland, and cropland renewable natural resources require that livestock forage management strategies focus on the critical components and meet the biological requirements of the plants and soil organisms, and foster the characteristics of the soil and the biogeochemical processes. The desired increase in profits can be achieved by objective evaluation and development of improved biologically efficient 12-month pasture and harvested forage management strategies with low cost forage that meets daily nutritional quality for high-performance beef cattle.

The renewable forage plant nutrients produced on the land natural resources are the original source of new wealth generated by livestock agriculture. The maximum quantity of wealth produced on the land natural resources is limited only by the biological capacity of the plants to produce herbage and nutrients from soil, sunlight, water, and carbon dioxide. The nutrients produced by forage plants are the primary power driving all ecosystem functions and the origin of all secondary production by wildlife and livestock. The quantity of new wealth generated by livestock agriculture from forage nutrients produced on the land resources is proportional to the forage management strategies' capabilities to be effective at meeting the biological requirements of the plants and soil organisms, to be efficient at capturing produced forage nutrients, and to be efficient at converting forage nutrients into salable commodities like calf weight.

Effectively meeting the biological requirements of plants and soil organisms occurs when the defoliation resistance mechanisms of grass plants and the biogeochemical processes of grassland ecosystems are activated by partial defoliation during phenological growth between the three and a half new leaf stage and the flowering (anthesis) stage. These mechanisms and processes help grass tillers withstand and recover from grazing by triggering compensatory physiological processes that increase growth rates, increase photosynthetic capacity, and increase allocation of carbon and nitrogen; by stimulating vegetative reproduction of secondary tillers from axillary buds; and by stimulating rhizosphere organism activity and increasing conversion of inorganic nitrogen from soil organic nitrogen. Activation of these mechanisms and processes result in increased herbage biomass production, increased plant density, increased available forage nutrients, increased soil aggregation, improved soil quality, increased soil water holding capacity, increased resistance to drought conditions, improved wildlife habitat, and improved grassland ecosystem health status.

Efficient forage nutrient capture occurs when a high proportion of the forage produced nutrient weight is harvested by grazing or haying. Forage nutrients are the valuable unit of production from grazinglands and haylands. The greater the weight of forage nutrients captured per acre, the greater the new wealth generated by livestock agriculture per acre. Forage nutrient weight per acre changes during the growing season and is related to the percent nutrient content of forage and to the weight of forage dry matter at the time of harvest by grazing or haying. The optimum plant growth stage for harvest is that at which the herbage production curve and the nutrient quality curve for a specific forage type yield the greatest nutrient weight per acre.

A pound of crude protein has a greater impact on the natural resources of an ecosystem to produce and a greater influence on the cost of livestock forage feed than the production of a pound of energy (TDN). 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 phenological growth stage with the greatest pounds of crude protein per acre for perennial grasses and annual cereal grasses is the flowering growth stage. High quantities of crude protein are captured by haying when grasses are cut early, between the boot stage and the early milk stage. Increased capture of crude protein from grasses by grazing requires stimulation of vegetative secondary tillers and partial defoliation of both the lead tillers and the secondary tillers during phenological growth between the three and a half new leaf stage and the flowering stage, respectively. The growth stage with the greatest pounds of crude protein per acre for legume forages is when the plants are at full growth but before the leaves start drying from senescence. High quantities of crude protein are captured by haying when legumes are cut one time during a late full-growth stage.

Efficient forage nutrient conversion into animal weight commodities occurs when nutrients are provided at the times and in the amounts required by livestock. Beef cow nutrient requirements change with the change in production periods. The forage nutrients available to the cattle from the forage types or combination of forage types should be changed to match the change in nutrient requirements.

Modern beef cattle do not deposit body fat to the extent of the old-style cattle. Short periods of nutrient deficiency drain body fat stores causing weight loss and reductions in milk production resulting in calf weight gains and calf weaning weights at below genetic potentials. Animal weight performance at below genetic potentials is inefficient conversion of forage nutrients and is high cost. Efficient 12-month forage management strategies select appropriate combinations of pasture forage types and harvested forage types so the herbage production curves and the nutrient quality curves of the forages supply the forage and nutrient quantities that match the dietary forage quantity and nutrient quality required by beef cattle during each period of the annual production cycle.

Improvement in performance of forage management systems requires paradigm shifts that consider the land natural resources to be the source of new wealth generated from livestock agriculture with the renewable forage nutrients as the primary unit of production and the produced animal weight as the commodity sold at market. Biologically efficient 12-month pasture and harvested forage management strategies effectively meet the biological requirements of plants and soil organisms, and improve the characteristics of soil; efficiently capture forage produced nutrients; and efficiently convert nutrients into animal weight commodities. These improvements permit renewable natural resource ecosystems to perform at biologically sustainable levels and modern high-performance beef cattle to perform at genetic potentials. Results of these improvements reduce costs per pound of crude protein, reduce costs per pound of calf weight gain, reduce costs per day of forage feed, and increase returns after feed costs per acre. These changes in costs and returns effectively increase profit margins for land and cattle enterprises and improve regional economies based on livestock agriculture.

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Herbage Quality and Range Cow Requirements

Annual Nutritional Quality Curves for Graminoids in the Northern Plains

Report DREC 08-3014c

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Introduction

Agricultural production from mixed grass prairie rangelands and domesticated grasslands of the Northern Plains can be substantially increased through the implementation of strategies that more efficiently capture the nutrients produced and convert them to a saleable product. Perennial grasses and sedges change in nutritional quality as they develop and mature through phenological stages. Annual nutritional quality curves for forage plants show these changes in nutrient content during the year. Coordination of annual nutritional quality curves of the available perennial forage plants with livestock nutritional requirement curves is necessary for development of biologically effective management strategies.

The major perennial graminoid plants used as forage by livestock are separated into four categories based on the period during which most of the plant growth occurs: domesticated cool-season grasses, native range upland sedges, native range cool-season grasses, and native range warm-season grasses. This report summarizes published information on the annual nutritional quality curves of these graminoids.

Methods

Three publications have reported the nutritional quality of perennial domesticated cool-season grasses, native range upland sedges, native range cool-season grasses, and native range warm-season grasses growing on the Northern Plains region of mixed grass prairie from central North Dakota to eastern Montana. The percent crude protein, phosphorus, and moisture, and the growth stage data from these three publications were reported in Manske (1999a,b,c,d) and have been summarized in this paper.

Whitman, Bolin, Klosterman, Klostermann, Ford, Moomaw, Hoag, and Buchanan (1951) published data on the carotene, protein, and phosphorus content of grasses and sedges in western North Dakota. Graminoid species samples were collected weekly in 1946 and 1947 from the Dickinson Experiment Station at Dickinson, North Dakota. Only current year's growth was included in the sample; previous year's growth was separated and discarded. An attempt to collect ungrazed samples was made for available species except Kentucky bluegrass, which had been grazed, and smooth bromegrass, which was cut for hay in mid June. Data were reported as percent of oven-dry weight. Plant condition by stage of plant development and growth habit was reported for each species on sample dates. These data were reported as phenological growth stage in Manske (1999a,b,c,d). A summary of these data is included in this report.

Marsh, Swingle, Woodward, Payne, Frahm, Johnson, and Hide (1959) reported percent crude protein and phosphorus data from three major native range grasses from the USDA Experiment Station at Miles City, Montana. Samples were collected by clipping every 28 days from August 1948 to June 1953 except when snow covered the vegetation. Data were reported as percent of oven-dry weight. Phenological growth stages of plants on sample dates were not reported. A summary of the crude protein and phosphorus data was reported in Manske (1999c,d).

Hopper and Nesbitt (1930) reported the chemical composition of native range grasses and upland sedges and domesticated cool-season grasses collected by J.T. Sarvis from the Northern Great Plains Field Station at Mandan, North Dakota. The years of sample collection were apparently 1920, 1921, and 1925. The results of the chemical analyses, which were calculated to a uniform moisture content of 15 percent, have been recalculated to 0% moisture to facilitate comparison with other data. A brief description of physical characteristics was made for each species on the sample dates; this information is presented in Manske (1999a,b,c,d) as phenology. Percent crude protein data were summarized and reported in Manske (1999a,b,c,d).

Table 1. Common and scientific names of forage plants from (A) Whitman et al. 1951, (B) Marsh et al. 1959, and (C) Hopper and Nesbitt 1930.

Common Names	Reference Citation	Scientific Names
Domesticated grasses		
Crested wheatgrass	A, C	*Agropyron cristatum*
Smooth bromegrass	A, C	*Bromus inermis*
Timothy	C	*Phleum pratense*
Fowl bluegrass	C	*Poa palustris*
Upland Sedges		
Threadleaf sedge	A, C	*Carex filifolia*
Sun sedge	C	*Carex heliophila*
Cool-season native grasses		
Slender wheatgrass	C	*Agropyron caninum majus*
Bearded wheatgrass	C	*Agropyron caninum unilaterale*
Western wheatgrsss	A,B,C	*Agropyron smithii*
Ticklegrass	C	*Agrostis hyemalis*
Red threeawn	C	*Aristida purpurea*
Plains reedgrass	A	*Calamagrostis montanensis*
Canada wildrye	C	*Elymus canadensis*
Prairie Junegrass	A, C	*Koeleria pyramidata*
Kentucky bluegrass	A	*Poa pratensis*
Prairie wedgegrass	C	*Sphenopholis obtusata*
Needle and thread	A,B,C	*Stipa comata*
Porcupine grass	C	*Stipa spartea*
Green needlegrass	A, C	*Stipa viridula*
Warm-season native grasses		
Big bluestem	A, C	*Andropogon gerardii*
Little bluestem	A, C	*Andropogon scoparius*
Side oats grama	C	*Bouteloua curtipendula*
Blue grama	A,B,C	*Bouteloua gracilis*
Buffalo grass	C	*Buchloe dactyloides*
Prairie sandreed	A, C	*Calamovilfa longifolia*
Inland saltgrass	C	*Distichlis spicata*
Plains muhly	C	*Muhlenbergia cuspidata*
Switchgrass	C	*Panicum virgatum*

Results

The nutritional quality of ungrazed domesticated cool-season grasses, native range upland sedges, native range cool-season grasses, and native range warm-season grasses changes with the plants' phenological development. Early season vegetative leaves of graminoids are generally high in crude protein and water. As the plants mature, their fiber content increases and percent crude protein, percent water, and digestibility decrease. The patterns of change in nutritional quality are similar from year to year because phenological development is regulated primarily by photoperiod (Manske 1998a,b), although annual variations in temperature, evaporation, and water stress may result in slight variations in nutritional quality from year to year. Nutritional quality is also related to rates of plant growth and plant senescence. These are affected by the level of photosynthetic activity, which in turn is affected by temperature. Rates of senescence increase with higher temperatures and with water stress, a result of water deficiency in the environment.

Coordination of the nutritional quality curves of ungrazed plants with livestock nutritional requirement curves is essential in the development of biologically effective management strategies. Livestock nutritional requirements (NRC 1996) change with production levels and size of the animals. A 1000-pound mature cow with average milk production requires 10.5% crude protein and 0.20% phosphorus during the first month of lactation. She requires an average of 9.6% crude protein and 0.18% phosphorus from her diet in order to maintain body weight and average lactation during the second through sixth months of lactation. She requires an average of 6.2% crude protein and 0.11% phosphorus during the dry portion of the second trimester of pregnancy and 7.8% crude protein and 0.15% phosphorus during the third trimester of pregnancy.

Domesticated Cool-Season Grass

The domesticated grass species included in the two published articles reporting nutritional quality of domesticated forage grasses of the Northern Plains are listed in table 1. Summaries of crude protein levels for ungrazed crested wheatgrass are shown in figure 1. Domesticated cool-season grasses contain the highest levels of crude protein during the early stages of development. As seed stalks begin to develop, crude protein levels begin to decrease. Crude protein levels remain above 9.6% until late June. Between the flowering stage and the seed mature stage, crude protein levels decrease rapidly. During seed development, which occurs shortly after the flowering stage, crude protein levels drop below 9.6%. They fall below 7.8% by early July and below 6.2% in early August. Phosphorus levels drop below 0.18% in late July.

One replication of smooth bromegrass in Whitman's study was not cut for hay. Summaries of crude protein levels for smooth bromegrass not cut for hay are shown in figure 2. Crude protein levels of smooth bromegrass remain above 9.6% from the early growth of the plant until late June. Crude protein levels of uncut smooth bromegrass drop below 9.6% after late June. From mid July to mid September crude protein levels decrease from around 7.8% to 5.0%. Phosphorus levels of mature uncut smooth bromegrass drop below 0.18% in early August.

Grasses that are hayed have nutrient curves different from those of grasses not cut for hay because defoliation manipulates the mechanisms that regulate vegetative reproduction. Data to illustrate this difference are limited to one example from the historical literature for the Northern Plains. Whitman's study includes one replication of data from hayed smooth bromegrass. Summaries of crude protein levels for hayed smooth bromegrass are shown in figure 3. The smooth bromegrass was cut for hay in mid June; the crude protein levels of the immature tillers that grew after the cutting event remained above 9.6% until after late September. These data from hayed smooth brome show that secondary tillers have crude protein levels above 9.6% for at least 2.5 months longer than undefoliated plants. Additional research data need to be collected on the effects haying and grazing produce on the crude protein and mineral levels of domesticated cool-season grasses.

Crude protein levels for ungrazed timothy and fowl bluegrass (Hopper and Nesbitt 1930, Manske 1999a) follow a pattern similar to that followed by other domesticated cool-season grasses. The grasses contain the highest levels of crude protein in the early stages of development. As seed stalks begin to develop, crude protein levels begin to decrease. Between the flowering stage and seed mature stage, crude protein levels rapidly decrease, usually falling below 9.6% shortly after the plant has reached flowering stage.

Native Range Upland Sedge

The native range upland sedge species included in the two published articles reporting nutritional quality of sedge plants of the Northern

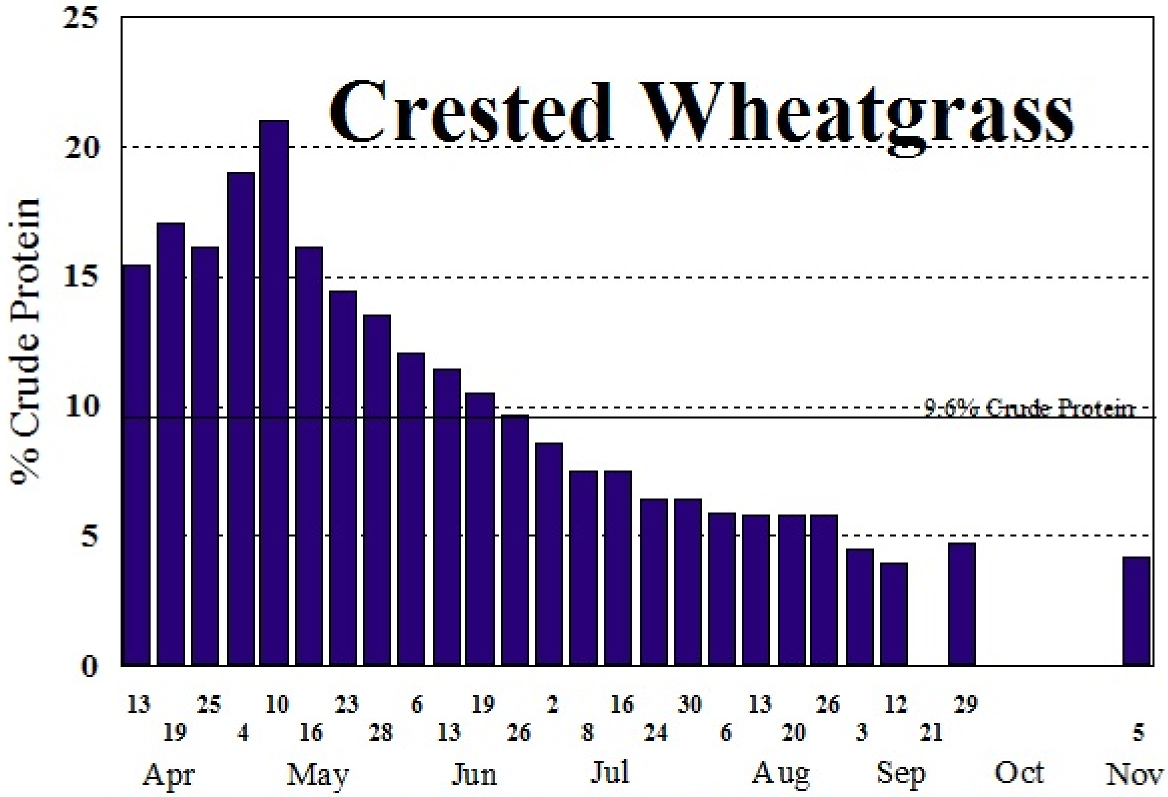

Fig 1. Mean percent crude protein of ungrazed crested wheatgrass in western North Dakota, data from Whitman et al. 1951.

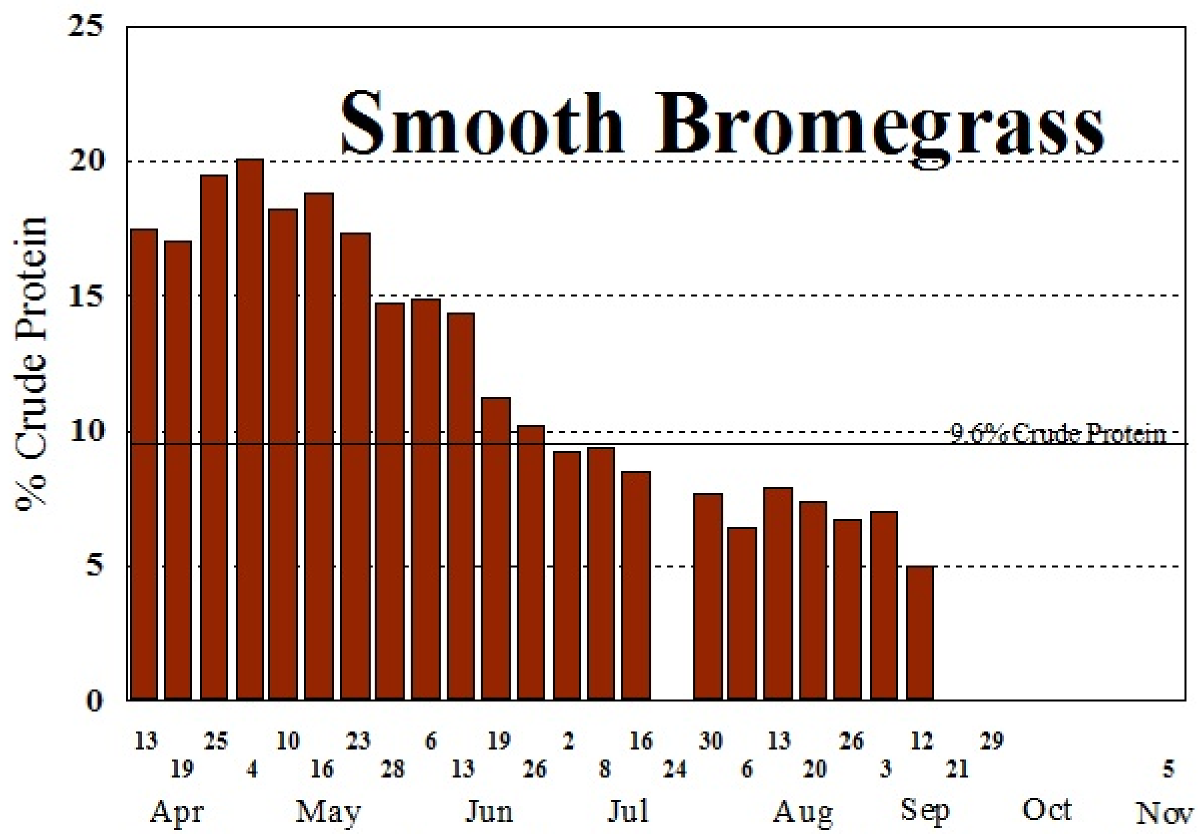

Fig 2. Mean percent crude protein of smooth bromegrass not cut for hay in western North Dakota, data from Whitman et al. 1951.

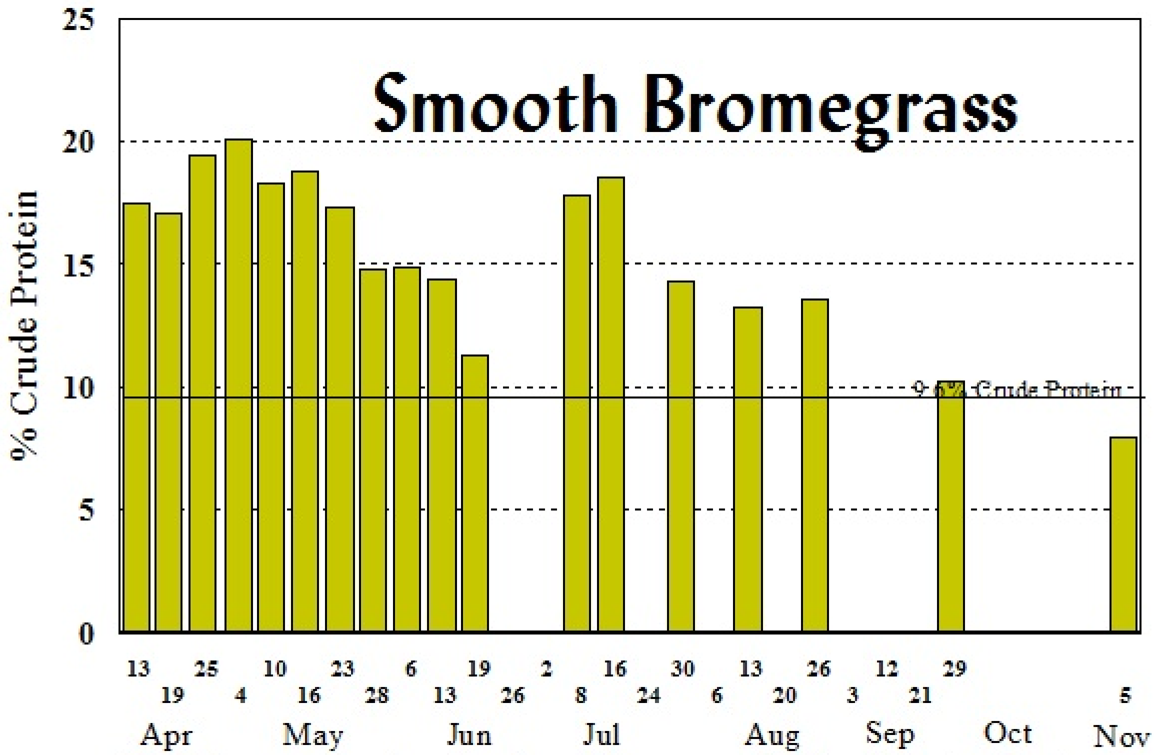

Fig 3. Mean percent crude protein of smooth bromegrass cut for hay at flowering stage in mid June in western North Dakota, data from Whitman et al. 1951.

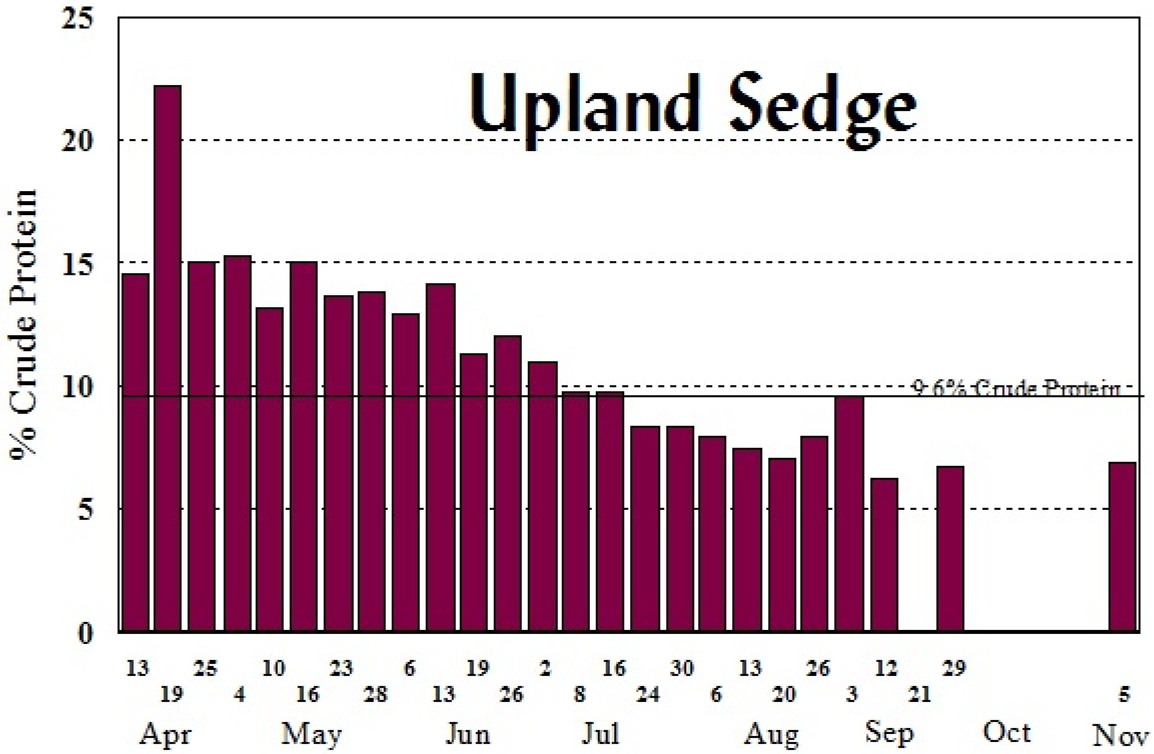

Fig 4. Mean percent crude protein of ungrazed native range upland sedges in western North Dakota, data from Whitman et al. 1951.

Plains are listed in table 1. Summaries of crude protein levels for ungrazed upland sedges are shown in figure 4. Sedges contain the highest levels of crude protein during the early stages of development. Crude protein curves of the upland sedges do not follow the same relationship with phenological growth stage as do the crude protein curves of cool-season grasses. Crude protein levels in upland sedges remain high through flowering and seed maturing stages and decrease with increases in senescence. Upland sedges grow very early and produce seed heads in late April to early May. Crude protein levels remain above 9.6% after seed mature stage, until mid July. Crude protein levels decrease below 7.8% in early August but do not fall below 6.2% for the remainder of the year. Phosphorus levels drop below 0.18% in mid May.

Graminoids defoliated by grazing and haying have nutrient curves different from those of ungrazed plants because defoliation manipulates the mechanisms that regulate vegetative reproduction. The reviewed literature contains no examples of defoliation's effects on the nutrient curves for native range upland sedges. Additional research data need to be collected on the effects grazing produces on the crude protein and mineral levels of native range upland sedges.

Native Range Cool-Season Grass

The native range cool-season grass species included in the three published articles reporting nutritional quality of forage grasses of the Northern Plains are listed in table 1. Summaries of crude protein levels for ungrazed cool-season grasses are shown in figure 5. One cool-season species in Whitman's study, Kentucky bluegrass, was not available in ungrazed condition, so grazed samples were collected. A summary of these data is shown in figure 6.

Crude protein levels of ungrazed cool-season native range grasses are very closely related to the phenological stages of growth and development, which are triggered primarily by the length of daylight. The length of daylight increases during the growing season to mid June and then decreases. The longest day length occurs at summer solstice, 21 June, when the sun's apparent path is farthest north of the equator. Ungrazed cool-season native range grasses contain the highest levels of crude protein during the early stages of development. Most cool-season plants are long-day plants which reach the flower phenological stage after exposure to a critical photoperiod and during the period of increasing daylight between mid April and mid June (21 June) (Weier et al. 1974, Leopold and Kriedemann 1975). Cool-season grasses usually reach flowering phenophase before 21 June. Crude protein levels remain above 9.6% at flower stage but decrease rapidly during seed development and seed mature stages, dropping below 7.8% by early August and below 6.2% in late August.

Crude protein levels are also related to rates of plant growth and senescence. These are affected by the level of photosynthetic activity, which in turn is affected by temperature. The optimum temperature range for photosynthesis for cool-season plants, which are C_3 photosynthesis pathway plants, is 50° to 77° F (10° to 25° C) (Coyne et al. 1995). Temperatures below 50° F (10° C) during the day or temperatures above 77° F (25° C) limit the growth rate of cool-season grasses because photosynthetic rates are reduced. Rates of senescence increase with higher temperatures and with water stress, a result of water deficiency in the environment. Water deficiencies occur about 50% of the time during August, September, and October (Manske 1998a, 1999e). Cool-season grasses do not use water as efficiently as do warm-season grasses, a factor that contributes to cool-season grasses functioning at optimum temperatures lower than those of warm-season grasses. Crude protein levels of ungrazed cool-season grasses decrease below 9.6% in mid July, dropping below 7.8% in early August and below 6.2% in late August. Phosphorus levels of ungrazed cool-season grasses drop below 0.18% in late July.

Grazed grasses have nutrient curves different from those of ungrazed grasses because defoliation manipulates the mechanisms that regulate vegetative reproduction. Data to illustrate this difference are limited to one example from the historical literature for the Northern Plains. Whitman's study includes data from grazed Kentucky bluegrass. Crude protein levels of grazed Kentucky bluegrass did not drop below 9.6% as did crude protein levels of ungrazed cool-season grasses; during most sample periods, crude protein levels of grazed Kentucky bluegrass remained at or above 9.6% until late September. Phosphorus levels of grazed Kentucky bluegrass remained above 0.18% through late September. Kentucky bluegrass is not an ideal example to illustrate the effects of grazing on the crude protein curves of all cool-season native range grasses because the lead tiller of Kentucky bluegrass has weak hormonal control of axillary bud activity and does not inhibit secondary tillering to the same extent that the lead tillers of other native range grasses do. However, these data show that secondary tillers have

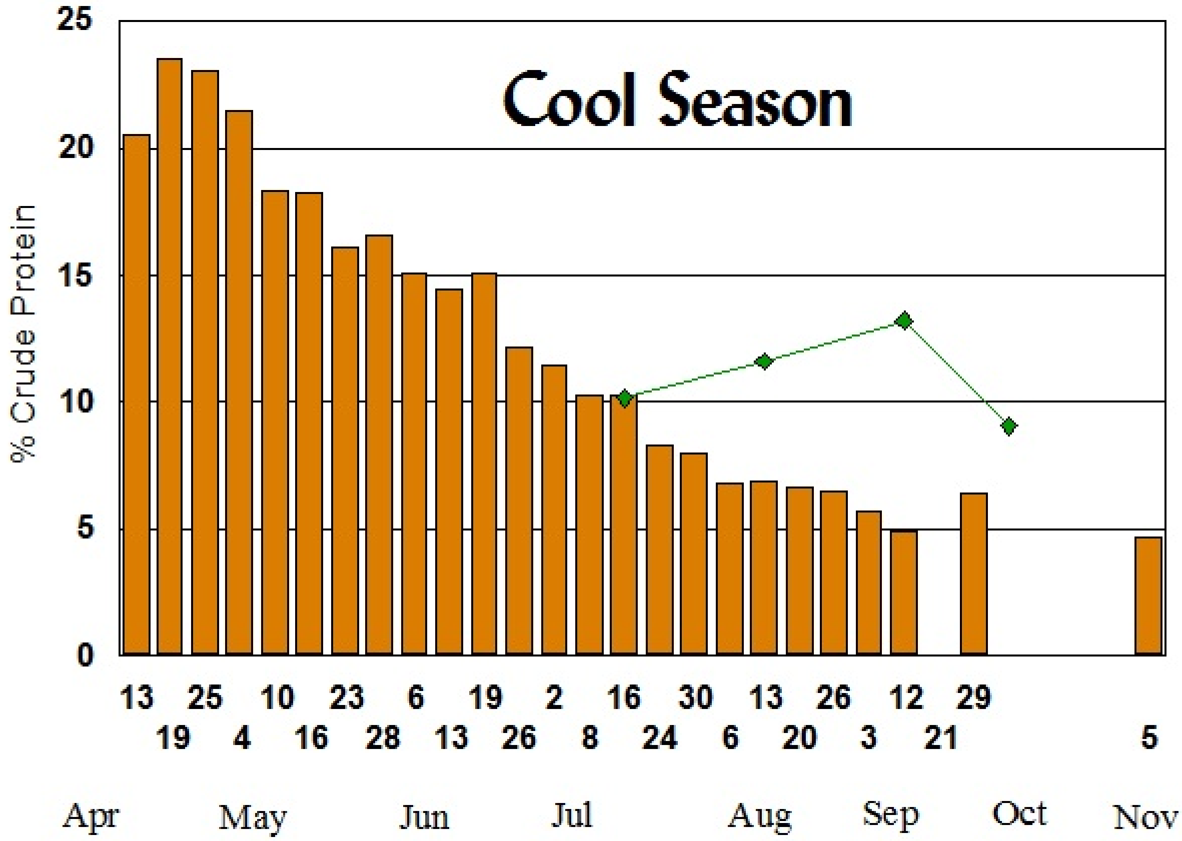

Fig 5. Mean percent crude protein of ungrazed native range cool season grasses in western North Dakota, data from Whitman et al. 1951 and secondary tiller data from Sedivec 1999.

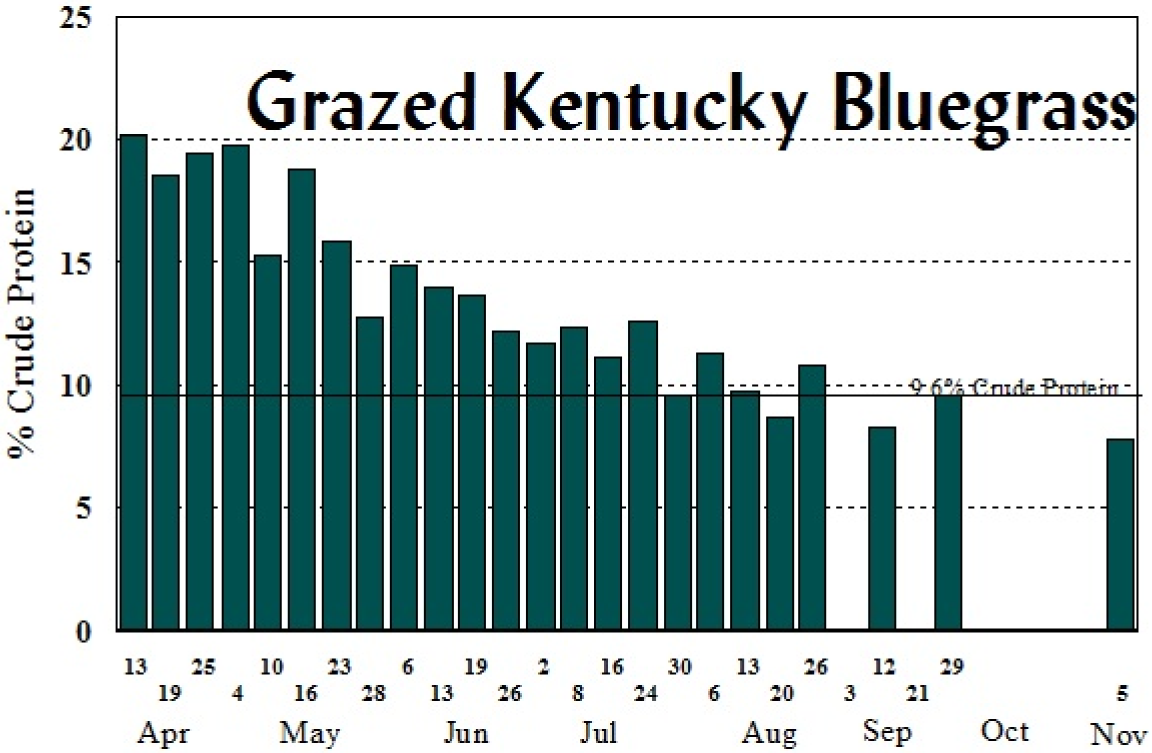

Fig 6. Mean percent crude protein of grazed Kentucky bluegrass in western North Dakota, data from Whitman et al. 1951.

crude protein levels above 9.6% for at least 2.5 months longer than ungrazed plants. Sedivec (1999) determined mean percent crude protein for grazing stimulated native range cool-season secondary tillers on twice-over rotation treatments in central North Dakota. Crude protein levels of cool-season secondary tillers increased during July and August to 13.2% in early September, decreased during September, and dropped below 9.6% in early to mid October (figure 5). Additional research data need to be collected on the effects grazing produces on the crude protein and mineral levels of native range cool-season grasses.

Native Range Warm-Season Grass

The native range warm-season grass species included in the three published articles reporting nutritional quality of forage grasses of the Northern Plains are listed in table 1. Summaries of crude protein levels for ungrazed warm-season grasses are shown in figure 7.

Crude protein levels of ungrazed warm-season native range grasses are very closely related to phenological stages of growth and development, which are triggered primarily by the length of daylight. The length of daylight increases during the growing season to mid June and then decreases. The longest day length occurs at summer solstice, 21 June, when the sun's apparent path is farthest north of the equator. Ungrazed warm-season native range grasses contain the highest levels of crude protein during the early stages of development. Most warm-season plants are short-day plants which are induced to flower by day lengths that are shorter than a critical length and that occur during the period of decreasing day length after mid June (21 June). Short-day plants are technically responding to the increase in the length of night period rather than to the decrease in the day length (Weier et al. 1974, Leopold and Kriedemann 1975). Warm-season grasses usually reach flowering phenophase after 21 June. Crude protein levels remain above 9.6% at flower stage but decrease rapidly during seed development and seed mature stages.

Crude protein levels are also related to rates of plant growth and plant senescence. These are affected by the level of photosynthetic activity, which in turn is affected by temperature. The optimum temperature range for photosynthesis for warm-season plants, which are C_4 photosynthesis pathway plants, is 86° to 105° F (30° to 40° C) (Coyne et al. 1995). Temperatures below 86° F (30° C) or above 95° F to 105° F (35° to 40° C) limit the growth rate of warm-season grasses because photosynthetic rates are reduced. Warm-season grasses use water more efficiently than do cool-season grasses, a characteristic that enables warm-season grasses to function efficiently at higher temperatures. Rates of senescence increase with higher temperatures and with water stress, a result of water deficiency in the environment. Water deficiencies occur about 50% of the time during August, September, and October (Manske 1998a, 1999e). Crude protein levels of ungrazed warm-season grasses decrease below 9.6% in late July, when plants are mature, and below 6.2% in early September. Phosphorus levels of ungrazed warm-season grasses drop below 0.18% in late August.

Grazed grasses have nutrient curves different from those of ungrazed grasses because defoliation manipulates the mechanisms that regulate vegetative reproduction. The reviewed literature contains no examples of defoliation's effects on the nutrient curves for native range warm-season grasses. Sedivec (1999) determined mean percent crude protein for grazing stimulated native range warm-season secondary tillers on twice-over rotation treatments in central North Dakota. Crude protein levels of warm-season secondary tillers increased during August to 10.0% in early September, decreased during September, and dropped below 9.6% in late September (figure 7). Additional research data need to be collected on the effects grazing produces on the crude protein and mineral levels of native range warm-season grasses.

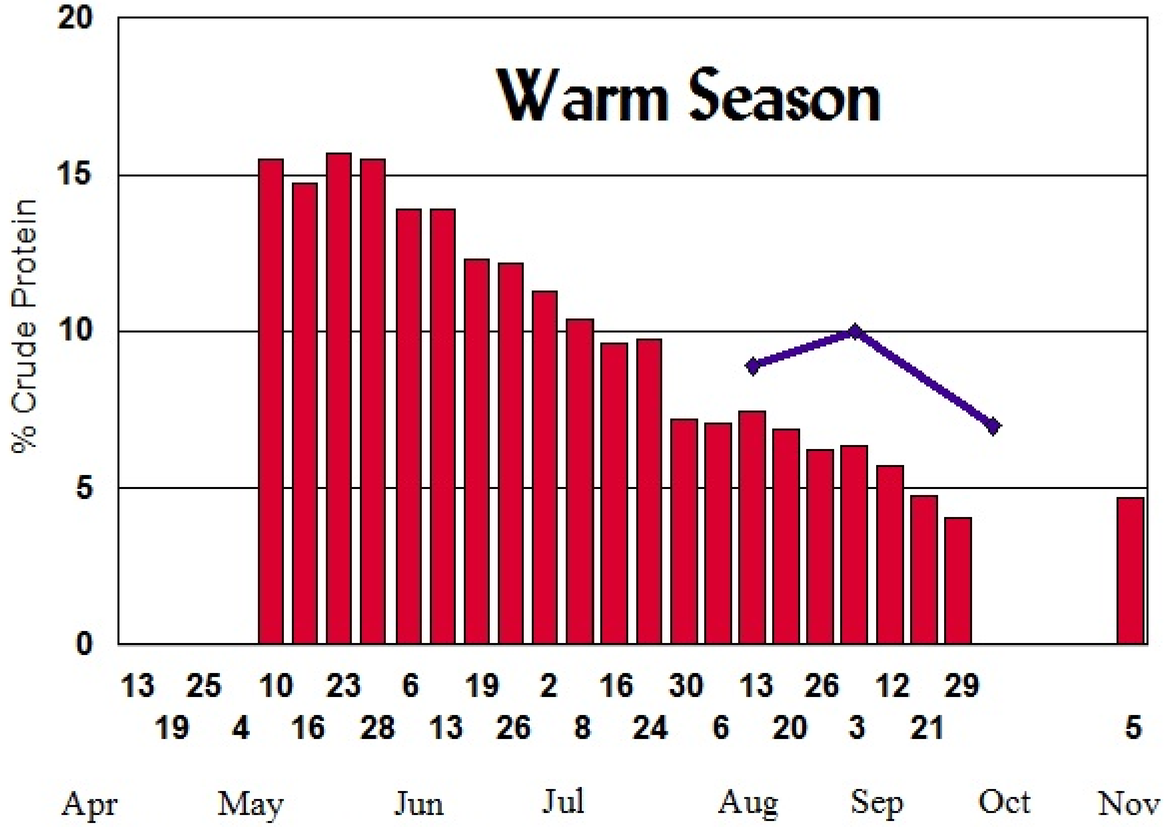

Fig 7. Mean percent crude protein of ungrazed native range warm season grasses in western North Dakota, data from Whitman et al. 1951 and secondary tiller data from Sedivec 1999.

Discussion

This report summarizes the limited published data reporting sequential nutritional quality of domesticated cool-season grasses, native range upland sedges, native range cool-season grasses, and native range warm-season grasses used on the Northern Plains and interprets the relationships between the changes in nutritional quality and the changes in phenological development of ungrazed plants.

The changes in nutritional quality of ungrazed domesticated cool-season grasses follow the plants' phenological stages. Plants contain the highest levels of crude protein in the earliest stages of development. As seed stalks develop, nutrient content begins to decrease, falling rapidly between the flowering stage and the seed mature stage. Crude protein levels of ungrazed domesticated cool-season grasses drop below 9.6% in late June and below 7.8% in early or mid July. Phosphorus levels of ungrazed domesticated cool-season grasses drop below 0.18% in late July or early August.

The nutritional quality of ungrazed native range upland sedges decreases as the plants mature, but the changes in nutritional quality do not follow the same relationships to phenological stages as do the changes in nutritional quality of cool-season grasses. The levels of crude protein are high in the early stages of sedge development. Crude protein levels remain high through flower stalk development, flowering, seed maturing, and seed shedding stages. Nutritional quality decreases with increased senescence in mature sedges. Crude protein levels of ungrazed native range upland sedges drop below 9.6% in mid July and below 7.8% in early August. Phosphorus levels drop below 0.18% in mid May.

The nutritional quality of ungrazed native range cool-season grasses changes with the stages of phenological development. Plants contain the highest levels of crude protein in the early stages of development. As seed stalks develop, nutrient levels begin to decrease, falling rapidly between the flowering stage and the seed mature stage. Levels of crude protein in ungrazed native range cool-season grasses drop below 9.6% in mid July, below 7.8% in early August, and below 6.2% in late August. Grazing stimulated cool-season secondary tillers provide levels of crude protein above 9.6% from mid July through late September during a 2.5 month period when levels of crude protein are below 9.6% in the lead tillers. The phosphorus content of cool-season grasses falls below 0.18% in late July.

The changes in nutritional quality of ungrazed native range warm-season grasses follow the changes in the phenological stages of growth and development. The plants contain the highest levels of crude protein during the early stages of development. As seed stalks develop, nutrient content begins to decrease, falling rapidly between the flowering stage and the seed mature stage. Crude protein levels of ungrazed native warm-season grasses drop below 9.6% in late July and below 6.2% in early September. Grazing stimulated warm-season secondary tillers provide levels of crude protein at or above 9.6% during August and September when levels of crude protein are below 9.6% in the lead tillers. Phosphorus levels of ungrazed native warm-season grasses drop below 0.18% in late August.

The crude protein requirements of 9.6% for cows with average lactation are not met by ungrazed domesticated cool-season grasses after late June, by ungrazed native range upland sedges after mid July, by ungrazed native range cool-season grasses after mid July, and by ungrazed native range warm-season grasses after late July. Grazing stimulated cool-season and warm-season secondary tillers extend the period of crude protein at levels above 9.6% for two to two and a half months until late September or mid October.

Grazing and haying affect grass plant biological mechanisms that regulate vegetative reproduction. These effects are not the same at all phenological growth stages during the growing season. Additional research should be conducted to study the effects defoliation by grazing and haying has on phenological development, vegetative reproduction, and changes in nutritional quality of the forage plants during the growing season.

Conclusion

Developing management strategies for operations that graze livestock on pastures and cut perennial forages for hay where the vegetation has changeable nutritional quality is challenging. Biologically effective pasture and harvested forage management strategies must protect the health of the plants and still allow the capture of the nutrients produced on the rangelands and grasslands and the conversion of these nutrients into a saleable product at a relatively low cost. Such management strategies match the herbage nutritional quality curves, the herbage production quantity curves, the forage plant phenological development curves, and the livestock nutritional requirement curves. These management strategies include a combination of forage types that have their phenological development and nutritional quality curves at different periods of the year. Complementary forage types are used in the appropriate sequence and proportions to meet the minimum nutritional requirements of livestock during the entire grazing and feeding season.

Nutritional quality data from ungrazed plants show the natural progression and development of the vegetation without alteration from defoliation. Nutritional data from ungrazed plants can be used to evaluate the biological effectiveness of management strategies. Nutrient curves of forage plants that have been defoliated by grazing or haying are different from the nutrient curves of undefoliated plants because defoliation manipulates the mechanisms that regulate vegetative reproduction.

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Annual Mineral Quality Curves for Graminoids in the Northern Plains

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Introduction

Beef cows require seventeen minerals to maintain proper body functions: seven macrominerals in large quantities and ten microminerals in trace amounts. The quantities of each mineral required vary with cow size, level of milk production, and production period (dry gestation, 3rd trimester, early lactation, lactation). Livestock mineral requirement curves show the amount of each mineral animals require during the production periods. Many essential minerals are provided to the animals by the forages they consume. The mineral content of perennial forage grasses and sedges changes as the plants develop and mature through phenological stages. Annual mineral quality curves for forage plants show these changes in mineral content during the year. Coordination of annual mineral quality curves of available perennial forage plants with livestock mineral requirement curves is necessary for the development of management strategies that efficiently provide the quantities of minerals animals require at each production stage.

The major perennial graminoid plants livestock use as forage are separated into four categories based on the period during which most of the plant growth occurs: domesticated cool-season grasses, native range upland sedges, native range cool-season grasses, and native range warm-season grasses. This report summarizes published information on the annual mineral quality curves of these four graminoid categories.

Methods

Two publications have reported the changes in mineral content of perennial grasses growing on the Northern Plains mixed grass prairie of western North Dakota and eastern Montana. In the historical literature for the Northern Plains, changes in mineral content and related phenological growth stages of perennial graminoids are reported only for phosphorus. Phosphorus is the mineral most commonly deficient in diets of cattle grazing forages. Calcium and salt (sodium and chlorine) are the other minerals most likely to be deficient in forage diets.

Whitman et al. (1951) published a bulletin on the nutrient content of grasses and sedges in western North Dakota. Graminoid species samples were collected weekly in 1946 and 1947 from the Dickinson Experiment Station at Dickinson, North Dakota. Only current year's growth was included in the sample; previous year's growth was separated and discarded. An attempt to collect ungrazed samples was made for available species except Kentucky bluegrass, which had been grazed, and smooth bromegrass, which was cut for hay in mid June. Data were reported as percent of oven-dry weight. Plant condition by stage of plant development and growth habit was reported for each species on sample dates. These data were presented as phenological growth stage in Manske (1999a, b, c, d). Weekly percent phosphorus of graminoid species reported by Whitman et al. (1951) was summarized by species and included in Manske (1999a, b, c, d). These data have been summarized and presented in four graminoid categories in this report.

Marsh et al. (1959) reported nutrient content of three grasses from the USDA Experiment Station at Miles City, Montana. Samples were collected by clipping every 28 days from August 1948 to June 1953 except when snow covered the vegetation. Data were reported as percent of oven-dry weight. Phenological growth stages of plants on sample dates were not reported. A summary of the phosphorus data by species was presented in Manske (1999c, d). These data have been summarized and presented in two graminoid categories in this report.

Results

The mineral quality of ungrazed domesticated cool-season grasses, native range upland sedges, native range cool-season grasses, and native range warm-season grasses changes with the phenological development of the plants. Early season vegetative growth of graminoids is generally high in phosphorus. As the plants mature, their phosphorus content decreases. Phenological development patterns are similar from year to year because they are regulated primarily by photoperiod (Manske 1998b, 2000), although annual differences in temperature, evaporation, and water stress may result in slight variation.

Daily Mineral Requirements

Understanding both the mineral quality curves for perennial forage plants and the mineral requirement curves for beef cows is necessary for efficient nutritional management of livestock. Beef cow daily nutritional requirements (NRC 1996), including phosphorus and calcium requirements, change with cow size, level of milk production, and production period. During the dry gestation period, beef cows with average milk production and live weights of 1000 lbs, 1200 lbs, and 1400 lbs require 0.11%, 0.12%, and 0.12% phosphorus in diet dry matter, respectively; during the 3rd trimester period, they require 0.15%, 0.16%, and 0.17% phosphorus in diet dry matter, respectively; during the early lactation period, they require 0.20%, 0.19%, and 0.19% phosphorus in diet dry matter, respectively; and during the lactation period, they require 0.18%, 0.18%, and 0.18% phosphorus in diet dry matter, respectively (table 1). During the dry gestation period, beef cows with average milk production and live weights of 1000 lbs, 1200 lbs, and 1400 lbs require 0.15%, 0.15%, and 0.16% calcium in diet dry matter, respectively; during the 3rd trimester period, they require 0.24%, 0.25%, and 0.26% calcium in diet dry matter, respectively; during the early lactation period, they require 0.30%, 0.29%, and 0.28% calcium in diet dry matter, respectively; and during the lactation period, they require 0.27%, 0.26%, and 0.26% calcium in diet dry matter, respectively (table 1). Beef cattle require greater amounts of calcium than of phosphorus. However, because perennial grasses contain considerably more calcium than phosphorus, diets of cattle grazing forages are more likely to be deficient in phosphorus.

Domesticated Cool-Season Grass

The domesticated grass species included in the study by Whitman et al. (1951) were crested wheatgrass and smooth bromegrass. Ungrazed or uncut domesticated cool-season grasses (table 2, figs. 1 and 2) contain their highest levels of phosphorus in early May, during the early stages of development. As the plants continue to develop, the percentage of phosphorus decreases. Phosphorus levels drop below 0.18% (the percentage required by lactating cows) in late July, when plants reach the mature seed stage.

One replication of smooth bromegrass in Whitman's study was cut for hay in mid June. Phosphorus levels of the immature tillers that grew after the cutting remained above 0.18% until early September (table 2, fig. 3). These data from hayed smooth bromegrass show that secondary tillers have phosphorus levels above 0.18% for at least one month longer than undefoliated plants. Additional research data need to be collected on the effects haying and grazing have on the mineral levels of domesticated cool-season grasses.

Native Range Upland Sedge

The native range upland sedge species included in the study by Whitman et al. (1951) was threadleaf sedge. Ungrazed upland sedges (table 2, fig. 4) contain their highest levels of phosphorus during the early stages of development, in late April. As the plants continue to develop, the percentage of phosphorus decreases. Upland sedges grow very early and produce seed heads in late April to early May. Phosphorus levels drop below 0.18% (the percentage required by lactating cows) in mid May, when plants reach the mature seed stage.

Defoliation by grazing or haying affects the mineral content of graminoids. The reviewed literature contains no examples of defoliation's effects on the mineral curves of native range upland sedges. Additional research data need to be collected on the effects haying and grazing have on the mineral levels of native range upland sedges.

Native Range Cool-Season Grass

The ungrazed native range cool-season grasses included in the study by Whitman et al. (1951) were western wheatgrass, plains reedgrass, prairie Junegrass, needle and thread, and green needlegrass. The grazed cool-season grass for which Whitman et al. (1951) reported data was Kentucky bluegrass. The native range cool-season grasses for which Marsh et al. (1959) reported data were western wheatgrass and needle and thread. Ungrazed native range cool-season grasses (table 2, fig. 5) contain their highest levels of phosphorus during the early stages of development, in April, May, and early June. As the plants continue to develop, the percentage of phosphorus decreases. In western North Dakota, phosphorus levels of ungrazed native range cool-season grasses drop below 0.18% (the percentage required by lactating cows) in late July, when plants reach the mature seed stage (table 2). In eastern Montana, phosphorus levels drop below 0.18% in late June (table 3). This difference between phosphorus levels of plants in two geographic areas suggests that the rate of leaf senescence may have an effect on mineral levels of grasses.

One cool-season species in Whitman's study, Kentucky bluegrass, was not available in ungrazed condition, so grazed samples were collected. During the grazing season, the grazed plants of Kentucky bluegrass were generally higher in phosphorus content than were ungrazed plants of the other cool-season species (table 2, fig. 6). Phosphorus levels of grazed Kentucky bluegrass remained above 0.18% through late September. Kentucky bluegrass is not an ideal example to illustrate the effects of grazing on the mineral curves of cool-season native range grasses because the lead tiller of Kentucky bluegrass has weak hormonal control of axillary bud activity and does not inhibit secondary tillering to the same extent that the lead tillers of other native range grasses do (Manske 2000). However, these data show that the secondary tillers of Kentucky bluegrass have phosphorus levels above 0.18% for at least two months longer than the undefoliated cool-season plants. Additional research data need to be collected on the effects haying and grazing have on the mineral levels of native range cool-season grasses.

Native Range Warm-Season Grass

The ungrazed native range warm-season grasses included in the study by Whitman et al. (1951) were big bluestem, little bluestem, blue grama, and prairie sandreed. The native range warm-season grass for which Marsh et al. (1959) reported data was blue grama. Ungrazed native range warm-season grasses (table 2, fig. 7) contain their highest levels of phosphorus in May, June, and July, during the early stages of development. As the plants continue to develop, the percentage of phosphorus decreases. In western North Dakota, phosphorus levels of ungrazed native range warm-season grasses drop below 0.18% (the percentage required by lactating cows) in late August, when plants reach the mature seed stage (table 2). In eastern Montana, the phosphorus levels drop below 0.18% in early July (table 3). This difference between phosphorus levels of plants in two geographic areas suggests that the rate of leaf senescence may have an effect on mineral levels of grasses.

Defoliation by grazing or haying affects the mineral content of graminoids. The reviewed literature contains no examples of defoliation's effects on the mineral curves of native range warm-season grasses. Additional research data need to be collected on the effects haying and grazing have on the mineral levels of native range warm-season grasses.

Table 1. Daily phosphorus and calcium requirements in pounds and percent dry matter for beef cows with average milk production during four production periods (data from NRC 1996).

Production Periods		1000 lb cows		1200 lb cows		1400 lb cows	
		Phosphorus	Calcium	Phosphorus	Calcium	Phosphorus	Calcium
Dry Gestation	pounds (lb)	0.02	0.03	0.03	0.04	0.03	0.04
	percent (%)	0.11	0.15	0.11	0.15	0.12	0.16
3rd Trimester	pounds (lb)	0.03	0.05	0.04	0.06	0.05	0.07
	percent (%)	0.15	0.24	0.16	0.25	0.17	0.26
Early Lactation	pounds (lb)	0.05	0.07	0.05	0.08	0.06	0.08
	percent (%)	0.20	0.30	0.19	0.29	0.19	0.28
Lactation	pounds (lb)	0.04	0.06	0.05	0.07	0.05	0.08
	percent (%)	0.18	0.27	0.18	0.26	0.18	0.26

Table 2. Weekly percent phosphorus content of graminoids in western North Dakota, means of 1946 and 1947, data from Whitman et al. (1951).

		Domesticated				Native Range			
		cool-season		upland sedge		cool-season		warm-season	
		uncut	hayed[1]	ungrazed	grazed	ungrazed	grazed[2]	ungrazed	grazed
Apr	1								
	13	0.263	0.269	0.270		0.315	0.314		
	19	0.280	0.244	0.317		0.346	0.313		
	25	0.289	0.264	0.210		0.320	0.232		
May	4	0.306	0.302	0.210		0.301	0.299		
	10	0.285	0.285	0.185		0.303	0.258	0.267	
	16	0.246	0.236	0.170		0.276	0.280	0.226	
	23	0.253	0.260	0.176		0.239	0.268	0.231	
	28	0.247	0.247	0.162		0.237	0.264	0.264	
Jun	6	0.248	0.264	0.160		0.253	0.258	0.299	
	13	0.254	0.253	0.160		0.258	0.287	0.286	
	19	0.233	0.240	0.179		0.244	0.267	0.286	
	26	0.222	-	0.152		0.232	0.231	0.275	
Jul	2	0.211	-	0.153		0.228	0.272	0.245	
	8	0.210	0.302	0.155		0.205	0.243	0.245	
	16	0.202	0.277	0.128		0.203	0.246	0.222	
	24	0.178	-	0.122		0.186	0.238	0.226	
	30	0.189	0.220	0.115		0.176	0.229	0.208	
Aug	6	0.148	-	0.097		0.149	0.237	0.175	
	13	0.158	0.184	0.109		0.157	0.255	0.186	
	20	0.169	-	0.118		0.153	0.145	0.194	
	26	0.167	0.190	0.091		0.141	0.189	0.150	
Sep	3	0.132	-	0.135		0.124	-	0.153	
	12	0.106	-	0.085		0.119	-	0.121	
	21		-				-	0.189	
	29	0.106	0.127	0.083		0.120	0.234	0.076	
Oct									
Nov	5	0.100	0.109	0.096		0.116	0.155	0.085	

[1]Hayed cool-season grass includes only smooth bromegrass data.
[2]Grazed cool-season grass includes only Kentucky bluegrass data.

Table 3. Monthly percent phosphorus content of grasses in eastern Montana, means of 1948-1953, data from Marsh et al. (1959).

Dates	Native Range	
	cool-season	warm-season
Jan 24	0.073	-
Feb 21	0.058	0.060
Mar 24	0.070	0.073
Apr 23	0.102	0.088
May 20	0.186	0.155
Jun 15	0.176	0.200
Jul 14	0.119	0.158
Aug 9	0.111	0.154
Sep 6	0.089	0.118
Oct 5	0.095	0.106
Nov 4	0.087	0.100
Dec 1	0.077	0.073
Dec 27	0.088	0.085

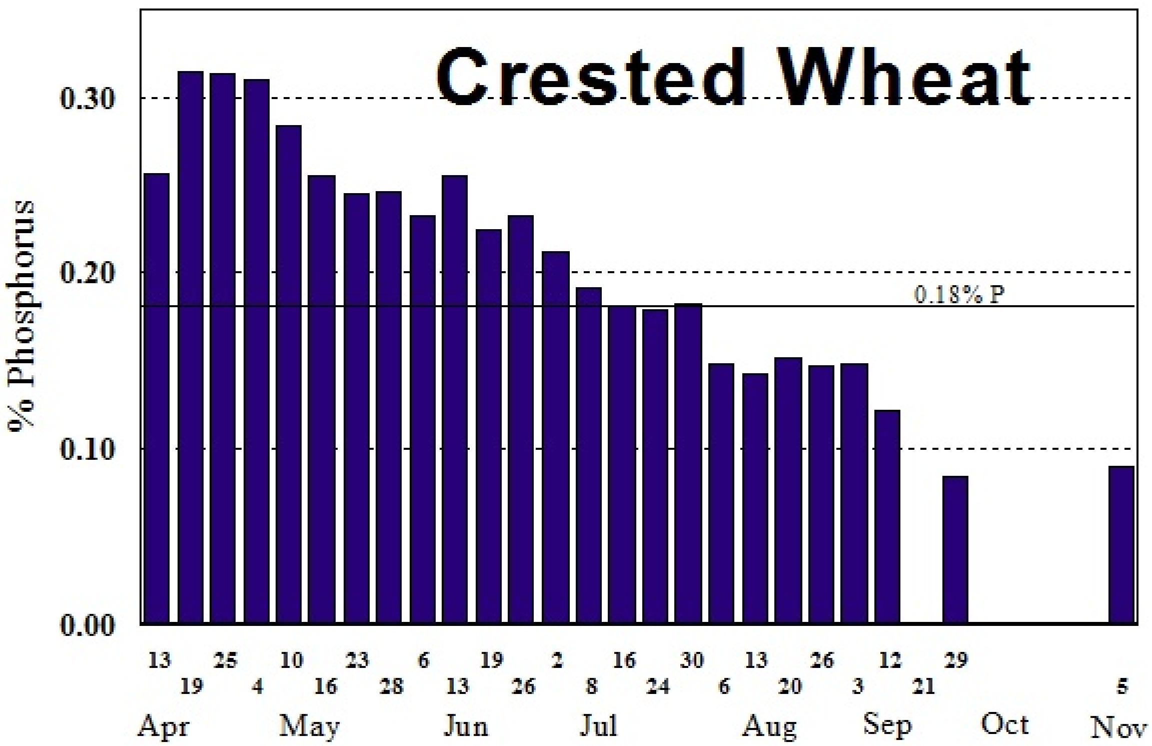

Fig 1. Mean percent phosphorus of ungrazed crested wheatgrass in western North Dakota, data from Whitman et al. 1951.

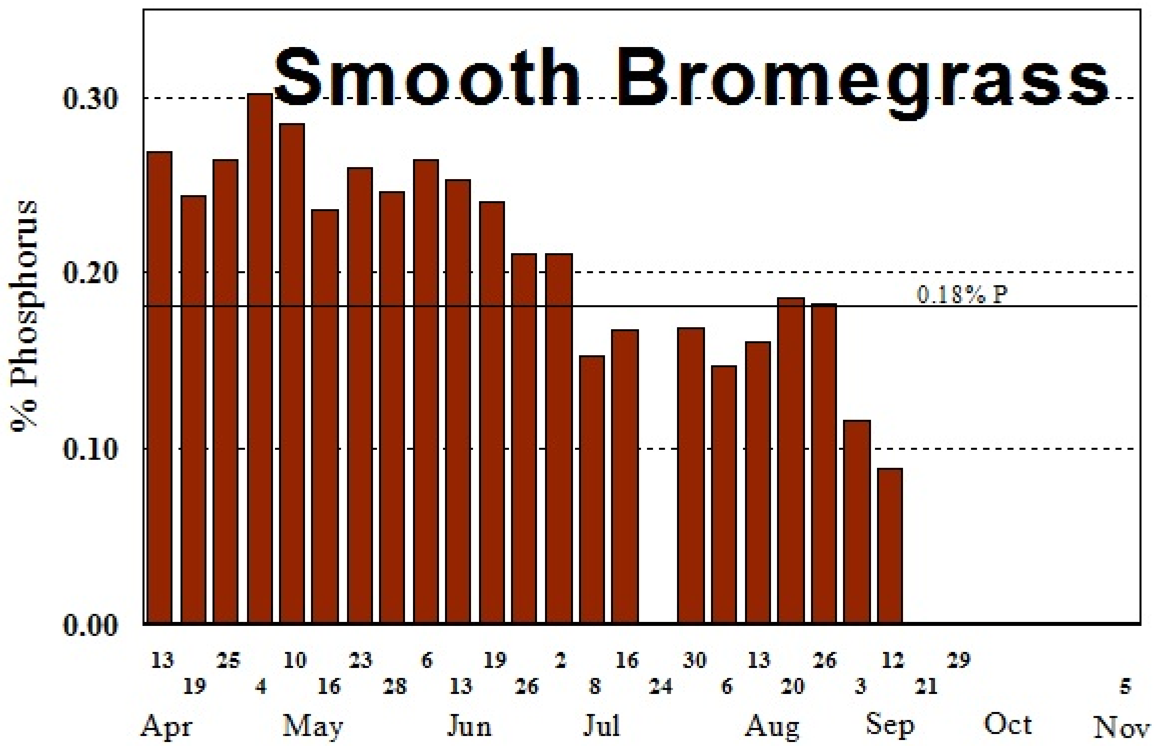

Fig 2. Mean percent phosphorus of smooth bromegrass not cut for hay in western North Dakota, data from Whitman et al. 1951.

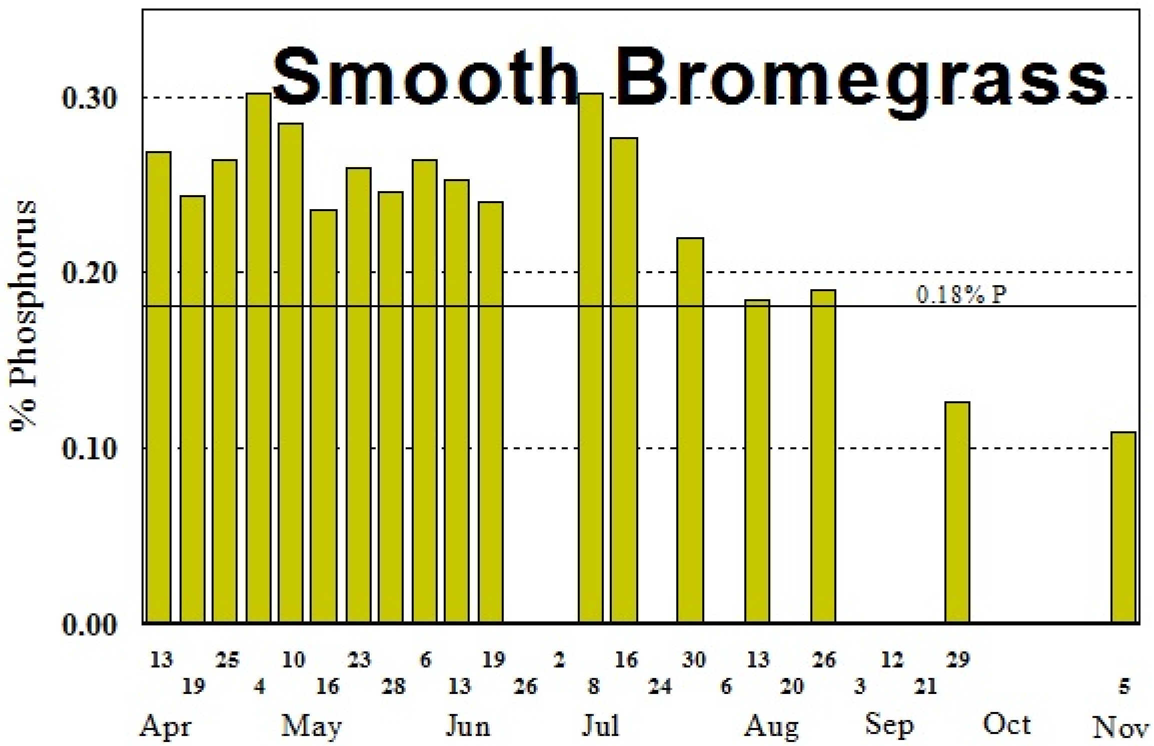

Fig 3. Mean percent phosphorus of smooth bromegrass cut for hay at flowering stage in mid June in western North Dakota, data from Whitman et al. 1951.

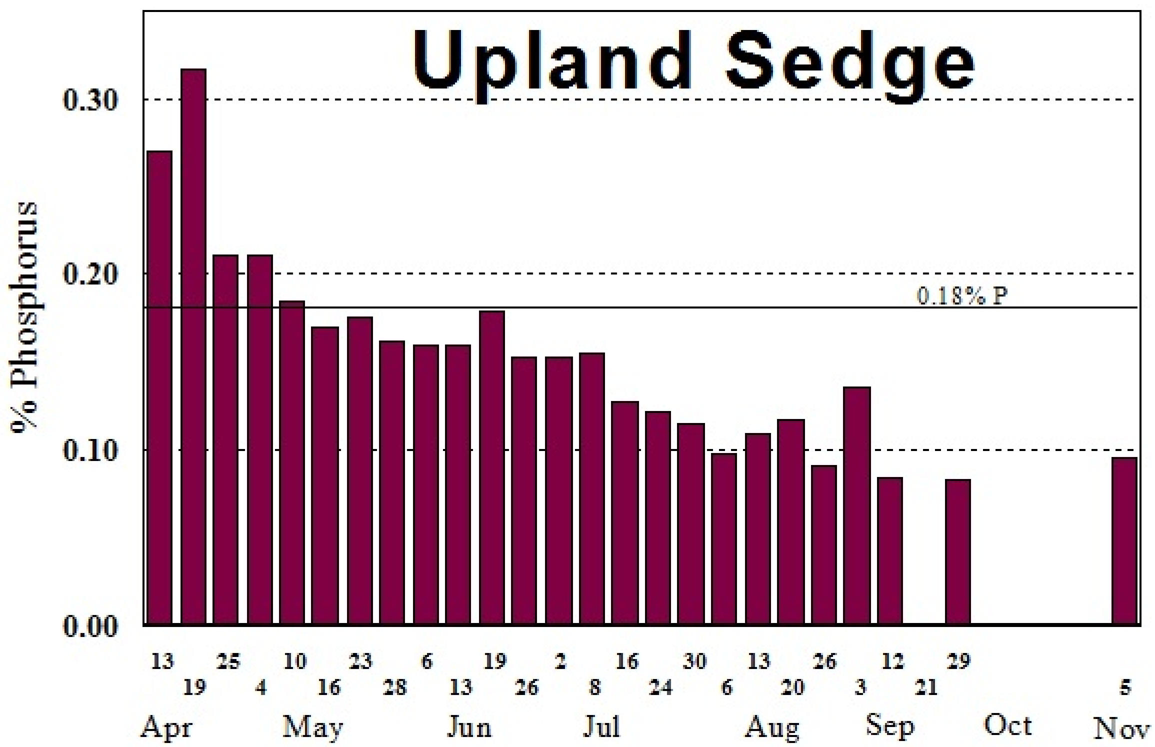

Fig 4. Mean percent phosphorus of ungrazed native range upland sedge in western North Dakota, data from Whitman et al. 1951.

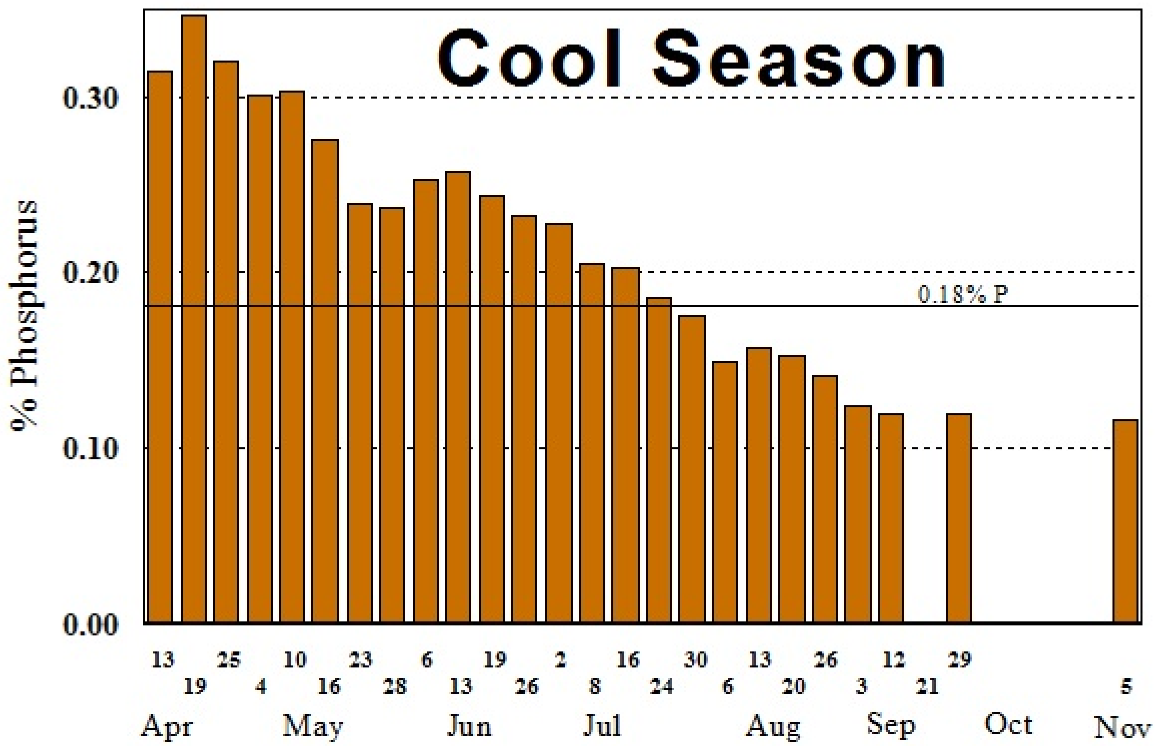

Fig 5. Mean percent phosphorus of ungrazed native range cool season grasses in western North Dakota, data from Whitman et al. 1951.

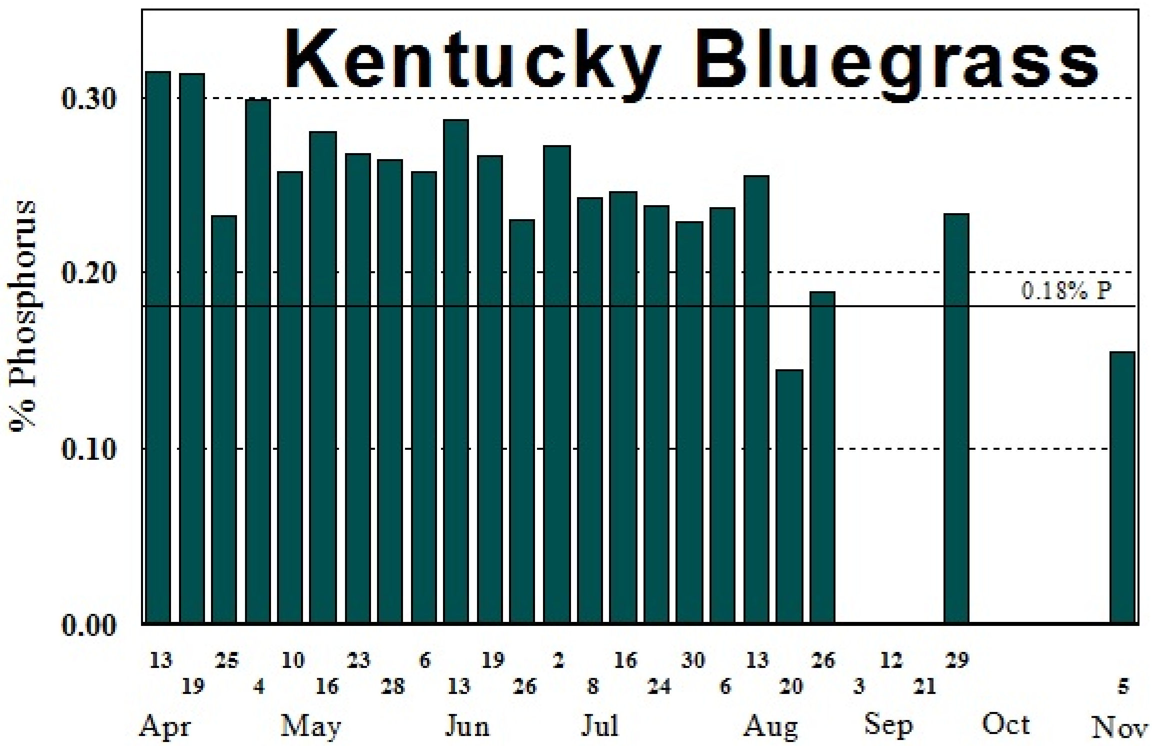

Fig 6. Mean percent phosphorus of grazed Kentucky bluegrass in western North Dakota, data from Whitman et al. 1951.

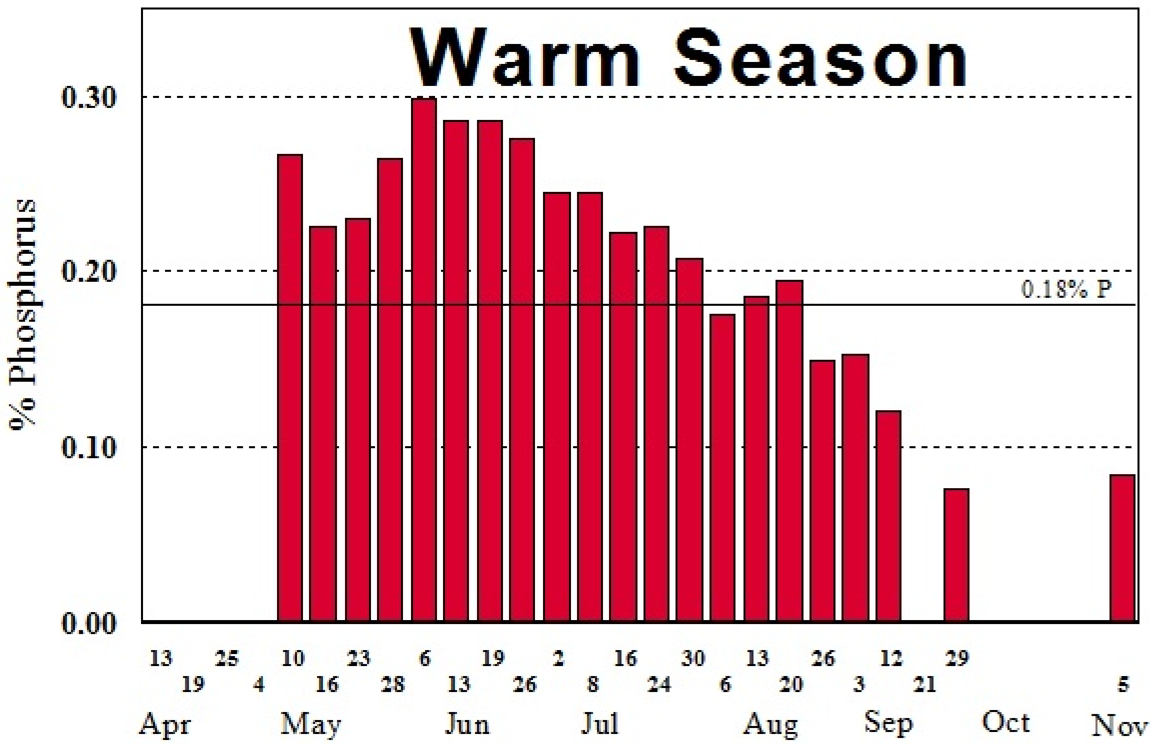

Fig 7. Mean percent phosphorus of ungrazed native range warm season grasses in western North Dakota, data from Whitman et al. 1951.

Discussion

Phosphorus content is high in domesticated cool-season grasses, native range upland sedges, native range cool-season grasses, and native range warm-season grasses during early phenological stages. At this time, these forages provide adequate levels of phosphorus (above 0.18%) for lactating beef cows. As the plants mature and continue to develop, the percentage of phosphorus decreases. Phosphorus levels drop below 0.18% during the mature seed phenological stage. In western North Dakota, ungrazed domesticated cool-season grasses develop mature seeds in late July; ungrazed native range upland sedges, in mid May; ungrazed native range cool-season grasses, in late July; and ungrazed native range warm-season grasses, in late August.

Defoliation of grasses manipulates the mechanisms that regulate vegetative reproduction (Manske 2000), causing changes in plant growth and mineral quality curves. Data to illustrate these changes in mineral quality curves are limited to one example of a domesticated cool-season grass cut for hay in mid June and one example of a grazed native range cool-season grass. The data from hayed smooth bromegrass show that secondary tillers have phosphorus levels above 0.18% until early September. The data from grazed Kentucky bluegrass show that secondary tillers have phosphorus levels above 0.18% through late September. Defoliation by haying extended the period that domesticated cool-season grasses contained phosphorus levels above 0.18% from late July to early September, and grazing extended the period that native range cool-season grasses contained phosphorus levels above 0.18% from late July through late September. Mineral quality curves of forage plants defoliated by haying or grazing are different from mineral quality curves of undefoliated plants.

Lactating beef cows grazing crested wheatgrass or smooth bromegrass spring pastures can obtain adequate phosphorus from the forage during May and June. After mid May, upland sedges do not contain adequate phosphorus levels to meet the requirements of a lactating beef cow. In western North Dakota, lactating beef cows grazing native range seasonlong can obtain adequate phosphorus from cool- and warm-season grasses during June and the early portion of July. In eastern Montana, phosphorus levels of cool- and warm-season grasses are below the requirements of a lactating cow in late June and early July. During late summer, phosphorus levels of ungrazed domesticated cool-season grasses, native range upland sedges, native range cool-season grasses, and native range warm-season grasses are below the levels required by lactating beef cows, and during fall and winter, phosphorus levels of these forages are below the levels required by dry gestating cows. Supplementation of phosphorus is needed after late June on native range pastures grazed seasonlong in eastern Montana, after mid July on native range pastures grazed seasonlong in western North Dakota, and on all pastures grazed late summer, fall, or winter.

Conclusion

This report summarizes the limited published data reporting sequential phosphorus content of domesticated cool-season grasses, native range upland sedges, native range cool-season grasses, and native range warm-season grasses used on the Northern Plains and interprets the relationships between the changes in phosphorus content and the phenological development of ungrazed plants. This report also summarizes the beef cow daily requirements for phosphorus and calcium, which change with cow size, level of milk production, and production period.

The changes in mineral content of ungrazed domesticated cool-season grasses, native range upland sedges, native range cool-season grasses, and native range warm-season grasses follow the phenological stages of the plants. Plants contain the highest levels of phosphorus in the early stages of development. As seed stalks develop, phosphorus content decreases. During the mature seed stage, phosphorus content drops below 0.18%, the level required by lactating cows with average milk production. The mature seed stage occurs in late July for domesticated cool-season grasses, in mid May for native range upland sedges, in late July for native range cool-season grasses, and in late August for native range warm-season grasses. Supplemental phosphorus should be provided to livestock during periods when forages do not contain sufficient levels.

Grazing and haying affect the biological mechanisms that regulate vegetative reproduction in grass plants. These effects are not the same at all phenological growth stages during the growing season. Additional research should be conducted to study the effects defoliation by grazing and haying has on phenological development, vegetative reproduction, and changes in mineral content of forage plants during the growing season.

The mineral requirements for beef cows change during the year with the production periods. The mineral content of perennial forage grasses and sedges changes as the plants develop and mature through phenological stages. At some phenological stages, forage plants have insufficient mineral content to meet nutritional requirements of cattle. During these times, forage diets must be supplemented to meet livestock mineral needs. Biologically effective management strategies efficiently supply combinations of forages and supplements to provide the quantities of minerals livestock require at each production period. Such strategies can be developed through coordination of annual mineral quality curves, which illustrate the changes in forage plant mineral content during the year, and livestock mineral requirement curves, which illustrate beef cow mineral requirements at each production period.

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Mineral Requirements for Beef Cows Grazing Native Rangeland

Report DREC 01-1033

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Introduction

Beef cows grazing native rangeland require seven macrominerals and ten microminerals for normal body functions. Understanding livestock mineral requirements, functions of each mineral, and mineral concentrations that result in deficiencies or toxicities is necessary to maintain beef cows at high levels of production. The quantities of each mineral required vary with cow size, level of milk production, and production period (dry gestation, 3rd trimester, early lactation, and lactation). Animals acquire most of these essential minerals from forages. Forage plant growth can be altered by differential defoliation treatment effects on plant growth processes (Manske 2000). Mineral concentrations in native range herbage are not constant, and the patterns of change during the grazing season differ with management treatment. Supplementation of minerals during periods when concentrations in herbage are below those required by beef cattle is necessary to maintain optimum livestock performance. This report summarizes information on the mineral requirements for beef cows grazing native rangeland of the mixed grass prairie in the Northern Plains.

Beef Cow Macromineral Requirements

The macrominerals required by beef cattle are calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), sodium (Na), chlorine (Cl), and sulfur (S). Phosphorus and calcium make up about 70% to 75% of the mineral matter in beef cattle, including over 90% of the mineral matter in the skeleton. Calcium is the most abundant mineral in the cow's body, with 98% of the calcium in the bones and teeth and the remainder in the extracellular fluids and soft tissue (NRC 1996). About 80% of the phosphorus in the cow's body is in the bones and teeth; the remainder occurs in soft tissue, mostly in organic forms. Phosphorus and calcium function together with magnesium in bone formation, and these minerals are required for normal skeletal development and maintenance (NRC 1996). Phosphorus exists in blood serum both in organic forms, as a constituent of lipids, and in inorganic forms. Phosphorus is a component of phospholipids, which are important in lipid transport and metabolism and in cell-membrane structure and cell growth. As a component of AMP, ADP, ATP, and creatine phosphate, phosphorus functions in energy metabolism, utilization, and transfer. Phosphorus is required for protein synthesis as phosphate, a component of RNA and DNA. Calcium exists in blood serum in both organic and inorganic forms. Slight changes in calcium, potassium, magnesium, and sodium concentrations control muscle contractions and the transmission of nerve impulses. Calcium and sulfur are required for normal blood coagulation (Church and Pond 1975, NRC 1996). Phosphorus, calcium, potassium, and magnesium are constituents of several enzyme systems. Phosphorus, calcium, potassium, magnesium, sodium, chlorine, and sulfur function in regulating fluid balance by maintaining osmotic pressure and the acid-base balance of the entire system. The blood contains more sodium and chlorine than other minerals. Sodium and chlorine are electrolytes and function in maintaining osmotic pressure in the body cells. Chlorine is required to form hydrochloric acid in gastric juice (Church and Pond 1975, NRC 1996). Phosphorus and sulfur are required by ruminal microorganisms for their growth and cellular metabolism (NRC 1996).

Relative levels of calcium and phosphorus are important. Dietary calcium to phosphorus ratios between 1:1 and 7:1 result in similar normal animal performance. Dietary phosphorus absorption (NRC 1996) occurs rapidly in the small intestine by passive diffusion across the intestine cell membrane against a concentration gradient in the presence of calcium. Cattle are not known to have an active transport system for phosphorus. About 68% of dietary phosphorus is absorbed. Dietary calcium absorption (NRC 1996) occurs in the first two sections of the small intestine both by passive diffusion and by active transport with a vitamin D-dependent protein carrier. About 50% of dietary calcium is absorbed. Calcium is maintained at a relatively constant concentration in the blood plasma by an elaborate control system that involves calcium deposition in and resorption from the bones, variations in reabsorption rate in the kidneys, and variations in the levels of absorption in the intestines. During periods when blood phosphorus or calcium concentrations are low, the kidney tubules can reabsorb an increased amount of the deficient minerals and the body can thereby conserve them. The skeleton of mature animals provides a large reserve of phosphorus and calcium that can be drawn on during periods of inadequate phosphorus or calcium intake. Skeletal reserves can subsequently be replenished during periods when phosphorus and calcium intake are high relative to requirements (Church and Pond 1975, NRC 1996).

The concentrations of calcium and phosphorus required by beef cows during lactation are 0.26%-0.27% and 0.18% diet dry matter, respectively (NRC 1996). A deficiency of either calcium or phosphorus can adversely affect the skeletal system. In young growing animals inadequate calcium or phosphorus can cause rickets, which develops when the blood becomes low or deficient in calcium, phosphorus, or both, and normal deposition of calcium and phosphorus in growing bones cannot occur. The bones become soft and weak. In severe cases, bones can become deformed, and with increased severity of the condition, bones can break or fracture readily. A deficiency of calcium or phosphorus in older mature animals can cause osteoporosis, which develops when large amounts of calcium and phosphorus are withdrawn from the bones to meet other systems' needs for these minerals. During prolonged periods of calcium and phosphorus deficiency, the bones become porous and weak, and in severe cases, they can break easily (Church and Pond 1975, NRC 1996).

Pregnancy and lactation produce high demands for calcium and phosphorus. Production of one pound of milk requires 0.020 ounces of calcium and 0.015 ounces of phosphorus (NRC 1996). Most cases of calcium deficiency occur early in lactation, during the period when milk production causes large drains on body calcium reserves. Calcium deficiency during lactation causes milk fever. Severe calcium deficiency produces hypocalcemia (low blood calcium) and interferes with the role calcium plays in normal muscle contractions, including those of the heart, and in normal transmission of nerve impulses; this condition results in tetany, convulsions, and, if not treated early, possibly death (Church and Pond 1975, NRC 1996).

Even when cattle diets are only slightly deficient in calcium or phosphorus, animal performance may suffer. Calcium deficiency causes reduced feed intake, loss of body weight, and failure of cows to come into heat regularly. Calcium deficiency also causes a reduction in the quantity of milk produced: the quality of the milk is not changed, and the mineral content of the milk remains relatively constant; however, reduction in the quantity of milk produced by a cow results in lower calf daily gain (Manske 1998). Phosphorus deficiency in beef cattle results in reduced growth and feed efficiency, decreased feed intake, impaired reproduction, reduced milk production, and weak, fragile bones. Cattle grazing forages low in phosphorus experience lower fertility and lighter calf weaning weights (NRC 1996).

Deficiencies of other macrominerals are also detrimental to beef cattle. Adequate quantities of supplemental minerals should be provided to livestock during periods when forages do not contain sufficient levels.

The concentration of magnesium required by beef cows during lactation is 0.17%-0.20% diet dry matter (NRC 1996). Magnesium deficiency causes grass tetany (hypomagnesemia or low blood magnesium), occurring most commonly in lactating cows grazing lush spring pastures high in protein and potassium. Magnesium deficiency in beef cattle results in nervousness, reduced feed intake, muscular twitching, and staggering gait. In advanced stages of magnesium deficiency, convulsions occur, the animal cannot stand, and death soon follows (Church and Pond 1975, NRC 1996). The maximum tolerable concentration of magnesium has been estimated at 0.40% diet dry matter (NRC 1996).

Intake of proper amounts of potassium, the third most abundant mineral in beef cattle, is important. The concentration of potassium required by beef cows during lactation is 0.70% diet dry matter (NRC 1996). Deficiency of potassium causes decreased feed intake and reduced weight gain. Cattle consuming diets with more than 3% potassium while grazing lush spring pastures experience reduced magnesium absorption and the related magnesium deficiency symptoms (Church and Pond 1975, NRC 1996). The maximum tolerable concentration of potassium has been set at 3.0% diet dry matter because of potassium's antagonistic action to magnesium absorption. High levels of potassium are not known to cause any other adverse effects (NRC 1996).

The concentration of sulfur required by beef cows is 0.15% diet dry matter (NRC 1996). Deficiency of sulfur, a component of some amino acids and some vitamins, causes reduced feed intake and decreased microbial digestion and protein synthesis. Severe sulfur deficiency results in diminished feed intake, major loss of body weight, weak and emaciated condition, excessive salivation, and death (Church and Pond 1975, NRC 1996). The maximum tolerable concentration of dietary sulfur has been estimated at 0.40% diet dry matter, but sulfur toxicity is not a practical problem because absorption of inorganic sulfur is low (Church and Pond 1975, NRC 1996).

Grazing cattle require supplemental salt (sodium and chlorine) because forages do not contain adequate amounts. The concentration of sodium required by beef cows during lactation is 0.10% diet dry matter (NRC 1996). The concentration of chlorine required by beef cows is not well defined, but the amounts supplied by dietary salt appear to be adequate (Church and Pond 1975, NRC 1996). Severe salt deficiency causes reduced feed intake, rapid loss of body weight, and reduced milk production. In some arid and semi-arid regions of the country, a portion of the required amount of salt is provided by the alkaline water. Supplemental salt can be provided free-choice in loose or block forms. Cattle grazing pastures consume more salt during spring and early summer when the forage is more succulent than later in the season when the forage is drier. High levels of dietary salt reduce feed intake. Cattle occasionally consume greater amounts of salt than required but will generally not consume excessive amounts except after experiencing periods without sufficient quantities (Church and Pond 1975, NRC 1996). The maximum tolerable concentration of dietary salt is estimated at 9.0% diet dry matter. Salt in drinking water is much more toxic; the maximum tolerable concentration of sodium in water is 0.70% (NRC 1996).

Toxicity of magnesium, potassium, sodium, or chlorine is unlikely because amounts in excess of those required are readily excreted by the kidneys. Toxicity problems can develop, however, when drinking water intake is restricted, drinking water contains more than 7,000 mg Na/kg (ppm), or the kidneys malfunction (Church and Pond 1975, NRC 1996).

Beef Cow Micromineral Requirements

The microminerals required by beef cattle are chromium (Cr), cobalt (Co), copper (Cu), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se), and zinc (Zn). Microminerals are primarily components of enzymes and organic compounds or are elements for activation of enzyme systems. The functions of microminerals are determined by the function of the compounds of which the microminerals are a part.

Chromium (Cr) is a cofactor in the action of insulin and is important in glucose utilization and the synthesis of cholesterol and fatty acids. Beef cattle may need supplemental chromium in some situations, but the current data are not sufficient to allow accurate determination of requirements. The maximum tolerable concentration in diet dry matter is estimated to be 1,000 mg Cr/kg (ppm) (Church and Pond 1975, NRC 1996).

Cobalt (Co) functions as a component of vitamin B_{12}. Two vitamin B_{12}-dependent enzymes are known to occur in cattle. Cattle are not dependent on a dietary source of vitamin B_{12} because ruminal microorganisms can synthesize B_{12} from dietary cobalt. The recommended concentration of cobalt in beef cattle diets is approximately 0.10 mg Co/kg (ppm) diet dry matter. Early signs of cobalt deficiency are decreased appetite, reduced milk production, and either failure to grow or moderate weight loss. With severe deficiency, animals exhibit unthriftiness, rapid weight loss, fatty degeneration of the liver, and pale skin and mucous membrane as a result of anemia. Cobalt concentrations in forages are dependent on levels of cobalt in the soil. Availability of cobalt in soil is highly dependent on soil pH, and some soils are deficient in cobalt. Legumes are generally higher in cobalt than grasses. Cobalt can be supplemented in mineral mixtures as cobalt sulfate and cobalt carbonate. Cobalt toxicity is not likely to occur because cattle can tolerate approximately 100 times the dietary requirements. Signs of cobalt toxicity are decreased feed intake, reduced body weight gain, anemia, emaciation, hyperchromia, debility, and increased liver cobalt (Church and Pond 1975, NRC 1996).

Copper (Cu) functions as an essential component of a number of enzymes and is required for normal red blood cell formation, normal bone formation, normal elastin formation in the aorta and cardiovascular system, normal myelination of the brain cells and spinal cord, and normal pigmentation of hair. Copper is important to the functions of the immune system. The recommended concentration of copper in beef cattle diets is 10 mg Cu/kg (ppm) diet dry matter. Copper requirements are affected by dietary molybdenum (Mo) and sulfur (S). Antagonistic action of molybdenum occurs at levels above 2 mg Mo/kg diet, and antagonistic action of sulfur occurs at levels above 0.25% sulfur. Molybdenum and sulfur interact in the rumen to form thiomolybdates, compounds that react with copper to form insoluble complexes that are poorly absorbed. Thiomolybdates also reduce metabolism of copper post absorption. Sulfur can react with copper to form copper sulfide, which also reduces absorption of copper. High concentrations of iron and zinc also reduce copper status. Copper deficiency is a widespread problem in many areas of North America. Signs of copper deficiency are anemia; reduced growth rate; changes in the growth, physical appearance, and pigmentation of hair; cardiac failure; fragile bones that easily fracture; diarrhea; and low reproduction levels resulting from delayed or depressed estrus. Copper concentrations in forages are highly variable, depending on plant species and availability of copper in the soil. Legumes are usually higher in copper than grasses. Copper can be supplemented in mineral mixtures in the sulfate or carbonate forms. Feed-grade copper oxide is largely biologically unavailable but has been used as a source of slow-release copper because it remains in the digestive tract for months. The maximum tolerable concentration of copper for cattle has been estimated at 100 mg Cu/kg (ppm) diet dry matter, but this amount is dependent on the concentrations of molybdenum, sulfur, and iron in the diet. The liver can accumulate large amounts of copper before signs of toxicity are observed (Church and Pond 1975, NRC 1996).

Iodine (I) is an essential component of thyroid hormones, which regulate the rate of energy metabolism. Iodine requirements of beef cattle have not been determined with certainty, but 0.5 mg I/kg (ppm) diet dry matter should be adequate. Signs of iodine deficiency are enlargement of the thyroid, calves born weak or dead, and reduced reproduction that results from irregular cycling, low conception rate, and retained placenta in cows and from decreased libido and semen quality in bulls. Iodine concentrations in forage depend on the availability of iodine in the soil, and many of the soils in central North America are deficient in iodine. Iodine can be supplemented in iodized salt or in mineral mixtures as calcium iodate or an organic form of iodine. Cattle tolerate maximum iodine levels of 50 mg I/kg (ppm) diet dry matter. Signs of iodine toxicity are coughing, excessive nasal discharge, reduced feed intake, and reduced weight gain (Church and Pond 1975, NRC 1996).

Iron (Fe) is a component of hemoglobin in red blood cells, myoglobin in muscles, and other proteins involved in transport of oxygen to tissues or utilization of oxygen. Iron is also a constituent of several enzymes associated with the mechanisms of electron transport, and iron is a component of several metalloenzymes. Iron is important to the functions of the immune system. The iron requirement of beef cattle is approximately 50 mg Fe/kg (ppm) diet dry matter. Iron requirements of older cattle are not well defined but are probably lower than those of young calves, in which blood volume is increasing. Iron deficiency is unlikely in cattle because adequate levels of iron are available from numerous sources. Iron concentration in forages is highly variable, but most forages are high in iron, containing from 70 to 500 mg Fe/kg. Water and ingested soil can be significant sources of iron for beef cattle. When iron needs to be supplemented, it can be added to mineral mixtures as ferrous sulfate or ferrous carbonate. Ferric oxide is basically biologically unavailable. Dietary iron concentrations as low as 250 to 500 mg/kg have caused copper depletion in cattle. In areas where drinking water or forages are high in iron, dietary copper may need to be increased to prevent copper deficiency. The maximum tolerable concentration of iron for cattle has been estimated at 1,000 mg Fe/kg (ppm) diet dry matter. Signs of iron toxicity are diarrhea, metabolic acidosis, hypothermia, reduced feed intake, and reduced weight gain (Church and Pond 1975, NRC 1996).

Manganese (Mn) is a component of a few metalloenzymes that function in carbohydrate metabolism and lipid metabolism. Manganese also stimulates and activates a number of other enzymes. Manganese is important in cattle reproduction because it is required for normal estrus and ovulation in cows and for normal libido and spermatogenesis in bulls. Manganese is essential for normal bone formation and growth. Manganese is important to the functions of the immune system. The recommended concentration of manganese for breeding cattle is 40 mg Mn/kg (ppm) diet dry matter. Signs of manganese deficiency are skeletal abnormalities in young animals and, in older animals, low reproductive performance resulting from depressed or irregular estrus, low conception rate, abortion, stillbirths, and low birth weights. Manganese concentrations in forage are generally adequate but are variable, depending on the availability of manganese because of soil pH and soil drainage. Manganese can be supplemented in mineral mixtures as manganese sulfate, manganese oxide, or various organic forms. Manganese oxide is less readily available biologically than manganese sulfate. Maximum tolerable concentration of manganese is set at 1,000 mg Mn/kg (ppm) diet dry matter (Church and Pond 1975, NRC 1996).

Molybdenum (Mo) is a component of a metalloenzyme and other enzymes. The requirements for molybdenum have not been established. No evidence that molybdenum deficiency occurs in cattle under practical conditions has been found. Metabolism of molybdenum is affected by copper and sulfur, which are antagonistic. Sulfide and molybdate interact in the rumen to form thiomolybdates, compounds that cause decreased absorption and reduced post absorption metabolism of molybdenum and increased urinary excretion of molybdate. Molybdenum concentrations in forages are generally adequate but vary greatly, depending on soil type and soil pH. Neutral or alkaline soils coupled with high moisture and organic matter favor molybdenum uptake by forages. High concentrations of molybdenum can cause toxicity. The maximum tolerable concentration of molybdenum for cattle has been estimated to be 10 mg Mo/kg (ppm) diet dry matter. Signs of molybdenum toxicity are diarrhea, anorexia, loss of weight, stiffness, and changes in hair color. Supplementation of large quantities of copper will overcome molybdenosis (Church and Pond 1975, NRC 1996).

Nickel (Ni) is an essential component of urease in rumen bacteria. Nickel deficiency in animals can be produced experimentally, but the function of nickel in mammalian metabolism is unknown. Research data are not sufficient to determine nickel requirements of beef cattle. Nickel can be supplemented in mineral mixtures as nickel chloride. The maximum tolerable concentration of nickel is estimated to be 50 mg Ni/kg (ppm) diet dry matter (Church and Pond 1975, NRC 1996).

Selenium (Se) is part of at least two metalloenzymes, and its functions are interrelated with vitamin E. Failure of functions involving selenium can result in nutritional muscular dystrophy. Selenium is also a component of an enzyme that has a role in maintaining integrity of cellular membranes. Selenium is required for normal pancreatic morphology and is involved in normal absorption of lipids and tocophenols. Selenium is important to the functions of the immune system. The factors that affect selenium requirements are not well defined, but beef cattle requirements can be met by 0.1-0.2 mg Se/kg (ppm) diet dry matter. Selenium deficiency results in degeneration of muscle tissue (white muscle disease) in young animals. Signs of deficiency are stiffness, lameness, and possible cardiac failure. Signs of selenium deficiency in older animals are unthriftiness, weight loss, diarrhea, anemia, and reduced immune responses. Selenium concentrations in forages vary greatly and depend primarily on the selenium content of the soil. Soils developed from Cretaceous or Eocene shales contain high levels of selenium. Some species of milkvetch (*Astragalus spp.*) absorb selenium more readily than other native plants. Cattle grazing plants high in selenium can consume toxic amounts. The maximum tolerable concentration of selenium has been estimated to be 2 mg Se/kg (ppm) diet dry matter. Signs of selenium toxicity are lameness, anorexia, emaciation, loss of vitality, liver cirrhosis, inflamed kidneys, loss of hair from the tail, and cracked, deformed, and elongated hoofs. Signs of acute selenium toxicity are labored breathing, diarrhea, loss of coordination, abnormal posture, and death from respiratory failure (Church and Pond 1975, NRC 1996).

Zinc (Zn) is a constituent of many enzymes and many metalloenzyme systems, and zinc is effective in activation of a large number of other enzymes. Zinc is required for normal protein synthesis and metabolism. A component of insulin, zinc functions in carbohydrate metabolism. Zinc is important for normal development and functioning of the immune system. The recommended requirement of zinc in beef cattle diets is 30 mg Zn/kg (ppm) diet dry matter, although zinc requirements of beef cattle fed forage-based diets and requirements for reproduction and milk production are not well defined. Dietary factors that affect zinc requirements in ruminants are not understood. Subclinical deficiencies of zinc cause decreased weight gain, reduced milk production, and reduced reproductive performance. Signs of severe zinc deficiency are listlessness, excessive salivation, reduced testicular growth, swollen feet, loss of hair, failure of wounds to heal, reduced growth, reduced feed intake, reduced feed efficiency, and lesions with horny growths on legs, neck, and head and around the nostrils. The zinc content of forages is affected by a number of factors, including plant species, plant maturity, and soil zinc. Legumes are generally higher in zinc than grasses. A relatively large portion of the zinc in forages is associated with the plant cell wall, but it is not known whether zinc's association with fiber reduces absorption. Zinc can be supplemented in mineral mixtures with feed-grade sources of bioavailable zinc in the form of zinc oxide, zinc sulfate, zinc methionine, and zinc proteinate. The maximum tolerable concentration of zinc is 500 mg Zn/kg (ppm) diet dry matter, a much greater amount than required. Signs of zinc toxicity are reduced feed intake, reduced feed efficiency, and decreased weight gain (Church and Pond 1975, NRC 1996).

Daily Mineral Requirements

Understanding mineral requirements for beef cows is necessary for effective nutritional management of livestock grazing native rangeland. Beef cow daily nutritional requirements (NRC 1996) change with cow size, level of milk production, and production period. Requirements for some macrominerals change with cow production period. Fetal development requires increased amounts of dietary calcium, phosphorus, and magnesium. Lactation requires increased amounts of dietary calcium, phosphorus, magnesium, potassium, and sodium. Milk production increases the demand for iodine and zinc, but dietary requirements do not increase because the demands are likely met by increases in absorption (NRC 1996). Daily macromineral and micromineral requirements for 1000-, 1200-, and 1400-pound cows with average milk production are shown in tables 1-6. Lactating cows grazing native rangeland require diet dry matter containing 0.26-0.27% calcium, 0.18% phosphorus, 0.17-0.20% magnesium, 0.70% potassium, 0.10% sodium, and 0.15% sulfur. Lactating cows require diet dry matter containing the following micromineral concentrations: 0.10 ppm cobalt, 10.0 ppm copper, 0.50 ppm iodine, 50.0 ppm iron, 40.0 ppm manganese, 0.10 ppm selenium, and 30.0 ppm zinc. The amounts of chlorine, chromium, molybdenum, and nickel lactating cows require from diet dry matter are not known.

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Table 1. Daily macromineral requirements in pounds per day and percent diet dry matter for 1000-pound beef cows with average milk production during four production periods (data from NRC 1996).

		Production Periods			
Macrominerals		Dry Gestation	3rd Trimester	Early Lactation	Lactation
Dry matter	lbs	21	21	24	24
Calcium	%	0.15	0.24	0.30	0.27
	lbs/day	0.03	0.05	0.07	0.06
Phosphorus	%	0.11	0.15	0.20	0.18
	lbs/day	0.02	0.03	0.05	0.04
Magnesium	%	0.12		0.17-0.20	
	lbs/day	0.03		0.04-0.05	
Potassium	%	0.60		0.70	
	lbs/day	0.13		0.17	
Sodium	%	0.06-0.08		0.10	
	lbs/day	0.01-0.02		0.02	
Chlorine	%	requirements are not well defined but a deficiency does not seem likely in practical conditions			
	lbs/day				
Sulfur	%	0.15		0.15	
	lbs/day	0.03		0.04	

Table 2. Daily macromineral requirements in pounds per day and percent diet dry matter for 1200-pound beef cows with average milk production during four production periods (data from NRC 1996).

		Production Periods			
Macrominerals		Dry Gestation	3rd Trimester	Early Lactation	Lactation
Dry matter	lbs	24	24	27	27
Calcium	%	0.15	0.25	0.29	0.26
	lbs/day	0.04	0.06	0.08	0.07
Phosphorus	%	0.12	0.16	0.19	0.18
	lbs/day	0.03	0.04	0.05	0.05
Magnesium	%	0.12	0.17-0.20		
	lbs/day	0.03	0.045-0.05		
Potassium	%	0.60	0.70		
	lbs/day	0.14	0.19		
Sodium	%	0.06-0.08	0.10		
	lbs/day	0.01-0.02	0.03		
Chlorine	%	requirements are not well defined but a deficiency does not seem likely in practical conditions			
	lbs/day				
Sulfur	%	0.15	0.15		
	lbs/day	0.04	0.04		

Table 3. Daily macromineral requirements in pounds per day and percent diet dry matter for 1400-pound beef cows with average milk production during four production periods (data from NRC 1996).

		Production Periods			
Macrominerals		Dry Gestation	3rd Trimester	Early Lactation	Lactation
Dry matter	lbs	27	27	30	30
Calcium	%	0.16	0.26	0.28	0.26
	lbs/day	0.04	0.07	0.08	0.08
Phosphorus	%	0.12	0.17	0.19	0.18
	lbs/day	0.03	0.05	0.06	0.05
Magnesium	%	0.12	0.17-0.20		
	lbs/day	0.03	0.05-0.06		
Potassium	%	0.60	0.70		
	lbs/day	0.16	0.21		
Sodium	%	0.06-0.08	0.10		
	lbs/day	0.016-0.022	0.03		
Chlorine	%	requirements are not well defined but a deficiency does not seem likely in practical conditions			
	lbs/day				
Sulfur	%	0.15	0.15		
	lbs/day	0.04	0.05		

Table 4. Daily micromineral requirements in grams per day and mg/kg (ppm) of diet dry matter for 1000-pound beef cows with average milk production during four production periods (data from NRC 1996).

		Production Periods			
Microminerals		Dry Gestation	3rd Trimester	Early Lactation	Lactation
Dry matter	lbs	21	21	24	24
Chromium	mg/kg (ppm)	current information is not sufficient to determine requirements			
	g/day				
Cobalt	mg/kg (ppm)	0.10	0.10	0.10	0.10
	g/day	0.0010	0.0010	0.0011	0.0011
Copper	mg/kg (ppm)	10.0	10.0	10.0	10.0
	g/day	0.0953	0.0953	0.1089	0.1089
Iodine	mg/kg (ppm)	0.50	0.50	0.50	0.50
	g/day	0.0048	0.0048	0.0054	0.0054
Iron	mg/kg (ppm)	50.0	50.0	50.0	50.0
	g/day	0.4763	0.4763	0.5443	0.5443
Manganese	mg/kg (ppm)	40.0	40.0	40.0	40.0
	g/day	0.3810	0.3810	0.4355	0.4355
Molybdenum	mg/kg (ppm)	requirements are not established but there is no evidence that deficiency occurs			
	g/day				
Nickel	mg/kg (ppm)	research data are not sufficient to determine requirements			
	g/day				
Selenium	mg/kg (ppm)	0.10	0.10	0.10	0.10
	g/day	0.0010	0.0010	0.0011	0.0011
Zinc	mg/kg (ppm)	30.0	30.0	30.0	30.0
	g/day	0.2858	0.2858	0.3266	0.3266

Table 5. Daily micromineral requirements in grams per day and mg/kg (ppm) of diet dry matter for 1200-pound beef cows with average milk production during four production periods (data from NRC 1996).

		Production Periods			
Microminerals		Dry Gestation	3rd Trimester	Early Lactation	Lactation
Dry matter	lbs	24	24	27	27
Chromium	mg/kg (ppm)	current information is not sufficient to determine requirements			
	g/day				
Cobalt	mg/kg (ppm)	0.10	0.10	0.10	0.10
	g/day	0.0011	0.0011	0.0012	0.0012
Copper	mg/kg (ppm)	10.0	10.0	10.0	10.0
	g/day	0.1089	0.1089	0.1225	0.1225
Iodine	mg/kg (ppm)	0.50	0.50	0.50	0.50
	g/day	0.0054	0.0054	0.0061	0.0061
Iron	mg/kg (ppm)	50.0	50.0	50.0	50.0
	g/day	0.5443	0.5443	0.6124	0.6124
Manganese	mg/kg (ppm)	40.0	40.0	40.0	40.0
	g/day	0.4355	0.4355	0.4899	0.4899
Molybdenum	mg/kg (ppm)	requirements are not established but there is no evidence that deficiency occurs			
	g/day				
Nickel	mg/kg (ppm)	research data are not sufficient to determine requirements			
	g/day				
Selenium	mg/kg (ppm)	0.10	0.10	0.10	0.10
	g/day	0.0011	0.0011	0.0012	0.0012
Zinc	mg/kg (ppm)	30.0	30.0	30.0	30.0
	g/day	0.3266	0.3266	0.3674	0.3674

Table 6. Daily micromineral requirements in grams per day and mg/kg (ppm) of diet dry matter for 1400-pound beef cows with average milk production during four production periods (data from NRC 1996).

		Production Periods			
Microminerals		Dry Gestation	3rd Trimester	Early Lactation	Lactation
Dry matter	lbs	27	27	30	30
Chromium	mg/kg (ppm)	current information is not sufficient to determine requirements			
	g/day				
Cobalt	mg/kg (ppm)	0.10	0.10	0.10	0.10
	g/day	0.0012	0.0012	0.0014	0.0014
Copper	mg/kg (ppm)	10.0	10.0	10.0	10.0
	g/day	0.1225	0.1225	0.1361	0.1361
Iodine	mg/kg (ppm)	0.50	0.50	0.50	0.50
	g/day	0.0061	0.0061	0.0068	0.0068
Iron	mg/kg (ppm)	50.0	50.0	50.0	50.0
	g/day	0.6124	0.6124	0.6804	0.6804
Manganese	mg/kg (ppm)	40.0	40.0	40.0	40.0
	g/day	0.4899	0.4899	0.5443	0.5443
Molybdenum	mg/kg (ppm)	requirements are not established but there is no evidence that deficiency occurs			
	g/day				
Nickel	mg/kg (ppm)	research data are not sufficient to determine requirements			
	g/day				
Selenium	mg/kg (ppm)	0.10	0.10	0.10	0.10
	g/day	0.0012	0.0012	0.0014	0.0014
Zinc	mg/kg (ppm)	30.0	30.0	30.0	30.0
	g/day	0.3674	0.3674	0.4082	0.4082

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Increasing Value Captured From the Land Natural Resources

Capturing Greater Wealth from the Land Natural Resources

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Animal agriculture of the Northern Plains has been hampered by high production costs and low profit margins. Efforts of the beef production industry to correct these problems has been to improve animal performance. The genetic make-up of the North American beef herd has been transformed over the past forty to fifty years, and we now have high-performance, fast-growing meat animals. However, the anticipated improved profit margins from this new-style of livestock have not materialized.

Forage management systems were not improved simultaneously with beef animal performance. Traditional livestock production paradigms assume the source of income to be from the sale of animal weight and traditional pasture and harvested forage management practices are extremely inefficient at capturing the forage plant nutrients produced on the land. A problematic mismatch of forage nutrients required and forage nutrients available exists between modern, high-performance cattle and traditional low-performance forage management practices. Modern cattle on traditional forage management practices developed for old-style cattle have reduced production efficiencies that depress cow and calf weight performance below genetic potentials causing reduced value received at market and reduced profits.

The basic components of the traditional pasture and harvested forage management concepts have not changed since they developed during the early stages of the beef industry. Forage resources continue to be managed from the perspective of their use as dry matter livestock feed. 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.

Forage dry matter does not have a real economic value because it is not incorporated into the beef weight produced. The dry matter is simply the carrier of the nutrients it contains. All of the dry matter ingested by livestock is deposited back on the land. The nutrients, mainly crude protein and energy (TDN), are the valuable products produced by forage plants on the land. The renewable forage nutrients are the primary unit of production in a beef operation, and forage nutrients are the authentic source of new wealth from agricultural use of grazingland and hayland resources of the Northern Plains.

Management of renewable land natural resources should not be directed towards the use of the land but be focused on meeting the requirements of all living and nonliving components of the ecosystem for the purpose of improving ecosystem processes and maintaining resource production at sustainable levels. The quantity of new wealth generated from renewable land natural resources is proportional to the biological effectiveness of the pasture and harvested forage management strategies. Biologically effective pasture and harvested forage management strategies perform three essential functions that increase forage nutrient production, improve nutrient capture efficiency, and enhance nutrient conversion effectiveness.

Biologically effective forage management strategies increase forage nutrient production per acre by coordinating defoliation periods with plant growth stages so that the biological requirements of the plants and soil organisms are met. Coordination of partial defoliation promotes vegetative reproduction by secondary tiller development, stimulates beneficial activity of rhizosphere organisms, and facilitates ecosystem biogeochemical processes.

Biologically effective forage management strategies improve nutrient capture efficiency by using various forage types during the periods in which the amount of nutrient weight captured per acre is a high proportion of the nutrients produced. The plant growth stage for harvest by grazing or haying is that at which the herbage production curve and the nutrient quality curve for a specific forage type cross. This period occurs at the flower (anthesis) stage for perennial and annual grasses.

Biologically effective forage management strategies enhance nutrient conversion effectiveness by providing adequate nutrients throughout the 12 month beef cow production cycle. High-performance livestock convert nutrients to animal weight at greater efficiency when their nutritional demands are met each day of each production period. Periods with nutrient deficiency limit livestock production. The forage nutrient supply can match the 12-month livestock nutrient demand by selection of appropriate combinations of pasture and harvested forage types and timing livestock use of the selected forages so that the herbage production curves and nutrient quality curves of plants match the dietary quality and quantity requirement curves of livestock during each beef cow production period.

Effectively meeting the biological requirements of plants and soil organisms occurs when the defoliation resistance mechanisms of grass plants and the biogeochemical processes of ecosystems are activated by partial defoliation during phenological growth between the three and a half new leaf stage and the flower (anthesis) stage. These mechanisms help grass tillers withstand and recover from grazing by triggering compensatory physiological processes that increase growth rates, increase photosynthetic capacity, and increase allocation of carbon and nitrogen; by stimulating vegetative reproduction of secondary tillers from axillary buds; and by stimulating rhizosphere organism activity and increasing conversion of inorganic nitrogen from soil organic nitrogen. Activation of these mechanisms results in increased herbage biomass production, increased plant density, increased available forage nutrients, increased soil aggregation, improved soil quality, increased soil water holding capacity, increased resistance to drought conditions, improved wildlife habitat, and improved grassland ecosystem health status.

Improvement in performance of forage management systems requires paradigm shifts that consider the land natural resources to be the source of new wealth generated from livestock agriculture with the renewable forage nutrients as the primary unit of production and the produced animal weight as the commodity sold at market. Biologically effective 12-month pasture and harvested forage management strategies efficiently meet the biological requirements of plants and soil organisms, improve the characteristics of soil, increase forage nutrient production, efficiently capture forage produced nutrients, and efficiently convert nutrients into animal weight commodities. These improvements permit renewable natural resource ecosystems to perform at biologically sustainable levels and modern high-performance beef cattle to perform at genetic potentials. Results of these improvements reduce costs per pound of crude protein, reduce costs per pound of calf weight gain, reduce costs per day of forage feed, and increase returns after feed costs per acre. These changes in costs and returns effectively increase profit margins for land and cattle enterprises and improve the regional livestock agricultural economy.

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The Modern Range Cow has Greater Nutrient Demand than the Old Style Range Cow

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The type of range cow roaming the grasslands of the Northern Plains has shifted from the old style, low performance cow to a fast growing, high performance cow with greater nutrient demand. The pasture and harvested forage management practices have been adjusted for the larger size cow, however, old style traditional forage management technologies with intentional periods of low quality forage continue to be used that minimize the modern cows advantage of greater production capabilities. Modern range cows have high production drain and do not produce at high performance levels when available forage nutrients are deficient resulting in calf weaning weights below their potential. Modern cows do not have the fat reserves that the old style cows produced and could draw on when forage quality was insufficient.

The greater size of modern range cows increases their nutrient demand throughout the production year, and their higher production levels increase the demand further. The increase in required nutrients of modern range cows is not simply proportional to the cows greater size.

A high performance 1200 lb range cow that has average milk production at 20 lb/d, and is 20% larger than an old style 1000 lb range cow that had milk production at 12 to 6 lb/d, requires 24% more energy and 33% more crude protein per year than the old style cow. The modern range cow with average milk requires 27% more energy and 41% more crude protein per day during the lactation production periods than the old style range cow (table 1).

A high performance 1200 lb range cow that has high milk production at 30 lb/d, and is 20% larger than an old style 1000 lb range cow that had milk production at 12 to 6 lb/d, requires 36% more energy and 55% more crude protein per year than the old style cow. The modern range cow with high milk requires 43% more energy and 72% more crude protein per day during the lactation production periods than the old style range cow (table 2).

The major increases in nutrient requirements occur during the lactation production periods. The modern range cow with average milk production at 20 lb/d requires 45% more crude protein during the early lactation period and requires 41% more crude protein during the spring, summer, and fall lactation periods than the old style range cow (table 1). The modern range cow with high milk production at 30 lb/d requires 79% more crude protein during the early lactation period and requires 72% more crude protein during the spring, summer, and fall lactation periods than the old style range cow (table 2).

The beef cow herd at Dickinson Research Extension Center was evaluated for the amount of weaned calf weight as a percentage of cow weight at weaning in 2007 (Ringwall 2008). These 5 to 9 year old modern cows had advanced genetic potential for fast growth, high performance, and high milk production at near 30 lb/d. The steer and heifer calves were about 7.5 months old (228 days) at weaning in mid November. The cows were separated into five weight categories from 1200 lbs to 1600 lbs with 100 lb increments (table 3).

Modern high performance cows should be expected to wean calf weight at greater than half the cows weight. However, the calf weight weaned by these very good beef cows was less than half the cows weight. As the cow weight increased, the percent calf weight weaned decreased from 49.7% for the 1200 lb cows to 33.7% for the 1600 cows (table 3). The cow crude protein requirements increase with increases in cow weight. The crude protein content of the available pasture forage managed by traditional old style practices decreases from early August to the end of the growing season in mid October. The crude protein content of less than 5% after mid October is tied to plant structural material and unavailable. The degree of deficiency in forage crude protein after early August increases with increases in cow weight and causes incrementally greater decreases in calf weaning weight for the calves of the incrementally larger cows.

Providing creep feed for the calves and supplemental crude protein for the cows attempts to treat the symptoms but does not solve this problem. The solution is two pronged: 1) lower mean cow weight to be in concordance with a herd of 1000 lb to 1200 lb cows, and 2) implement a biologically effective grazing management strategy that activates vegetative tiller production from axillary buds which increase the available forage quality during early August to mid October.

Modern range cows perform more efficiently and produce near potential rates when the forage nutrients provided meet the quantity of nutrients required during each production period. Biologically effective forage management strategies designed for high performance range cows (Manske 2012, 2014a, 2014b) are based on providing adequate nutrients that match the livestock nutrient requirements every day of each production period. Beef producers can select appropriate combinations of pasture types and harvested forage types and coordinate the livestock use of those forage types so that the herbage production curves and nutritional quality curves of the plants meet the dietary quantity and quality requirement curves of each cow production period. Matching the forage nutrient quality and quantity with livestock nutrient requirements is necessary for efficient beef production. Biologically effective forage management strategies improve cow performance, reduce cost per pound of captured crude protein, reduce acreage needed to carry a cow-calf pair, reduce forage feed costs per acre and per day, increase calf accumulated weight gain per acre, reduce cost per pound of calf weight gain, increase net return after pasture and harvested forage costs per cow-calf pair, and increase net return after forage feed costs per acre increasing the quantity of new wealth captured from the land natural resources.

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Table 1. Intake nutrient requirements (lb/d) and percent difference between modern 1200 lb range cow with average production and old style 1000 lb range cow.

Nutrient Requirements and Percent Difference		Dry Gestation	Third Trimester	Early Lactation	Lactation Spring, Summer, Fall	12-month Season
		Cow Production Periods				
Old Style 1000 lb range cow with milk production at 12 to 6 lb/d						
Dry Matter	lb/d	21.0	21.0	21.6	22.3	21.78
Energy (TDN)	lb/d	9.64	10.98	12.05	11.98	11.54
Crude Protein	lb/d	1.30	1.64	1.88	1.78	1.72
Modern 1200 lb range cow with average milk production at 20 lb/d						
Dry Matter	lb/d	24.0	24.0	27.0	27.0	26.0
Energy (TDN)	lb/d	11.02	12.62	15.85	15.23	14.29
Crude Protein	lb/d	1.49	1.87	2.73	2.51	2.29
Percent increase in nutrient requirements for average production 1200 lb cow						
Dry Matter	%	14.29	14.29	25.00	21.08	19.38
Energy (TDN)	%	14.32	14.94	31.54	27.13	23.83
Crude Protein	%	14.62	14.02	45.21	41.01	33.14

Data from NRC 1996.

Table 2. Intake nutrient requirements (lb/d) and percent difference between modern 1200 lb range cow with high production and old style 1000 lb range cow.

		Cow Production Periods				
Nutrient Requirements and Percent Difference		Dry Gestation	Third Trimester	Early Lactation	Lactation Spring, Summer, Fall	12-month Season
Old Style 1000 lb range cow with milk production at 12 to 6 lb/d						
Dry Matter	lb/d	21.0	21.0	21.6	22.3	21.78
Energy (TDN)	lb/d	9.64	10.98	12.05	11.98	11.54
Crude Protein	lb/d	1.30	1.64	1.88	1.78	1.72
Modern 1200 lb range cow with high milk production at 30 lb/d						
Dry Matter	lb/d	24.1	24.2	29.2	29.08	27.45
Energy (TDN)	lb/d	11.07	12.73	18.0	17.17	15.64
Crude Protein	lb/d	1.50	1.90	3.36	3.06	2.67
Percent increase in nutrient requirements for high production 1200 lb cow						
Dry Matter	%	14.76	15.24	35.19	30.40	26.03
Energy (TDN)	%	14.83	15.94	49.38	43.32	35.53
Crude Protein	%	15.38	15.85	78.72	71.91	55.23

Data from NRC 1996.

Table 3. Weaned calf weight as percentage of cow weight at weaning.

		Cow Weight Categories (lbs)				
		1200-1299	1300-1399	1400-1499	1500-1599	1600-1699
#Cow-Calf Pairs		37	39	38	33	22
Mean Cow Weight	lbs	1242	1357	1456	1549	1698
Mean Calf Weight	lbs	617	611	589	598	572
Mean Weight/D of Age	lb/d	2.71	2.68	2.58	2.62	2.51
Calf Wt % Cow Wt	%	50%	45%	41%	39%	34%

Data from Ringwall 2008.

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Range Cow Nutrient Requirements during Production Periods

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Improvement in profit margins from beef production requires a reduction in forage-feed costs because these costs comprise 60% to 65% of the production costs of cow-calf operations. Traditional pasture-forage management practices used to provide feed for range cows are inefficient in the capture of the forage nutrients produced on a land base and in the conversion of those nutrients into a saleable commodity like calf weight. High forage-feed costs result.

The basic concepts for traditional management practices were developed during the early stages of the beef industry in the Northern Plains when the dry matter requirements for the livestock were the major consideration and the cost of land area per animal added little to the total production costs. The traditional practices brought numerous family operations in the region through depression, drought, severe winter storms, wild fires, and other natural and man-made calamities but are not adequately serving producers facing current conditions. The old practices ineffectively address two major changes that have occurred. The first major change is that the modern fast-growing, high-performance cattle are genetically different from the old-style cattle. Modern cattle have higher rates of weight gain, produce greater quantities of milk, are larger and weigh more, and deposit less fat on their bodies. Modern animals have higher levels of nutrient requirements, which traditional practices do not efficiently meet. The second major change is that the swine, poultry, and dairy industries have switched to efficient feed management systems that evaluate feed costs by the cost per unit of weight of the nutrients. This shift has reduced production costs for these industries and increased competition for the beef industry. With traditional practices, the beef industry cannot reduce production costs enough to remain competitive.

Feed management systems for beef production in the Northern Plains need to be changed and improved. The modern animal, which has reduced body fat, performs best when provided with the required quantities of nutrients throughout the production year, and feed costs are lower when greater quantities of the produced nutrients are efficiently captured from the land base.

The nutrients beef animals require are energy, protein, minerals, vitamins, and water. The quantities of each nutrient required vary with cow size, level of milk production, and production period. Forages provide primarily energy and protein and also some portion of the required minerals and vitamins. The amounts of minerals deficient in forage can be supplied by a free-choice salt/mineral program. Vitamin A can be supplemented if carotene is low in range cow feeds. Adequate quantities of clean water must be provided for satisfactory animal performance.

Forage dry matter intake is influenced primarily by cow size. Larger cows need more feed than smaller cows for satisfactory reproductive and production performance. Daily dry matter intake is generally around 2% of body weight but ranges from 1.5% to 3.0% of body weight (Holecheck et al. 1995) and can be affected by the quality or the water content of forage and by environmental conditions. The dry matter intake requirement for beef cows is the quantity of forage dry matter that contains the required amount of energy (NRC 1996).

Modern high-performance cows produce greater quantities of milk than the old-style cows. Higher milk production requires that cows consume more energy, protein, calcium, and phosphorus for satisfactory performance (NRC 1996). Forages that do not meet these nutrient requirements cause loss of cow weight and reduced milk production.

The quantity of nutrients range cows require is not consistent throughout the year. The level of nutrients required above maintenance levels varies with the changes in nutrient demand from milk production for the nursing calf as it grows and with the changes in nutrient demand of the physiological preparation for breeding and the development of the fetus that will be the next calf (BCRC 1999). The various combinations of these changing nutritional requirements (table 1) are separated into four production periods: dry gestation, third trimester, early lactation, and lactation, which is subdivided into spring, summer, and fall portions.

The dry gestation production period has the lowest nutrient requirements because there is no nursing calf or milk production and the developing fetus is still small during middle gestation and does not have high nutrient demands. Heavy cows can lose weight during this period without detrimental future effects on reproduction and production performance. Cows with moderate body condition should maintain body weight because the cost to replace lost pounds is greater during other production periods. Thin cows should gain weight during this period because each pound gained requires less feed and costs less than weight gained during other production periods.

The third trimester production period has increased nutrient requirements. Although the cow has no calf at her side and is not producing milk, the developing fetus is growing at an increasing rate. The weight gain from the fetus and related fluid and tissue is about one pound per day during the last 2 or 2.5 months, when the fetus is growing very rapidly (BCRC 1999). It is important that higher-quality forage that meets the nutritional requirements be provided during this period to maintain the weight of cows in moderate or good body condition and to ensure a strong, healthy calf. Feeding forages containing insufficient nutrients during this period causes a reduction in cow body condition and results in delayed estrual activity and a delay in rebreeding.

The early lactation production period has the greatest nutritional requirements of the production periods because the birth of the calf initiates production of increasing amounts of milk and the reproductive organs require repair and pre-conditioning to promote the rapid onset of the estrus cycle. Cows gaining weight during this period produce amounts of milk at or near the animals' genetic potential. Cows increasing in body condition will have adequate time to complete at least one estrus cycle prior to the start of the breeding season; this rapid recovery improves the percentage of cows that conceive in the first cycle of the breeding season (BCRC 1999). Feeding forages containing insufficient nutrients during this period causes a reduced cow body condition that results in milk production at levels below the animals' genetic potential and in a delayed onset of estrual activity so that the period between calving and the first estrus cycle is lengthened and conception rates in the cow herd are reduced.

The spring portion of the lactation production period has nutritional requirements slightly reduced from those of the previous period. The quantity of milk produced continues to increase until the peak is reached during the later part of the second month or the early part of the third month after calving (BCRC 1999). Cows gaining weight during this period produce amounts of milk at or near the animals' genetic potential. Providing harvested or pasture forages with high nutrient content prior to and during breeding season stimulates ovulation in the cows: cows with improving body condition start estrus cycles earlier and can rebreed in 80 to 85 days after calving (BCRC 1999). The rate of calf weight gain continues to increase during the spring period. Calves that are around a month old in early May have developed enough to take advantage of the greater quantities of milk produced by cows grazing high-quality forage on domesticated grass spring complementary pastures and add weight at high rates.

The summer portion of the lactation production period has nutritional requirements above maintenance. The greater part of the additional nutrients is for the production of milk for the nursing calf, and a smaller amount is for the support of an embryo at the early stages of development. The nutritional quality of the forage during the summer plays a role in maintaining the pregnancy. Cows maintaining or improving body condition have lower rates of embryo loss than cows losing body condition (BCRC 1999). The quantity of milk produced during the summer period declines from peak levels. The nutritional quality of the forage affects the rate of decrease. If the forage quality is at or above the animals' nutritional requirements, cows can maintain milk production near their genetic potential during most of the lactation period (BCRC 1999). Cows with higher milk production produce heavier calves at weaning. Cows grazing pasture treatments with forage quality insufficient to meet animal nutritional requirements have milk production below their genetic potential and produce calves that are lighter at weaning and have higher costs per pound of weight gained.

The fall portion of the lactation production period has nutritional requirements above maintenance. The greater part of the additional nutrients is for the production of milk for the nursing calf, and a smaller amount is for development of the fetus. The nutritional quality of the forage affects the quantities of milk produced. If forage quality is at or near animal nutritional requirements, milk production can be fairly high and rate of calf weight gain can be satisfactory (BCRC 1999). Forage quality of mature perennial grasses on traditionally managed pastures is below the requirements of a lactating cow. Forage-feed costs increase when the nutrient quality of the grass or forage provided does not meet the nutritional requirements of the cow. Cows lose body weight and body condition when body reserves are converted into milk production. The level of milk production and the rate of calf weight gain are low; the result is higher costs per pound of calf weight gained.

The time of year during which the cow production periods occur is set by the calving date, which is determined by the breeding date. The sequences of production periods of cows with calving dates in January to April are shown in table 2. The date of calving should be selected so that the nutritional requirements of the cow during her production periods are synchronized with the nutritional quality of the grass and forage resources. The nutritional quality of the common domesticated grassland and native rangeland pastures in the Northern Plains (Whitman et al. 1951, Manske 1999a, b) matches the nutritional requirements of the lactation production periods of cows with calving dates in January through April (figs. 1-4). The nutritional requirements of cows with calving dates in late spring, summer, or fall are not synchronized with the changes in nutritional quality of perennial forages on grazinglands (figs. 5-12). Forage from sources other than perennial grass grazinglands is required to provide low-cost nutrients for cows with calving dates later than April.

Tables 3 to 14 show cow nutrient requirements from grazingland forage or harvested forage during the production periods for 1000-pound, 1200-pound, and 1400-pound cows with calving dates in January to April. The 1200-pound cow with a calf born in mid March will be used as the example throughout this report. The 12-month nutritional requirements for a 1200-pound cow (table 10) are 9489 pounds of forage dry matter, 5217.2 pounds of energy as TDN, 835.8 pounds of crude protein, 24.1 pounds of calcium, and 16.7 pounds of phosphorus. The 12-month forage-feed costs for a cow depend on the amount paid for each pound of nutrient.

Accurate evaluations of costs among various management treatments and forage types are based on costs per pound of nutrient. Cost per pound of crude protein could be used in cost comparisons for different forage types. Small but positive profit margins can be achieved for beef production during a low market with calf weight value at \$0.70 per pound at weaning time when the average calf weaning weight is 535 pounds and the pasture-forage costs are 60% of total beef production costs with average forage-feed costs of \$0.62 per day, forage dry matter costs of \$48.00 per ton, and crude protein costs of \$0.25 per pound.

Nutritional requirements for beef cows are determined on a dry-matter basis. Almost all forages consumed by range cows have some water content. Table 15 shows the wet weight equivalent of forages with various water contents. Cows can consume a greater weight of wet forage than of dry forage (BCRC 1999).

Forage dry matter intake of grazing animals is affected by the size of the cow. Large cows consume more forage than medium- and standard-sized cows. A more accurate estimate of daily or monthly forage demand of livestock on grazinglands can be determined with the metabolic weight of the animal rather than its live weight. Metabolic weight is live weight to the 0.75 power (NRC 1996). A 1000-pound cow with a calf is the standard, which is defined as 1.00 animal unit (AU) and has a daily dry matter allocation of 26 pounds of forage (Bedell 1998). The metabolic weight of a 1200-pound cow with a calf is 1.147 animal unit equivalent (AUE), which has a daily dry matter allocation of 30 pounds of forage. The metabolic weight of a 1400-pound cow with a calf is 1.287 animal unit equivalent (AUE), which has a daily dry matter allocation of 33 pounds of forage (Manske 1998a). The amount of forage dry matter consumed in one month by one animal unit, a 1000-pound cow with a calf, is an animal unit month (AUM) (Bedell 1998). During the grazing season from May through November, the length of the average month is 30.5 days (Manske 1998b).

Range cow nutritional requirements change with cow size, milk production level, and production period. Coordination of pasture and forage quantity and quality with dietary quantity and quality requirements of the cow during production periods improves efficiency of nutrient capture and conversion, resulting in lower pasture-forage costs.

Acknowledgment

I am grateful to Sheri Schneider for assistance in production of this manuscript and for development of the tables and figures. I am grateful to Amy M. Kraus for assistance in preparation of this manuscript.

Table 1. Intake nutrient requirements in pounds per day for range cows with average milk production during 12 months of production periods (data from NRC 1996).

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

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

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

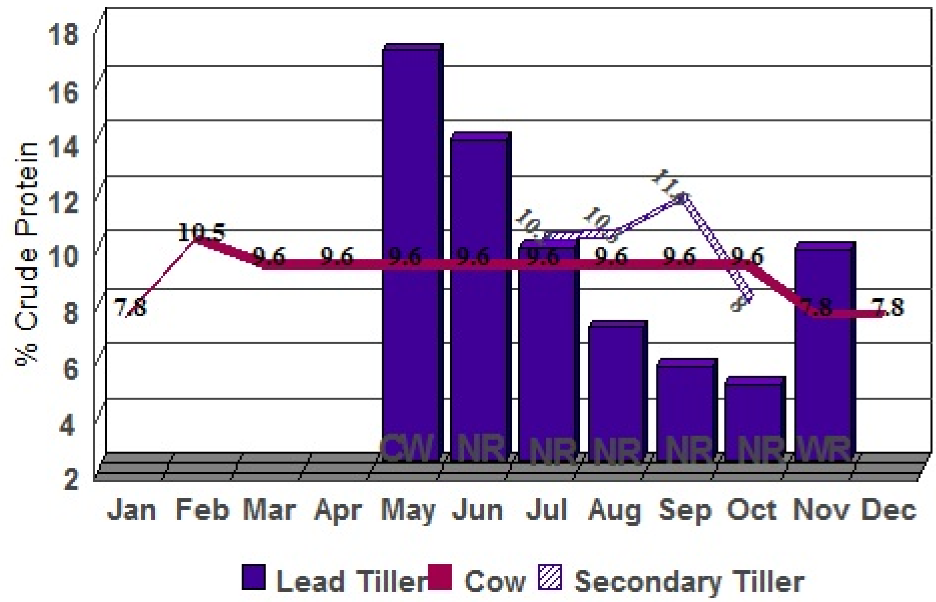

Fig. 1. Cow nutritional requirements for calf birth in January and pasture nutritional quality.

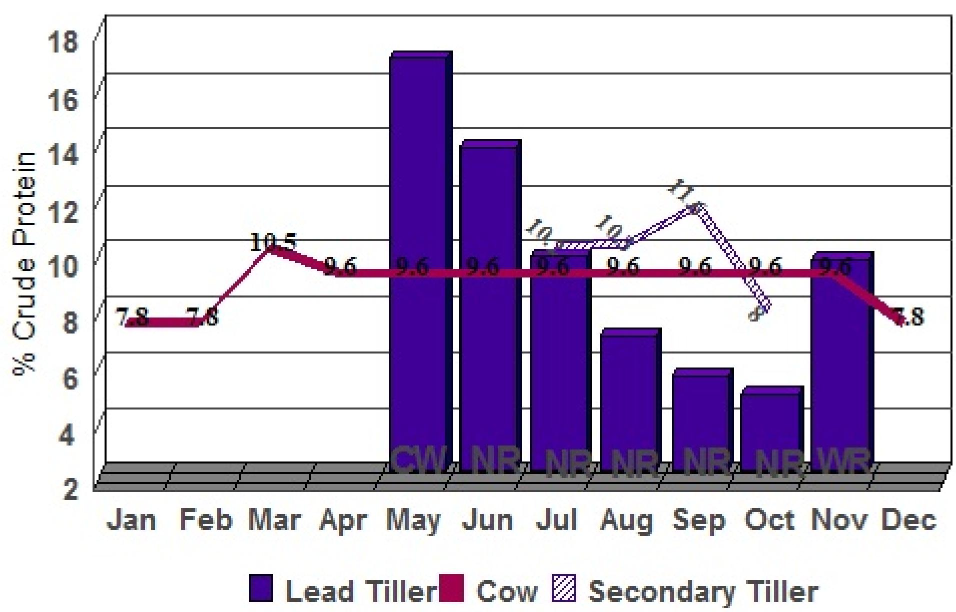

Fig. 2. Cow nutritional requirements for calf birth in February and pasture nutritional quality.

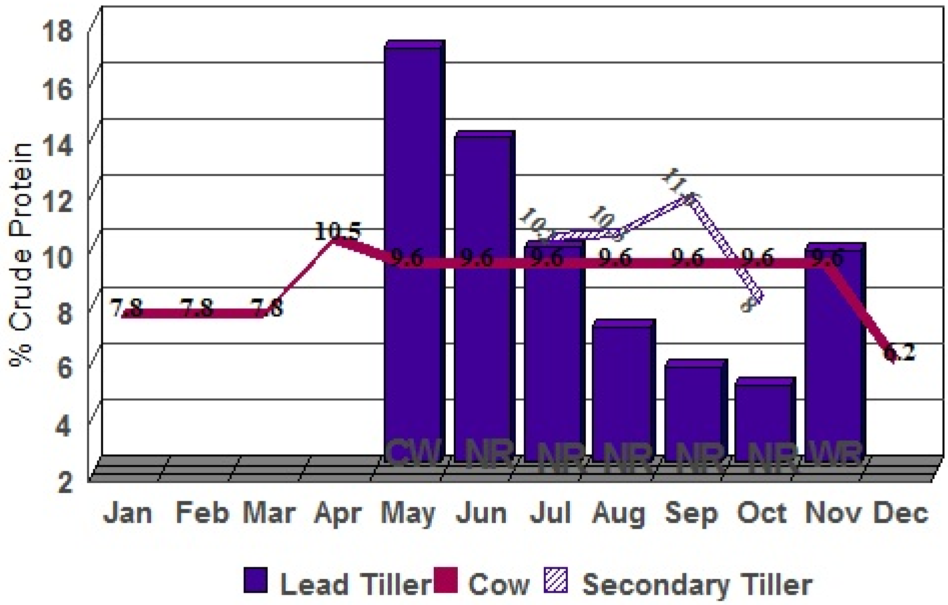

Fig. 3. Cow nutritional requirements for calf birth in March and pasture nutritional quality.

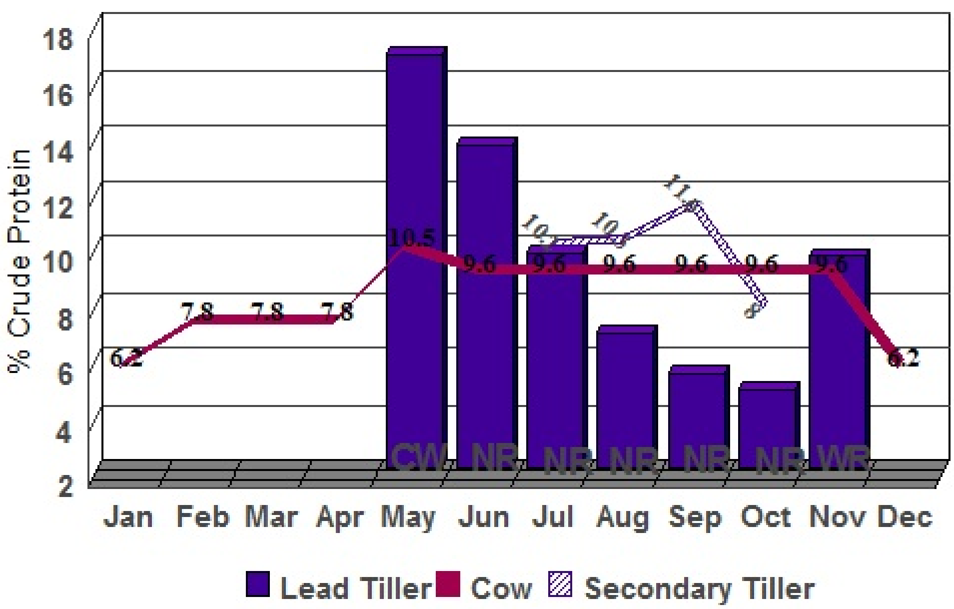

Fig. 4. Cow nutritional requirements for calf birth in April and pasture nutritional quality.

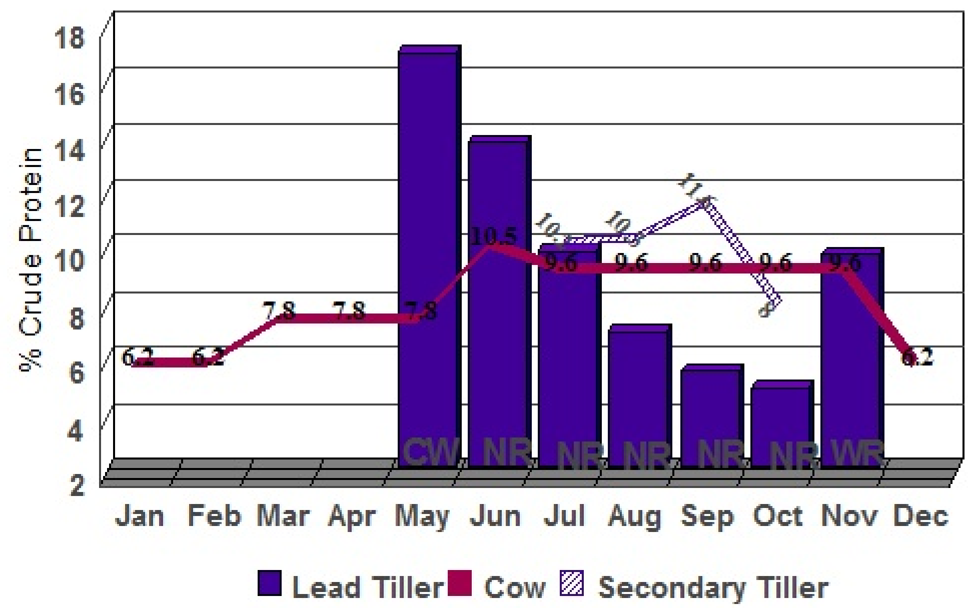

Fig. 5. Cow nutritional requirements for calf birth in May and pasture nutritional quality.

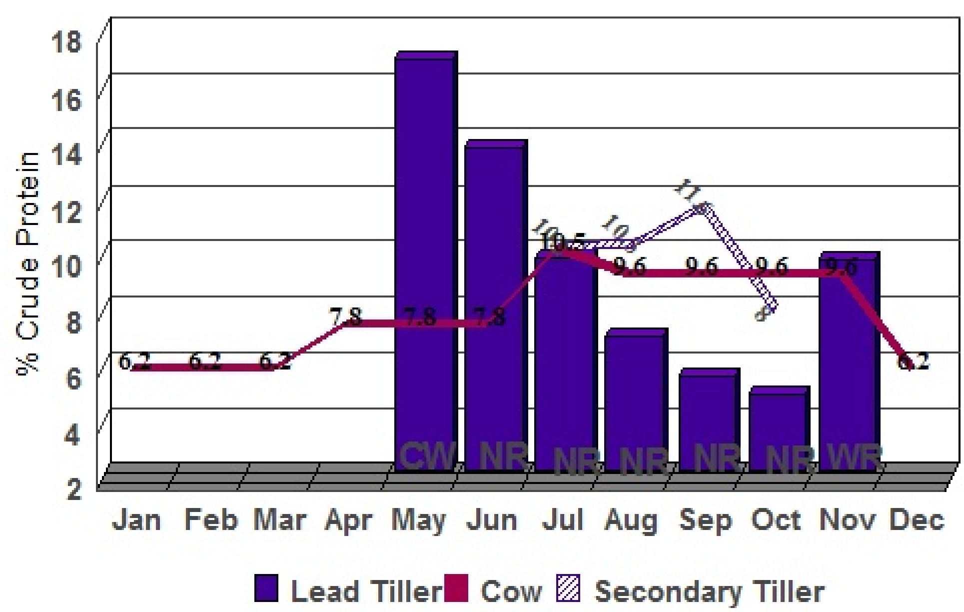

Fig. 6. Cow nutritional requirements for calf birth in June and pasture nutritional quality.

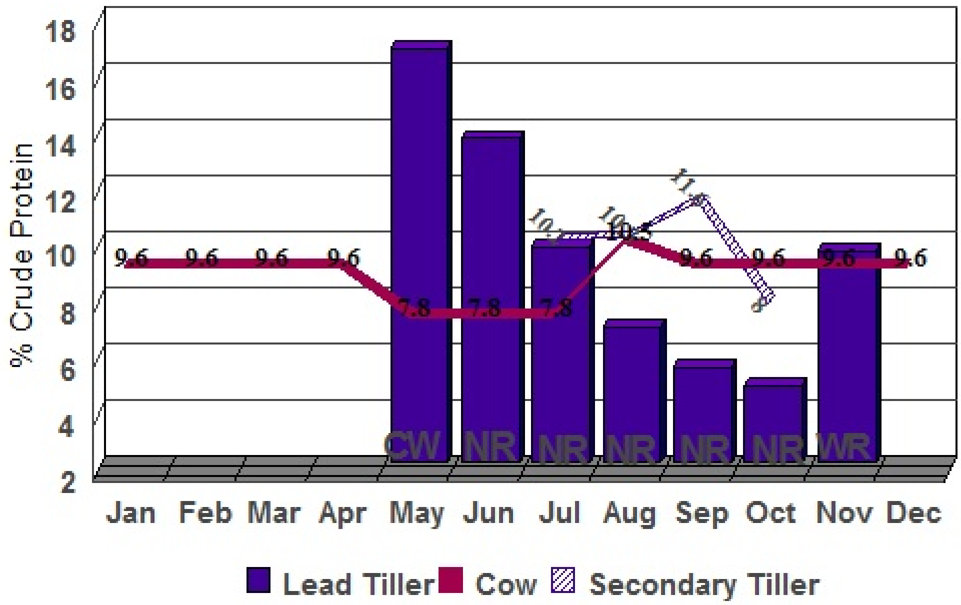

Fig. 7. Cow nutritional requirements for calf birth in July and pasture nutritional quality.

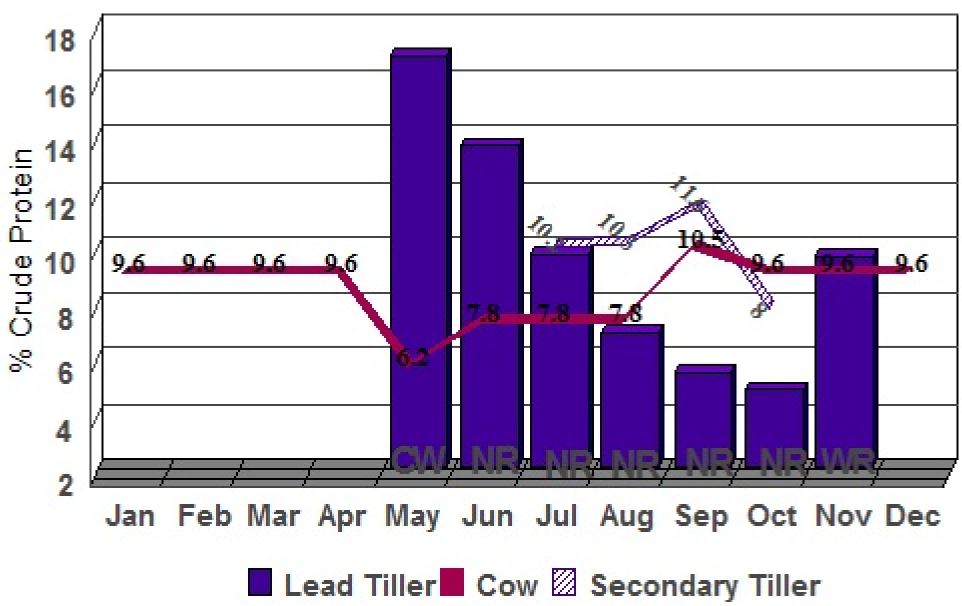

Fig. 8. Cow nutritional requirements for calf birth in August and pasture nutritional quality.

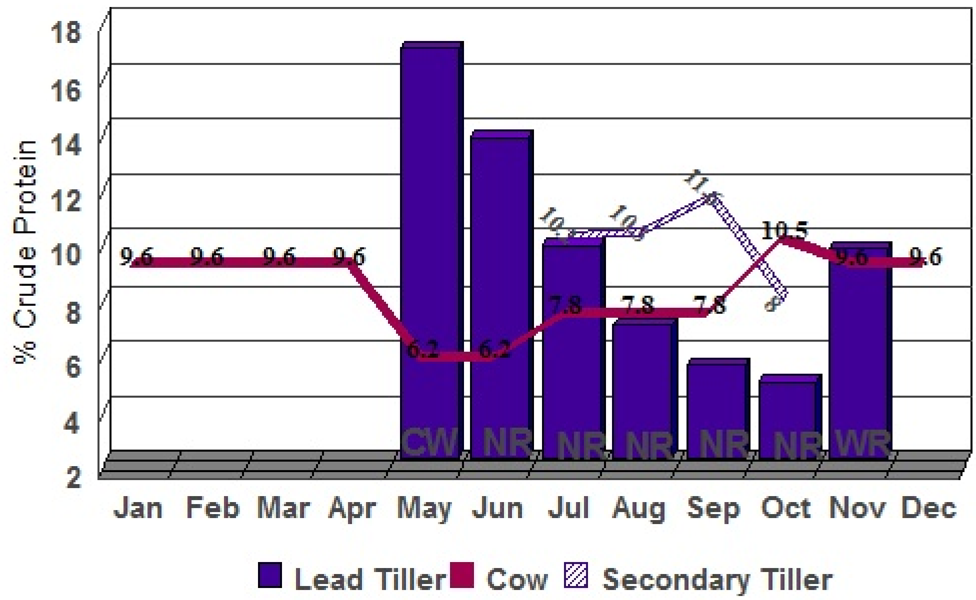

Fig. 9. Cow nutritional requirements for calf birth in September and pasture nutritional quality.

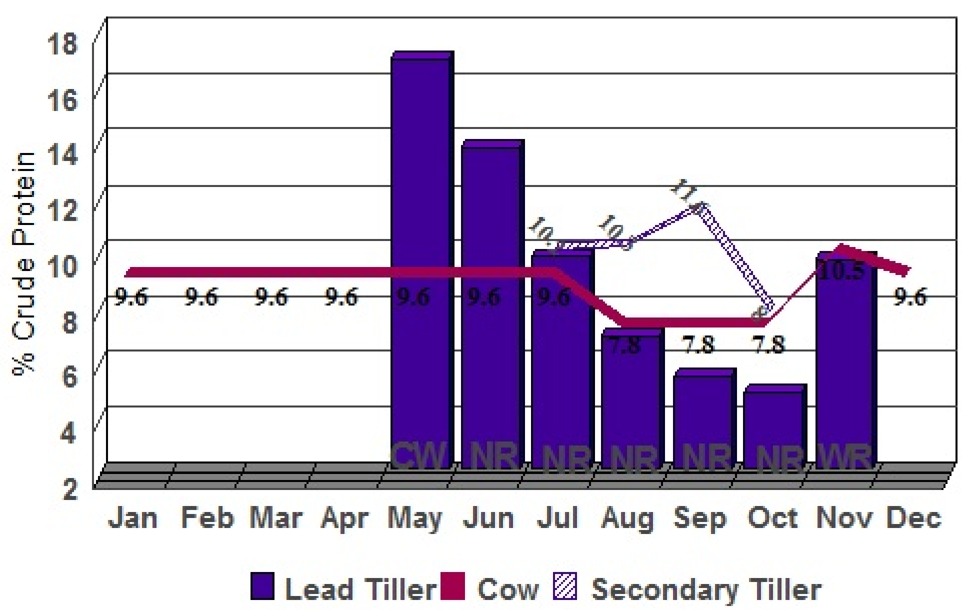

Fig. 10. Cow nutritional requirements for calf birth in October and pasture nutritional quality.

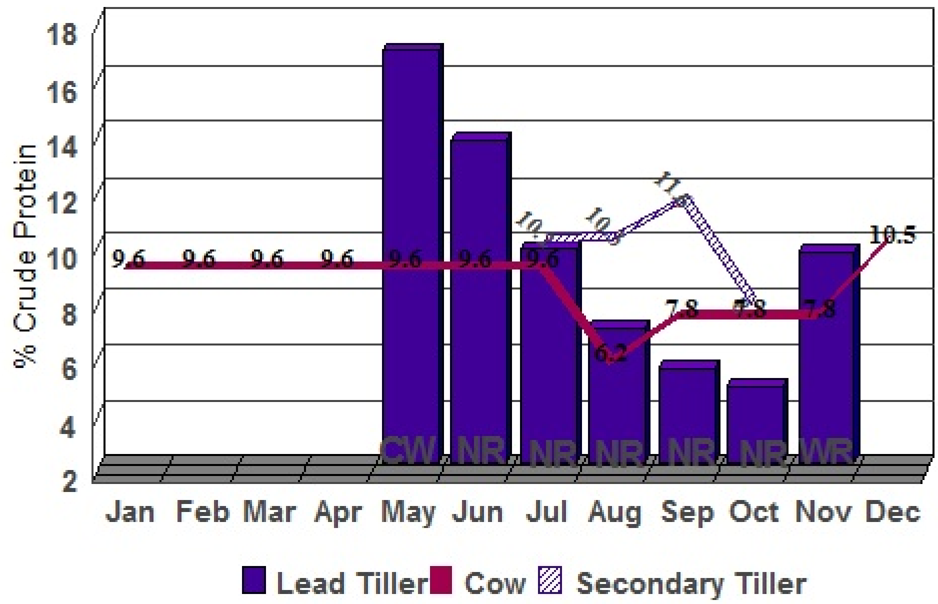

Fig. 11. Cow nutritional requirements for calf birth in November and pasture nutritional quality.

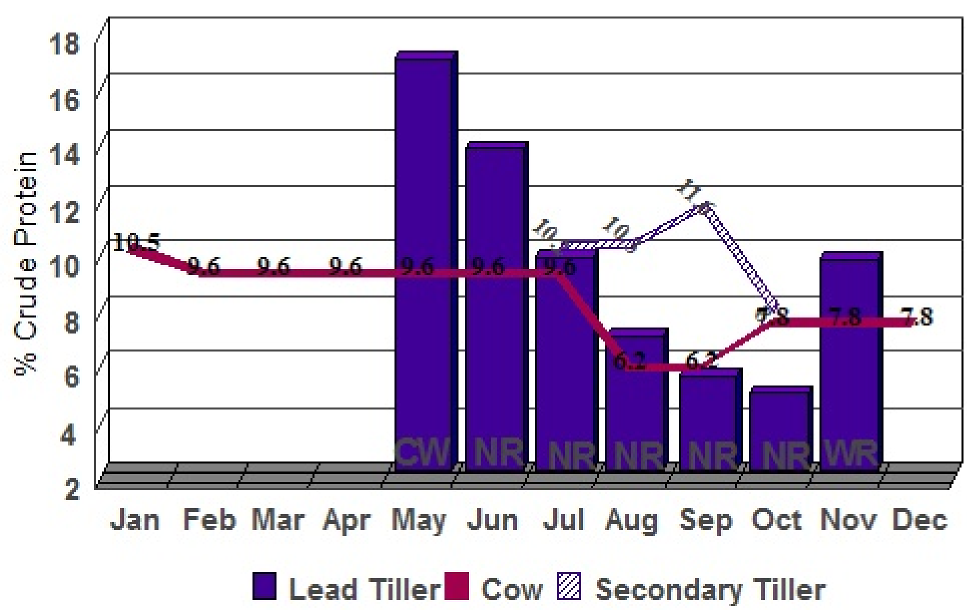

Fig. 12. Cow nutritional requirements for calf birth in December and pasture nutritional quality.

Table 3. Twelve-month nutrient requirements for 1000-pound range cows with calf birth dates in January.

	Dry Gestation		3rd Trimester		Early Lactation		Lactation			
	Ration	Pasture	Ration	Pasture	Ration	Pasture	Ration	Spring Pasture	Summer Pasture	Fall Pasture
Days			90		32		75	31	137	
Daily Requirements in Pounds										
Dry Matter			21		24				24	
Energy (TDN)			10.98		14.30				13.73	
Crude Protein			1.64		2.52				2.30	
Calcium			0.05		0.07				0.06	
Phosphorus			0.03		0.05				0.04	
Production Period Requirements in Pounds										
Dry Matter			1890		768		1800	744	3288	
Energy (TDN)			988.20		457.60		1029.75	425.63	1881.01	
Crude Protein			147.60		80.64		172.50	71.30	315.10	
Calcium			4.50		2.24		4.50	1.86	8.22	
Phosphorus			2.70		1.60		3.00	1.24	5.48	

12-Month Requirements in Pounds

	Totals for Rations	Totals for Pastures	Totals for 12 Months
Dry Matter	4458	4032	8490
Energy (TDN)	2475.55	2306.64	4782.19
Crude Protein	400.74	386.40	787.14
Calcium	11.24	10.08	21.32
Phosphorus	7.30	6.72	14.02

Table 4. Twelve-month nutrient requirements for 1200-pound range cows with calf birth dates in January.

	Dry Gestation		3rd Trimester		Early Lactation		Lactation			
	Ration	Pasture	Ration	Pasture	Ration	Pasture	Ration	Spring Pasture	Summer Pasture	Fall Pasture
Days			90		32		75	31	137	
Daily Requirements in Pounds										
Dry Matter			24		27				27	
Energy (TDN)			12.62		15.85				15.23	
Crude Protein			1.87		2.73				2.51	
Calcium			0.06		0.08				0.07	
Phosphorus			0.04		0.05				0.05	
Production Period Requirements in Pounds										
Dry Matter			2160		864		2025	837	3699	
Energy (TDN)			1135.80		507.20		1142.25	472.13	2086.51	
Crude Protein			168.30		87.36		188.25	77.81	343.87	
Calcium			5.40		2.56		5.25	2.17	9.59	
Phosphorus			3.60		1.60		3.75	1.55	6.85	

12-Month Requirements in Pounds

	Totals for Rations	Totals for Pastures	Totals for 12 Months
Dry Matter	5049	4536	9585
Energy (TDN)	2785.25	2558.64	5343.89
Crude Protein	443.91	421.68	865.59
Calcium	13.21	11.76	24.97
Phosphorus	8.95	8.40	17.35

Table 5. Twelve-month nutrient requirements for 1400-pound range cows with calf birth dates in January.

	Dry Gestation		3rd Trimester		Early Lactation		Lactation			
	Ration	Pasture	Ration	Pasture	Ration	Pasture	Ration	Spring Pasture	Summer Pasture	Fall Pasture
Days			90		32		75	31	137	
Daily Requirements in Pounds										
Dry Matter			27		30				30	
Energy (TDN)			14.28		17.40				16.71	
Crude Protein			2.13		2.94				2.70	
Calcium			0.07		0.08				0.08	
Phosphorus			0.05		0.06				0.05	
Production Period Requirements in Pounds										
Dry Matter			2430		960		2250	930	4110	
Energy (TDN)			1285.20		556.80		1253.25	518.01	2289.27	
Crude Protein			191.70		94.08		202.50	83.70	369.90	
Calcium			6.30		2.56		6.00	2.48	10.96	
Phosphorus			4.50		1.92		3.75	1.55	6.85	

12-Month Requirements in Pounds

	Totals for Rations	Totals for Pastures	Totals for 12 Months
Dry Matter	5640	5040	10680
Energy (TDN)	3095.25	2807.28	5902.53
Crude Protein	488.28	453.60	941.88
Calcium	14.86	13.44	28.30
Phosphorus	10.17	8.40	18.57

Table 6. Twelve-month nutrient requirements for 1000-pound range cows with calf birth dates in February.

	Dry Gestation		3^{rd} Trimester		Early Lactation		Lactation			
	Ration	Pasture	Ration	Pasture	Ration	Pasture	Ration	Spring Pasture	Summer Pasture	Fall Pasture
Days			90		32		45	31	137	30
Daily Requirements in Pounds										
Dry Matter			21		24				24	
Energy (TDN)			10.98		14.30				13.73	
Crude Protein			1.64		2.52				2.30	
Calcium			0.05		0.07				0.06	
Phosphorus			0.03		0.05				0.04	
Production Period Requirements in Pounds										
Dry Matter			1890		768		1080	744	3288	720
Energy (TDN)			988.20		457.60		617.85	425.63	1881.01	411.90
Crude Protein			147.60		80.64		103.50	71.30	315.10	69.00
Calcium			4.50		2.24		2.70	1.86	8.22	1.80
Phosphorus			2.70		1.60		1.80	1.24	5.48	1.20

12-Month Requirements in Pounds

	Totals for Rations	Totals for Pastures	Totals for 12 Months
Dry Matter	3738	4752	8490
Energy (TDN)	2063.65	2718.54	4782.19
Crude Protein	331.74	455.40	787.14
Calcium	9.44	11.88	21.32
Phosphorus	6.10	7.92	14.02

Table 7. Twelve-month nutrient requirements for 1200-pound range cows with calf birth dates in February.

	Dry Gestation		3rd Trimester		Early Lactation		Lactation			
	Ration	Pasture	Ration	Pasture	Ration	Pasture	Ration	Spring Pasture	Summer Pasture	Fall Pasture
Days			90		32		45	31	137	30
Daily Requirements in Pounds										
Dry Matter			24		27				27	
Energy (TDN)			12.62		15.85				15.23	
Crude Protein			1.87		2.73				2.51	
Calcium			0.06		0.08				0.07	
Phosphorus			0.04		0.05				0.05	
Production Period Requirements in Pounds										
Dry Matter			2160		864		1215	837	3699	810
Energy (TDN)			1135.80		507.20		685.35	472.13	2086.51	456.90
Crude Protein			168.30		87.36		112.95	77.81	343.87	75.30
Calcium			5.40		2.56		3.15	2.17	9.59	2.10
Phosphorus			3.60		1.60		2.25	1.55	6.85	1.50

12-Month Requirements in Pounds

	Totals for Rations	Totals for Pastures	Totals for 12 Months
Dry Matter	4239	5346	9585
Energy (TDN)	2328.35	3015.54	5343.89
Crude Protein	368.61	496.98	865.59
Calcium	11.11	13.86	24.97
Phosphorus	7.45	9.90	17.35

Table 8. Twelve-month nutrient requirements for 1400-pound range cows with calf birth dates in February.

	Dry Gestation		3rd Trimester		Early Lactation		Lactation			
	Ration	Pasture	Ration	Pasture	Ration	Pasture	Ration	Spring Pasture	Summer Pasture	Fall Pasture
Days			90		32		45	31	137	30
Daily Requirements in Pounds										
Dry Matter			27		30				30	
Energy (TDN)			14.28		17.40				16.71	
Crude Protein			2.13		2.94				2.70	
Calcium			0.07		0.08				0.08	
Phosphorus			0.05		0.06				0.05	
Production Period Requirements in Pounds										
Dry Matter			2430		960		1350	930	4110	900
Energy (TDN)			1285.20		556.80		751.95	518.01	2289.27	501.30
Crude Protein			191.70		94.08		121.50	83.70	369.90	81.00
Calcium			6.30		2.56		3.60	2.48	10.96	2.40
Phosphorus			4.50		1.92		2.25	1.55	6.85	1.50

12-Month Requirements in Pounds

	Totals for Rations	Totals for Pastures	Totals for 12 Months
Dry Matter	4740	5940	10680
Energy (TDN)	2593.95	3308.58	5902.53
Crude Protein	407.28	534.60	941.88
Calcium	12.46	15.84	28.30
Phosphorus	8.67	9.90	18.57

Table 9. Twelve-month nutrient requirements for 1000-pound range cows with calf birth dates in March.

	Dry Gestation		3rd Trimester		Early Lactation		Lactation			
	Ration	Pasture	Ration	Pasture	Ration	Pasture	Ration	Spring Pasture	Summer Pasture	Fall Pasture
Days		32	90		45			31	137	30
Daily Requirements in Pounds										
Dry Matter		21	21		24				24	
Energy (TDN)		9.64	10.98		14.30				13.73	
Crude Protein		1.30	1.64		2.52				2.30	
Calcium		0.03	0.05		0.07				0.06	
Phosphorus		0.02	0.03		0.05				0.04	
Production Period Requirements in Pounds										
Dry Matter		672	1890		1080			744	3288	720
Energy (TDN)		308.48	988.20		643.50			425.63	1881.01	411.90
Crude Protein		41.60	147.60		113.40			71.30	315.10	69.00
Calcium		0.96	4.50		3.15			1.86	8.22	1.80
Phosphorus		0.64	2.70		2.25			1.24	5.48	1.20

12-Month Requirements in Pounds

	Totals for Rations	Totals for Pastures	Totals for 12 Months
Dry Matter	2970	5424	8394
Energy (TDN)	1631.70	3027.02	4658.72
Crude Protein	261.00	497.00	758.00
Calcium	7.65	12.84	20.49
Phosphorus	4.95	8.56	13.51

Table 10. Twelve-month nutrient requirements for 1200-pound range cows with calf birth dates in March.

	Dry Gestation		3rd Trimester		Early Lactation		Lactation			
	Ration	Pasture	Ration	Pasture	Ration	Pasture	Ration	Spring Pasture	Summer Pasture	Fall Pasture
Days		32	90		45			31	137	30
Daily Requirements in Pounds										
Dry Matter		24	24		27				27	
Energy (TDN)		11.02	12.62		15.85				15.23	
Crude Protein		1.49	1.87		2.73				2.51	
Calcium		0.04	0.06		0.08				0.07	
Phosphorus		0.03	0.04		0.05				0.05	
Production Period Requirements in Pounds										
Dry Matter		768	2160		1215			837	3699	810
Energy (TDN)		352.64	1135.80		713.25			472.13	2086.51	456.90
Crude Protein		47.68	168.30		122.85			77.81	343.87	75.30
Calcium		1.28	5.40		3.60			2.17	9.59	2.10
Phosphorus		0.96	3.60		2.25			1.55	6.85	1.50

12-Month Requirements in Pounds

	Totals for Rations	Totals for Pastures	Totals for 12 Months
Dry Matter	3375	6114	9489
Energy (TDN)	1849.05	3368.18	5217.23
Crude Protein	291.15	544.66	835.80
Calcium	9.00	15.14	24.14
Phosphorus	5.85	10.86	16.71

Table 11. Twelve-month nutrient requirements for 1400-pound range cows with calf birth dates in March.

	Dry Gestation		3rd Trimester		Early Lactation		Lactation			
	Ration	Pasture	Ration	Pasture	Ration	Pasture	Ration	Spring Pasture	Summer Pasture	Fall Pasture
Days		32	90		45			31	137	30
Daily Requirements in Pounds										
Dry Matter		27	27		30				30	
Energy (TDN)		12.42	14.28		17.40				16.71	
Crude Protein		1.67	2.13		2.94				2.70	
Calcium		0.04	0.07		0.08				0.08	
Phosphorus		0.03	0.05		0.06				0.05	
Production Period Requirements in Pounds										
Dry Matter		864	2430		1350			930	4110	900
Energy (TDN)		397.44	1285.20		783.00			518.01	2289.27	501.30
Crude Protein		53.44	191.70		132.30			83.70	369.90	81.00
Calcium		1.28	6.30		3.60			2.48	10.96	2.40
Phosphorus		0.96	4.50		2.70			1.55	6.85	1.50

12-Month Requirements in Pounds

	Totals for Rations	Totals for Pastures	Totals for 12 Months
Dry Matter	3780	6804	10584
Energy (TDN)	2068.20	3706.02	5774.22
Crude Protein	324.00	588.04	912.04
Calcium	9.90	17.12	27.02
Phosphorus	7.20	10.86	18.06

Table 12. Twelve-month nutrient requirements for 1000-pound range cows with calf birth dates in April.

	Dry Gestation		3rd Trimester		Early Lactation		Lactation			
	Ration	Pasture	Ration	Pasture	Ration	Pasture	Ration	Spring Pasture	Summer Pasture	Fall Pasture
Days	62		90		15	15		16	137	30
Daily Requirements in Pounds										
Dry Matter	21		21		24				24	
Energy (TDN)	9.64		10.98		14.30				13.73	
Crude Protein	1.30		1.64		2.52				2.30	
Calcium	0.03		0.05		0.07				0.06	
Phosphorus	0.02		0.03		0.05				0.04	
Production Period Requirements in Pounds										
Dry Matter	1302		1890		360	360		384	3288	720
Energy (TDN)	597.68		988.20		214.50	214.50		219.68	1881.01	411.90
Crude Protein	80.60		147.60		37.50	37.50		36.80	315.10	69.00
Calcium	1.86		4.50		1.05	1.05		0.96	8.22	1.80
Phosphorus	1.24		2.70		0.75	0.75		0.64	5.48	1.20

12-Month Requirements in Pounds

	Totals for Rations	Totals for Pastures	Totals for 12 Months
Dry Matter	3552	4752	8304
Energy (TDN)	1800.38	2727.09	4527.47
Crude Protein	265.70	458.40	724.10
Calcium	7.41	12.03	19.44
Phosphorus	4.69	8.07	12.76

Table 13. Twelve-month nutrient requirements for 1200-pound range cows with calf birth dates in April.

	Dry Gestation		3rd Trimester		Early Lactation		Lactation			
	Ration	Pasture	Ration	Pasture	Ration	Pasture	Ration	Spring Pasture	Summer Pasture	Fall Pasture
Days	62		90		15	15		16	137	30
Daily Requirements in Pounds										
Dry Matter	24		24		27				27	
Energy (TDN)	11.02		12.62		15.85				15.23	
Crude Protein	1.49		1.87		2.73				2.51	
Calcium	0.04		0.06		0.08				0.07	
Phosphorus	0.03		0.04		0.05				0.05	
Production Period Requirements in Pounds										
Dry Matter	1488		2160		405	405		432	3699	810
Energy (TDN)	683.24		1135.80		237.75	237.75		243.68	2086.51	456.90
Crude Protein	92.38		168.30		40.95	40.95		40.16	343.87	75.30
Calcium	2.48		5.40		1.20	1.20		1.12	9.59	2.10
Phosphorus	1.86		3.60		0.75	0.75		0.80	6.85	1.50

12-Month Requirements in Pounds

	Totals for Rations	Totals for Pastures	Totals for 12 Months
Dry Matter	4053	5346	9399
Energy (TDN)	2056.79	3024.84	5081.63
Crude Protein	301.63	500.28	801.91
Calcium	9.08	14.01	23.09
Phosphorus	6.21	9.90	16.11

Table 14. Twelve-month nutrient requirements for 1400-pound range cows with calf birth dates in April.

	Dry Gestation		3rd Trimester		Early Lactation		Lactation			
	Ration	Pasture	Ration	Pasture	Ration	Pasture	Ration	Spring Pasture	Summer Pasture	Fall Pasture
Days	62		90		15	15		16	137	30
Daily Requirements in Pounds										
Dry Matter	27		27		30				30	
Energy (TDN)	12.42		14.28		17.40				16.71	
Crude Protein	1.67		2.13		2.94				2.70	
Calcium	0.04		0.07		0.08				0.08	
Phosphorus	0.03		0.05		0.06				0.05	
Production Period Requirements in Pounds										
Dry Matter	1674		2430		450	450		480	4110	900
Energy (TDN)	770.04		1285.20		261.00	261.00		267.36	2289.27	501.30
Crude Protein	103.54		191.70		44.10	44.10		43.20	369.90	81.00
Calcium	2.48		6.30		1.20	1.20		1.28	10.96	2.40
Phosphorus	1.86		4.50		0.90	0.90		0.80	6.85	1.50

12-Month Requirements in Pounds

	Totals for Rations	Totals for Pastures	Totals for 12 Months
Dry Matter	4554	5940	10494
Energy (TDN)	2316.24	3318.93	5635.17
Crude Protein	339.34	538.20	877.54
Calcium	9.98	15.84	25.84
Phosphorus	7.26	10.05	17.31

Table 15. Dry weight of forage and as fed weight of forage in pounds at various percent water content levels.

% water	dry weight	dry weight	dry weight	dry weight	dry weight	dry weight
0	21	24	26	27	30	33
	wet weight	wet weight	wet weight	wet weight	wet weight	wet weight
5	22.1	25.3	27.4	28.4	31.6	34.7
10	23.3	26.7	28.9	30.0	33.3	36.7
15	24.7	28.2	30.6	31.8	35.3	38.8
20	26.3	30.0	32.5	33.8	37.5	41.3
25	28.0	32.0	34.7	36.0	40.0	44.0
30	30.0	34.3	37.1	38.6	42.9	47.1
35	32.3	36.9	40.0	41.5	46.2	50.8
40	35.0	40.0	43.3	45.0	50.0	55.0
45	38.2	43.6	47.3	49.1	54.5	60.0
50	42.0	48.0	52.0	54.0	60.0	66.0
55	46.7	53.3	57.8	60.0	66.7	73.3
60	52.5	60.0	65.0	67.5	75.0	82.5
65	60.0	68.6	74.3	77.1	85.7	94.3
70	70.0	80.0	86.7	90.0	100.0	110.0
75	84.0	96.0	104.0	108.0	120.0	132.0
80	105.0	120.0	130.0	135.0	150.0	165.0
85	140.0	160.0	173.3	180.0	200.0	220.0
90	210.0	240.0	260.0	270.0	300.0	330.0
95	420.0	480.0	520.0	540.0	600.0	660.0

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Diagnostic Examination of the Value Captured from Land Natural Resources by Twelve Month Forage Management Strategies for Range Cows

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The traditionally assumed premise that the source of revenue from beef production has been from the sale of livestock weight has directed the focus on improving animal performance in order to raise profit margins for the beef production industry. Consequently, pasture and harvested forage, labor, and equipment have been considered to be the costs of production. Profits result when the paid costs of production are lower than the value received from the sale of livestock weight. After numerous decades of improvements in animal performance, high production costs and low profit margins continue to be problems for the beef production industry.

The beef production industry has neglected to recognize the importance of forage nutrients as the source of livestock weight gain and failed to simultaneously improve the efficiencies of forage management systems. The swine, poultry, and dairy industries have switched to efficient feed management systems that evaluate feed costs from the cost per unit of the nutrients. Low profit problems persist in the beef industry as a result of the mismatch of forage nutrients required and forage nutrients available between modern, high-performance cattle and traditional low-performance old-style livestock forage management practices.

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. She also requires 27% more energy and 41% more crude protein per day during the lactation period. 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 (Manske 2008).

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.

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 acre and 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 acre and 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.

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.

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).

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 acre and per day are important diagnostic values 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 acres per cow needed during a production period determine the forage feed costs per acre. 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.

Twelve-month forage management strategies are developed by selection of a pasture forage type or a harvested forage type for use during each range cow production period. The combined sequence of assembled forage types composes a 12-month forage management strategy. Diagnostic examinations were conducted on three 12-month forage management strategies: the Repeated Seasonal, No Hay, the Traditional Seasonlong, and the Biologically Effective Twice-over Rotation. The beef cattle nutrient requirements were from NRC 1996 and BCRC 1999. The harvested forage data were from Manske and Carr 2000. The pasture forage data and the cow and calf performance data were from Manske 2001, 2002, 2003a, 2003b, 2004, and 2008. The methods used were from Manske 2008.

Twelve-month forage management strategy development that is based on traditional concepts treat livestock as the source of revenue and forage as the feedstuffs livestock eat. Traditional forage management strategies emphasize the use of land as feed for livestock and promote minimal use of harvested forages. Traditional selection criteria for forage types are based on the quantity of forage dry matter weight per acre and on low cash flow costs or low production costs per acre.

Twelve-month forage management strategy development that is based on biologically effective concepts treat forage crude protein produced on the land resources as the source of new wealth generation and the beef weight produced as the commodity sold at market. Biologically effective management strategies emphasize meeting plant biological requirements and promote stimulation of vegetative reproduction by tillering and enhancement of rhizosphere organism activity and the biogeochemical processes in the ecosystem. Biologically effective selection criteria for forage types are based on low forage feed costs per day, low forage crude protein costs per pound, low calf weight gain costs per pound, small land areas per cow, and high returns after feed costs per acre.

Range Cow Production Periods

Dry Gestation

The dry gestation production period was 32 days during late fall from mid November to mid December. The dry gestation production period has the lowest nutrient requirements because there is no nursing calf or milk production and the developing fetus is still small during middle gestation and does not have high nutrient demands. Heavy cows can lose weight during this period without detrimental future effects on reproduction and production performance. Cows with moderate body condition should maintain body weight because the cost to replace lost pounds is greater during other production periods. Thin cows should gain weight during this period because each pound gained requires less feed and costs less than weight gained during other production periods. Pasture forage and harvested forage costs and returns after feed costs were determined for a 1200-pound range cow during the dry gestation production period. The cow requires a daily intake of 24 lbs dry matter (DM) at 6.2% crude protein (CP) (1.49 lbs CP/day).

Third Trimester

The third trimester production period was 90 days during winter from mid December to mid March. The third trimester production period has increased nutrient requirements. Although the cow has no calf at her side and is not producing milk, the developing fetus is growing at an increasing rate. The weight gain from the fetus and related fluid and tissue is about one pound per day during the last 2 or 2.5 months when the fetus is growing very rapidly (BCRC 1999). It is important that higher-quality forage that meets the nutritional requirements be provided during this period to maintain the weight of cows in moderate or good body condition and to ensure a strong, healthy calf. Feeding forages containing insufficient nutrients during this period causes a reduction in cow body condition and results in delayed estrual activity and a delay in rebreeding. Pasture forage and harvested forage costs and returns after feed costs were determined for a 1200-pound range cow during the 90-day third trimester production period. The cow requires a daily intake of 24 lbs dry matter (DM) at 7.8% crude protein (CP) (1.87 lbs CP/day).

Early Lactation

The early lactation production period was 45 days during early spring from mid March to late April. The early lactation production period has the greatest nutritional requirements of the production periods because the birth of the calf initiates production of increasing amounts of milk and the reproductive organs require repair and pre-conditioning to promote the rapid onset of the estrus cycle. Cows gaining weight during this period will produce milk in quantities at or near the animals' genetic potential. Cows increasing in body condition will have adequate time to complete at least one estrus cycle prior to the start of the breeding season; this rapid recovery improves the percentage of cows that conceive in the first cycle of the breeding season (BCRC 1999). Feeding forages containing insufficient nutrients during this period causes a reduced cow body condition that results in milk production at levels below the animals' genetic potential and in a delayed onset of estrual activity so that the period between calving and the first estrus cycle is lengthened and conception rates in the cow herd are reduced. Pasture forage and harvested forage costs and returns after feed costs were determined for a 1200-pound range cow during the early lactation production period. The cow requires a daily intake of 27 lbs dry matter (DM) at 10.1% crude protein (CP) (2.73 lbs CP/day).

Spring Lactation

The spring lactation production period was 31 days from early May until late May. The spring lactation production period has nutritional requirements slightly reduced from those of the previous period. The quantity of milk produced continues to increase until the peak is reached during the later part of the second month or the early part of the third month after calving (BCRC 1999). Cows gaining weight during this period produce milk in quantities at or near the animals' genetic potential. Providing harvested forages or pasture forages with high nutrient content prior to and during breeding season stimulates ovulation in the cows; cows with improving body condition start estrus cycles earlier and can rebreed in 80 to 85 days after calving (BCRC 1999). The rate of calf weight gain continues to increase during the spring period. Calves that are around a month old in early May have developed enough to take advantage of the high levels of milk produced by cows grazing high-quality forage on domesticated grass spring complementary pastures and add weight at high rates. Pasture forage and harvested forage costs and returns after feed costs were determined for a 1200-pound range cow with a calf during the spring lactation production period. A grazing cow with a calf requires an allocation of 30 lbs of pasture forage dry matter per day. The cow requires a daily intake of 27 lbs dry matter (DM) at 9.3% crude protein (CP) (2.51 lbs CP/day).

Summer Lactation

The summer lactation production period was 137 days from early June until mid October. The summer lactation production period has nutritional requirements above maintenance. The greater part of the additional nutrients is for the production of milk for the nursing calf, and a smaller amount is for the support of an embryo at the early stages of development. The nutritional quality of the forage during the summer plays a role in maintaining the pregnancy. Cows maintaining or improving body condition have lower rates of embryo loss than cows losing body condition (BCRC 1999). The quantity of milk produced during the summer period declines from peak levels. The nutritional quality of the forage affects the rate of decrease. If the forage quality is at or above the animals' nutritional requirements, cows can maintain milk production near their genetic potential during most of the lactation period (BCRC 1999). Cows with higher milk production produce heavier calves at weaning. Cows grazing pasture treatments with forage quality insufficient to meet animal nutritional requirements have milk production below their genetic potential and produce calves that are lighter at weaning and have higher costs per pound of weight gained. Pasture forage and harvested forage costs and returns after feed costs were determined for a 1200-pound range cow with a calf during the summer lactation production period. A grazing cow with a calf requires an allocation of 30 lbs of pasture forage dry matter per day. The cow requires a daily intake of 27 lbs dry matter (DM) at 9.3% crude protein (CP) (2.51 lbs CP/day).

Fall Lactation

The fall lactation production period was 30 days from mid October until mid November. The fall lactation production period has nutritional requirements above maintenance. The greater part of the additional nutrients is for the production of milk for the nursing calf, and a smaller amount is for fetus development. The nutritional quality of the forage affects the quantities of milk produced. If forage quality is at or near animal nutritional requirements, milk production can be fairly high and rate of calf weight gain can be satisfactory (BCRC 1999). Forage quality of mature perennial grasses on traditionally managed pastures is below the requirements of a lactating cow. Forage-feed costs increase when the nutrient quality of the grass or forage provided does not meet the nutritional requirements of the cow. Cows lose body weight and body condition when body reserves are converted into milk production. The level of milk production and the rate of calf weight gain are low; the result is higher costs per pound of calf weight gained. Pasture forage and harvested forage costs and returns after feed costs were determined for a 1200-pound range cow with a calf during the fall lactation production period. A grazing cow with a calf requires an allocation of 30 lbs of pasture forage dry matter per day. The cow requires a daily intake of 27 lbs dry matter (DM) at 9.3% crude protein (CP) (2.51 lbs CP/day).

Repeated Seasonal, No Hay

Dry Gestation

Reserved native rangeland managed as a repeated seasonal pasture was evaluated during the dry gestation production period for 32 days between mid November and mid December (table 1). Native rangeland forage during the fall dormancy period has a crude protein content of around 4.8%. Late-season native rangeland forage has pasture rent value or production costs of $8.76 per acre, forage dry matter costs of $97.33 per ton, and crude protein costs of $1.01 per pound. A cow grazing during the dry gestation production period would require 5.33 acres (5.08 acres per month) at a forage cost of $46.75 per production period. The crude protein content of mature native rangeland forage is below the requirements of a cow in the dry gestation stage, and crude protein would need to be supplemented at 0.05 lbs per cow per day at a cost of $0.48 per period. Total feed costs would be $47.23 per period and $8.86 per acre, or $1.48 per day. Calf fetus weight gain was assumed to be 0.78 lbs per day; accumulated weight gain was 24.92 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $17.44 per calf and $3.27 per acre. The net returns after pasture costs were a loss of $29.79 per cow-calf pair and a loss of $5.59 per acre. The cost of calf fetus weight gain was $1.90 per pound.

Reserved native rangeland forage grazed as a repeated seasonal pasture during the dry gestation production period was high-cost forage because the quantities of crude protein captured per acre were low and the quantity of forage dry matter available per acre was low. Total forage costs for reserved native rangeland pastures was high, even though the equipment costs, labor costs, land rent per acre, and forage production costs per acre were low, because the input costs do not directly regulate livestock forage feed costs. The cost per pound of crude protein ($1.01/lb CP) was very high because the quantity of crude protein captured per acre was very low. The crude protein content of the forage was below the requirements of a dry cow making it necessary to provide purchased supplement crude protein. The forage dry matter cost ($97.33/ton) was very high because the quantity of forage weight per acre was low. The low forage weight per acre made it necessary to use more than double the land area that would have been needed during the summer period to provide a cow with adequate forage dry matter for a month in the same pasture. The large land area (5.33 acres) per cow caused the forage costs per period to be high. The total daily forage and supplemental crude protein costs ($1.48/day) were very high. The total feed costs were greater than the low market value of the accumulated calf fetus weight causing a high loss in returns after feed costs ($-29.79) per cow and a moderate loss in returns after feed costs ($-5.59) per acre. The cost per pound of calf fetus weight gain ($1.90/lb) was extremely high because of the low forage dry matter yields per acre, the low crude protein content in the forage, the large land area per cow, and growth in weight of the fetus was relatively slow.

Third Trimester

Reserved native rangeland managed as a repeated seasonal pasture was evaluated during the third trimester production period for 90 days between mid December and mid March (table 1). Native rangeland forage during the fall and winter dormancy period has a crude protein content of around 4.8%. Late-season native rangeland forage has pasture rent value or production costs of $8.76 per acre, forage dry matter costs of $120.83 per ton, and crude protein costs of $1.26 per pound. A cow grazing during the third trimester would require 18.62 acres (6.31 acres per month) at a forage cost of $163.12 per production period. The crude protein content of mature native rangeland forage is below the requirements of a cow in the third trimester, and crude protein would need to be supplemented at 0.43 lbs per cow per day at a cost of $11.61 per period. Total feed costs would be $174.73 per period and $9.38 per acre, or $1.94 per day. Calf fetus weight gain was assumed to be 0.78 lbs per day; accumulated weight gain was 70.08 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $49.06 per calf and $2.63 per acre. The net returns after pasture costs were a loss of $125.67 per cow-calf pair and a loss of $6.75 per acre. The cost of calf fetus weight gain was $2.49 per pound.

Reserved native rangeland forage grazed as a repeated seasonal pasture during the third trimester production period was high-cost forage because the quantities of crude protein captured per acre were low and the quantity of forage dry matter available per acre was low. Total forage costs for reserved native rangeland pastures was high, even though the equipment costs, labor costs, land rent per acre, and forage production costs per acre were low, because the input costs do not directly regulate livestock forage feed costs. The cost per pound of crude protein ($1.26/lb CP) was extremely high because the quantity of crude protein captured per acre was extremely low. The crude protein content of the forage was below the requirements of a gestating cow making it necessary to provide purchased supplemental crude protein. The forage dry matter cost ($120.83/ton) was extremely high because the quantity of forage weight per acre was low. The low forage weight per acre made it necessary to use 2.5 times the land area that would have been needed during the summer period to provide a cow with adequate forage dry matter for a month in the same pasture. The large land area (18.62 acres) per cow caused the forage costs per period to be high. The total daily forage and supplemental crude protein costs ($1.94/day) were extremely high. The total feed costs were greater than the low market value of the accumulated calf fetus weight causing an extremely high loss in returns after feed costs ($-125.67) per cow and a moderate loss in returns after feed costs of ($-6.75) per acre. The cost per pound of calf fetus weight gain ($2.49/lb) was extremely high because of the very low crude protein and very low forage dry matter yields per acre, the large land area per cow, and growth in weight of the fetus was relatively slow.

Early Lactation

Reserved native rangeland managed as a repeated seasonal pasture was evaluated during the early lactation production period for 45 days between mid March and late April (table 1). Forage on native rangeland pasture during early spring has a crude protein content of around 9.2%. Early spring native rangeland forage has pasture rent value or production costs of $8.76 per acre, forage dry matter costs of $140.16 per ton, and crude protein costs of $0.76 per pound. A cow grazing during the early lactation period would require 10.80 acres (7.32 acres per month) at a forage cost of $94.64 per production period. The crude protein content of early spring native rangeland forage is below the requirements of a cow during early lactation, however, crude protein was not supplemented. Total feed costs would be $94.64 per period and $8.76 per acre, or $2.10 per day. Calf weight gain was assumed to be 1.80 lbs per day; accumulated weight gain was 81.0 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $56.70 per calf and $5.25 per acre. The net returns after pasture costs were a loss of $37.94 per cow-calf pair and a loss of $3.51 per acre. The cost of calf weight gain was $1.17 per pound.

Reserved native rangeland forage grazed as a repeated seasonal pasture during the early lactation production period was high-cost forage because the quantities of crude protein captured per acre were low and the quantity of forage dry matter available per acre was very low. Total forage costs for reserved native rangeland pastures was high, even though the equipment costs, labor costs, land rent per acre, and forage production costs per acre were low, because the input costs do not directly regulate livestock forage feed costs. The cost per pound of crude protein ($0.76/lb CP) was very high because the quantity of crude protein captured per acre was low. The crude protein content of the forage was below the requirements of a lactating cow, however, crude protein was not supplemented. The forage dry matter cost ($140.16/ton) was excessively high because the quantity of forage weight per acre was extremely low. The low forage weight per acre made it necessary to use about three times the land area that would have been needed during the summer period to provide a cow with adequate forage dry matter for a month in the same pasture. The large land area (10.80 acres) per cow caused the forage costs per period to be very high. The total daily forage feed costs ($2.10/day) were extremely high. The total feed costs were greater than the low market value of the accumulated calf weight causing a very high loss in returns after feed costs ($-37.94) per cow and a moderate loss in returns after feed costs ($-3.51) per acre. The cost per pound of calf weight gain ($1.17/lb) was very high because of the low forage dry matter yields per acre, the low crude protein content in the forage, and the large land area per cow-calf pair.

Spring Lactation

Native rangeland managed as a repeated seasonal pasture was evaluated during the spring lactation production period for 31 days between early and late May (table 1). Native rangeland grass plants have not reached the three and a half new leaf growth stage and are not physiologically ready for grazing during the spring lactation production period in May. Native rangeland forage during the spring has a crude protein content of around 16.3%. Spring native rangeland forage had pasture rent value or production costs of $8.76 per acre, forage dry matter costs of $89.85 per ton, and crude protein costs of $0.28 per pound. A cow grazing during the spring lactation period required 4.77 acres (4.62 acres per month) at a forage cost of $41.85 per production period. Additional roughage or crude protein were not supplemented on this pasture forage type. Total forage feed costs were $41.85 per period and $8.76 per acre, or $1.35 per day. Calf weight gain was 1.80 lbs per day and 11.70 lbs per acre; accumulated weight gain was 55.80 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $39.06 per calf and $8.18 per acre. The net returns after pasture costs were a loss of $2.79 per cow-calf pair and a loss of $0.58 per acre. The cost of calf weight gain was $0.75 per pound.

Native rangeland forage grazed as a repeated seasonal pasture during the spring lactation production period was high-cost forage because the quantities of crude protein captured per acre were low and the quantity of forage dry matter available per acre was low, despite the equipment costs, labor costs, land rent per acre, and forage production costs per acre being low. The cost per pound of crude protein ($0.28/lb CP) was high because the quantity of crude protein captured per acre was low. The forage dry matter cost ($89.85/ton) was very high because the quantity of forage weight per acre was low. The low forage weight per acre made it necessary to use about two times the land area that would have been needed during the summer period to provide a cow with adequate forage dry matter for a month in the same pasture. The large land area (4.77 acres) per cow caused the forage costs per period to be high. The total daily forage feed costs ($1.35/day) were very high. The total feed costs were greater than the low market value of the accumulated calf weight causing a moderate loss in returns after feed costs ($-2.79) per cow and a low loss in returns after feed costs ($-0.58) per acre. The cost per pound of calf weight gain ($0.75/lb) was high because the low crude protein and low forage dry matter yields per acre, and the large land area per cow-calf pair.

Summer Lactation

Native rangeland managed as a repeated seasonal pasture was evaluated during the summer lactation production period for 137 days between early June and mid October (table 1). Native rangeland forage during mid summer has a crude protein content of around 9.6%. Summer native rangeland forage had pasture rent value or production costs of $8.76 per acre, forage dry matter costs of $48.26 per ton, and crude protein costs of $0.25 per pound. A cow grazing during the summer lactation period required 11.32 acres (2.52 acres per month) at a forage cost of $98.64 per production period. Additional roughage or crude protein were not supplemented on this pasture forage type. Total forage feed costs were $98.64 per period and $8.76 per acre, or $0.72 per day. Calf weight gain was 1.80 lbs per day and 21.78 lbs per acre; accumulated weight gain was 246.60 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $172.62 per calf and $15.30 per acre. The net returns after pasture costs were $73.98 per cow-calf pair and $6.54 per acre. The cost of calf weight gain was $0.40 per pound.

Native rangeland forage grazed as a repeated seasonal pasture during the summer lactation production period was moderate-cost forage because the quantities of crude protein captured per acre were moderate and the quantity of forage dry matter available per acre was moderate. The equipment costs, labor costs, land rent per acre, and forage production costs per acre were low. The cost per pound of crude protein ($0.25/lb CP) was moderate because of the moderate quantity of crude protein weight contained in the forage. The forage dry matter cost ($48.26/ton) was high because of the moderate quantity of forage dry matter production. The large land area (11.32 acres) per cow caused the forage costs per period to be high. The total daily forage feed costs ($0.72/day) were high. The total feed costs were lower than the low market value of the accumulated calf weight resulting in high returns after feed costs ($73.98) per cow and in low returns after feed costs ($6.54) per acre. The cost per pound of calf weight gain ($0.40/lb) was moderately high because of the moderate crude protein and moderate forage dry matter yields per acre and the large land area per cow-calf pair.

Fall Lactation

Native rangeland managed as a repeated seasonal pasture was evaluated during the fall lactation production period for 30 days between mid October and mid November (table 1). Native rangeland forage during the fall has a crude protein content of around 4.8%. Fall native rangeland forage had pasture rent value or production costs of $8.76 per acre, forage dry matter costs of $88.85 per ton, and crude protein costs of $0.92 per pound. A cow grazing during the fall lactation period required 4.60 acres at a forage cost of $40.30 per production period. The crude protein content of mature native rangeland forage is below the requirements of a lactating cow during the fall, and crude protein would need to be supplemented at 1.21 lbs per cow per day at a cost of $10.90 per period. Total forage feed costs were $51.20 per period and $11.13 per acre, or $1.71 per day. Calf weight gain was 1.80 lbs per day and 11.83 lbs per acre; accumulated weight gain was 54.00 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $37.80 per calf and $8.22 per acre. The net returns after pasture costs were a loss of $13.40 per cow-calf pair and a loss of $2.91 per acre. The cost of calf weight gain was $0.95 per pound.

Native rangeland forage grazed as a repeated seasonal pasture during the fall lactation production period was high-cost forage because the quantities of crude protein captured per acre were low and the quantity of forage dry matter available per acre was low. Total forage costs for native rangeland grazed as a repeated seasonal pasture was high, even though the equipment costs, labor costs, land rent per acre, and forage production costs per acre were low, because the input costs did not directly regulate livestock forage feed costs. The cost per pound of crude protein ($0.92/lb CP) was very high because of the low quantity of crude protein weight contained in the forage. The crude protein content of the forage was below the requirements of a lactating cow making it necessary to provide purchased supplemental crude protein. The forage dry matter cost ($88.85/ton) was very high because of the low quantity of forage dry matter production. The low forage weight per acre made it necessary to use about two times the land area that would have been needed during the summer period to provide a cow with adequate forage dry matter for a month in the same pasture. The large land area (4.60 acres) per cow caused the forage costs per period to be high. The total daily forage and supplemental crude protein costs ($1.71/day) were extremely high. The total feed costs were greater than the low market value of the accumulated calf weight causing a high loss in returns after feed costs ($-13.40) per cow and a moderate loss in returns after feed costs ($-2.91) per acre. The cost per pound of calf weight gain ($0.95/lb) was very high because of the low crude protein and low forage dry matter yields per acre and the large land area per cow-calf pair.

12-month Season

The 12-month repeated seasonal management strategy with native rangeland and reserved native rangeland pastures was a high-cost forage management strategy (table 1). The 12-month forage feed costs at $1.39 per day were very high, the 12-month forage crude protein costs at $0.62 per pound were very high, and the 12-month calf weight gain costs at $0.95 per pound were very high. The 12-month land area per cow at 55.44 acres was extremely large. The 12-month returns after feed costs at $-135.61 per cow was an extremely high loss and at $-2.45 per acre was a moderate loss. The 12-month repeated seasonal management strategy has no harvested forage feeds; the cattle graze six different pastures during the year. There are no equipment costs or labor costs charged to the forage feed costs. And yet, this management strategy has the highest forage feed costs per day, the highest forage crude protein costs per pound, the highest calf weight gain costs per pound, and the largest land area per cow. The returns after feed costs were the greatest loss per cow and the greatest loss per acre. The elimination of equipment costs, labor costs, and harvested forage costs does not reduce beef production costs and improve profit margins.

The reserved native rangeland pastures grazed during the nongrowing season of the repeated seasonal management strategy gave the false impression of being low cost forage because the production costs per acre were low and no harvested forage was fed. However, because the forage dry matter yield per acre was about 40% of the forage dry matter yield during the summer period, the weight of crude protein capture per acre was about 20% to 25% of the crude protein capture per acre during the summer period, and the land area required per cow was greater than 2.5 times the land area required per cow during the summer period, the forage from the reserved pastures was high-cost. The cost of the forage was greater than the low market value of the calf weight accumulated during the nongrowing season (mid November to late April) resulting in a high loss of $193.40 per cow and a high loss of $5.57 per acre. Additional financial losses were derived as a result of the decision to use the pastures as reserved forage during the nongrowing season rather than to use the pastures as metabolically active forage during the growing season, which in effect, prevented the capture of the potential new wealth generated from the land resources. The potential revenue that could be captured from the forage crude protein produced on the land and available during the summer period ranges between $40 and $133 per cow and between $2 and $15 per acre depending on the management treatment implemented. This potential new wealth generated from the land resources that was not captured during the growing season was a major loss that should be considered when developing management plans that include reserved native rangeland pastures grazed during the nongrowing season.

Table 1. Twelve month costs and returns on the No Hay Repeated Seasonal management strategy for 1200 lb cow with 8 month old calf born mid March.

		Production Period						
		Dry Gestation	Third Trimester	Early Lactation	Spring Lactation	Summer Lactation	Fall Lactation	12-month Season
Days		32	90	45	31	137	30	365
Forage Type		Native Range	Native Range	Native Range	Native Range	Native Range	Native Range	
Forage DM Weight	lbs/ac	180.0	145.0	125.0	195.0	363.0	199.0	197.76
Production Costs	$/ac	8.76	8.76	8.76	8.76	8.76	8.76	8.76
Forage DM Costs	$/ton	97.33	120.83	140.16	89.85	48.26	88.85	88.59
Crude Protein	%	4.8	4.8	9.2	16.3	9.6	4.8	7.10
CP Yield	lbs/ac	8.6	6.96	11.5	31.79	34.85	9.55	14.13
* CP Costs (≤ $0.25)	$/lb	1.01	1.26	0.76	0.28	0.25	0.92	0.62
Forage Allocation	lbs/pp	960.0	2700.0	1350.0	930.0	4110.0	900.0	10950.0
* Land Area	ac	5.33	18.62	10.80	4.77	11.32	4.60	55.44
Roughage Allocation	lbs/pp	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CP Supp.	lbs/pp	1.6	38.7	0.0	0.0	0.0	36.3	76.6
Forage Costs	$/pp	46.75	163.12	94.64	41.85	98.64	40.30	485.30
Roughage Costs	$/pp	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CP Supp. Costs	$/pp	0.48	11.61	0.0	0.0	0.0	10.90	22.99
Total Feed Costs	$/pp	47.23	174.73	94.64	41.85	98.64	51.20	508.29
Feed Cost/Acre	$/ac	8.86	9.38	8.76	8.76	8.76	11.13	9.17
* Cost/Day (≤ $0.62)	$/d	1.48	1.94	2.10	1.35	0.72	1.71	1.39
Accumulated Calf Wt.	lbs	24.92	70.08	81.00	55.80	246.60	54.00	532.40
Weight Value @ $0.70/lb	$	17.44	49.06	56.70	39.06	172.62	37.80	372.68
Gross Return/Acre	$	3.27	2.63	5.25	8.18	15.30	8.22	6.72
Net Return/c-cpr	$	-29.79	-125.67	-37.94	-2.79	73.98	-13.40	-135.61
* Net Return/acre	$	-5.59	-6.75	-3.51	-0.58	6.54	-2.91	-2.45
*Cost/lb of Calf Gain (≤ $0.42)	$	1.90	2.49	1.17	0.75	0.40	0.95	0.95

* Factors with diagnostic value in selection of low cost-high return forage types and 12 month management strategies.

Traditional Seasonlong

Dry Gestation

Crested wheatgrass hay cut late, at a mature plant stage, has a crude protein content of around 6.4%. This low-quality perennial grass hay has production costs of $28.11 per acre, forage dry matter costs of $35.14 per ton, and crude protein costs of $0.28 per pound. Late-cut crested wheatgrass hay would be fed at 23.4 lbs DM/day to provide 1.5 lbs CP/day. An additional 0.6 lbs of roughage per day would need to be provided, at a cost of $0.34 per period. Production of late-cut crested wheatgrass hay to feed during the dry gestation production period (table 2) would require 0.47 acres, and the forage would cost $13.21 per production period. Total forage and supplement costs would be $13.55 per period and $28.83 per acre, or $0.42 per day. Calf fetus weight gain was assumed to be 0.78 lbs per day; accumulated weight gain was 24.92 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $17.44 per calf and $37.11 per acre. The net returns after feed costs were $3.89 per cow-calf pair and $8.28 per acre. The cost of calf fetus weight gain was $0.54 per pound.

Crested wheatgrass hay cut at a mature growth stage and fed during the dry gestation production period was moderate-cost forage. Basically, the dry gestation production period is the only period that the nutrient content of mature crested wheatgrass hay meets the dietary requirements of range cows and is the only period that mature crested wheatgrass hay is lower cost, by a few cents, than crested wheatgrass hay cut at the boot stage. The forage dry matter cost ($35.14/ton) was moderate for mature crested wheatgrass hay and lower than the forage dry matter cost per ton for early cut crested wheatgrass hay because greater dry matter weight of the mature crested wheatgrass hay was harvested per acre. The cost per pound of crude protein ($0.28/lb CP) was high for mature crested wheatgrass hay and double the cost per pound of crude protein for early cut crested wheatgrass hay because of the lower crude protein weight in the mature crested wheatgrass hay harvested per acre. The land area (0.47 acres) per cow for mature crested wheatgrass hay was small but greater than the land area required per cow for early cut crested wheatgrass hay because of the greater crude protein weight per acre in the early cut crested wheatgrass hay. The total daily forage cost ($0.42/day) for mature crested wheatgrass hay was low because very little supplemental roughage was needed to be provided. The total feed costs were lower than the low market value of the accumulated calf fetus weight resulting in low returns after feed costs ($3.89) per cow and ($8.28) per acre. The cost per pound of calf fetus weight gain ($0.54/lb) was moderate because the production costs per acre were moderate and mature crested wheatgrass hay met the nutrient requirements of dry range cows.

Third Trimester

Oat forage hay cut late, at the hard dough stage, has a crude protein content of 7.8%. This oat forage hay has production costs of $74.53 per acre, forage dry matter costs of $26.40 per ton, and crude protein costs of $0.17 per pound. Late-cut oat hay would be fed at 24.0 lbs DM/day to provide 1.9 lbs CP/day. Production of late-cut oat hay to feed during the third trimester (table 2) would require 0.38 acres, and the forage would cost $28.80 per production period. Total forage feed costs would be $28.80 per period and $75.79 per acre, or $0.32 per day. Calf fetus weight gain was assumed to be 0.78 lbs per day; accumulated weight gain was 70.08 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $49.06 per calf and $129.11 per acre. The net returns after feed costs were $20.26 per cow-calf pair and $53.32 per acre. The cost of calf fetus weight gain was $0.41 per pound.

Oat forage hay cut at the hard dough growth stage and fed during the third trimester production period was low-cost forage. The production costs per acre were high for late cut oat forage hay because the equipment costs, labor costs, and land rent per acre were high. The forage dry matter cost ($26.40/ton) was low because of the high forage dry matter production. The cost per pound of crude protein ($0.17/lb CP) was low because of the high crude protein weight contained in the forage. The cost per pound of crude protein for late cut oat forage hay was greater than the cost per pound of crude protein for early cut oat forage hay because of the lower crude protein weight harvested per acre in the late cut oat forage hay. The land area (0.38 acres) per cow was small because of the high crude protein and high forage dry matter yields per acre. The total daily forage feed costs ($0.32/day) were low because of the low cost of crude protein per pound and the high forage dry matter production. The total forage feed costs for late cut oat forage hay were lower than the total forage feed costs for early cut oat forage hay because of the greater quantity of supplemental roughage in the forage ration for early cut oat forage hay. The total feed costs were lower than the low market value of the accumulated calf fetus weight resulting in moderate returns after feed costs ($20.26) per cow and in high returns after feed costs ($53.32) per acre. The cost per pound of calf fetus weight gain ($0.41/lb) was moderate because growth in weight of the fetus was relatively slow.

Early Lactation

Oat forage hay cut late, at the hard dough stage, has a crude protein content of 7.8%. This oat forage hay has production costs of $74.53 per acre, forage dry matter costs of $26.40 per ton, and crude protein costs of $0.17 per pound. Late-cut oat hay would be fed at 27.0 lbs DM/day to provide 2.1 lbs CP/day. An additional 0.62 lbs of crude protein per day would need to be provided, at a cost of $8.37 per period. Production of late-cut oat hay to feed during the early lactation period (table 2) would require 0.21 acres, and the forage would cost $16.04 per production period. Total forage and supplement costs would be $24.41 per period and $116.24 per acre, or $0.54 per day. Calf weight gain was assumed to be 1.90 lbs per day; accumulated weight gain was 85.5 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $59.85 per calf and $285.00 per acre. The net returns after feed costs were $35.44 per cow-calf pair and $168.76 per acre. The cost of calf weight gain was $0.29 per pound.

Oat forage hay cut at the hard dough growth stage and fed during the early lactation production period was low-cost forage. The production costs per acre were high for late cut oat forage hay because the equipment costs, labor costs, and land rent per acre were high. The forage dry matter cost ($26.40/ton) was low because of the high forage dry matter production. The cost per pound of crude protein ($0.17/lb CP) was low because of the high crude protein weight contained in the forage. The cost per pound of crude protein for late cut oat forage hay was greater than the cost per pound of crude protein for early cut oat forage hay because of the lower crude protein weight harvested per acre in the late cut oat forage hay. The land area (0.21 acres) per cow was small because of the high forage dry matter yield per acre. The crude protein content of the forage was below the requirements of a lactating cow making it necessary to provide purchased supplemental crude protein. The total daily forage and supplemental crude protein costs ($0.54/day) were moderate because of the high cost of the supplemental crude protein. The total feed costs were lower than the low market value of the accumulated calf weight resulting in high returns after feed costs ($35.44) per cow and in very high returns after feed costs ($168.76) per acre. The cost per pound of calf weight gain ($0.29/lb) was low because of the very small land area per cow-calf pair.

Spring Lactation

Crested wheatgrass seeded domesticated grassland managed as an unfertilized complementary spring pasture was evaluated during the spring lactation production period for 31 days between early and late May (table 2). Unfertilized crested wheatgrass forage during the spring has a crude protein content of around 16.8%. Crested wheatgrass grassland forage had pasture rent value or production costs of $8.76 per acre and forage dry matter costs of $35.39 per ton. A cow grazing during the spring lactation period required 1.88 acres at a forage cost of $16.47 per production period. Additional roughage or crude protein were not supplemented on this pasture forage type. Total forage feed costs were $16.47 per period and $8.76 per acre, or $0.52 per day. Cow weight gain was 1.95 lbs per day and 32.15 lbs per acre; accumulated weight gain was 60.45 lbs. Calf weight gain was 1.91 lbs per day and 31.49 lbs per acre; accumulated weight gain was 59.21 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $41.45 per calf and $22.05 per acre. The net returns after pasture costs were $24.98 per cow-calf pair and $13.29 per acre. The cost of calf weight gain was $0.27 per pound.

Crested wheatgrass grassland grazed as complementary pasture during the spring lactation production period was low-cost forage because the quantities of crude protein captured per acre were seasonally high, the quantity of forage dry matter available per acre was seasonally high, and the equipment costs, labor costs, land rent per acre, and forage production costs per acre were low. The cost per pound of crude protein ($0.11/lb CP) was low because of the seasonally high crude protein weight contained in the forage. The forage dry matter cost ($35.39/ton) was moderate because of the rapid early season forage dry matter production. The land area (1.88 acres) per cow was small because of the seasonally high crude protein and seasonally high forage dry matter yields per acre. The total daily forage feed costs ($0.52/day) were low because of the low cost of crude protein per pound and the small land area per cow. The total feed costs were lower than the low market value of the accumulated calf weight resulting in moderate returns after feed costs ($24.98) per cow and in moderate returns after feed costs ($13.29) per acre. The cost per pound of calf weight gain ($0.27/lb) was low because of the low cost per pound of crude protein and the small land area per cow-calf pair.

Summer Lactation

Native rangeland managed as a 4.5-month seasonlong pasture was evaluated during the summer lactation production period for 137 days between early June and mid October (table 2). Native rangeland forage had pasture rent value or production costs of \$8.76 per acre and forage dry matter costs of \$54.75 per ton. A cow grazing during the summer lactation period was allotted 12.70 acres (2.86 acres per month) at a forage cost of \$111.25 per production period. Additional roughage or crude protein were not supplemented on this pasture forage type. Total forage feed costs were \$111.25 per period and \$8.76 per acre, or \$0.81 per day. Cow weight gain was 0.34 lbs per day and 3.67 lbs per acre; accumulated weight gain was 46.58 lbs. Calf weight gain was 2.09 lbs per day and 22.55 lbs per acre; accumulated weight gain was 286.33 lbs. When calf accumulated weight was assumed to have a value of \$0.70 per pound, the gross return was \$200.43 per calf and \$15.78 per acre. The net returns after pasture costs were \$89.18 per cow-calf pair and \$7.02 per acre. The cost of calf weight gain was \$0.39 per pound.

Native rangeland forage grazed as a 4.5-month seasonlong pasture during the summer lactation production period was high-cost forage because the quantity of forage dry matter available per acre was low and the crude protein content in the forage was low after early August, despite the equipment costs, labor costs, land rent per acre, and forage production costs per acre being very low. The forage dry matter cost (\$54.75/ton) was high because the quantity of forage weight per acre was low. The low forage availability per acre and the low crude protein content in the forage after early August were major causes of the low cow and calf weight performance per acre. The large land area (12.70 acres) per cow caused the forage costs per period to be high. The total daily forage feed costs (\$0.81/day) were high. The total feed costs were lower than the low market value of the accumulated calf weight resulting in high returns after feed costs (\$89.18) per cow and in low returns after feed costs (\$7.02) per acre. The cost per pound of calf weight (\$0.39/lb) was moderately low because of the low forage dry matter yields per acre, the low crude protein content of the forage during the latter portion of the grazing season, the low animal weight performance per acre, and the large land area per cow-calf pair.

Fall Lactation

The traditional management strategy had a separate native rangeland pasture for fall grazing and was evaluated during the fall lactation production period for 30 days between mid October and mid November (table 2). Native rangeland forage had pasture rent value or production costs of \$8.76 per acre and forage dry matter costs of \$79.28 per ton. The stocking rate was adjusted from the summer rates to match the reduction in fall herbage biomass. A cow grazing during the fall lactation period was allotted 4.07 acres at a forage cost of \$35.65 per production period. The crude protein content of mature native rangeland forage is below the requirements of a lactating cow during the fall, and crude protein would need to be supplemented at 1.07 lbs per cow per day at a cost of \$9.63 per period. Total forage feed costs were \$45.28 per period and \$11.13 per acre, or \$1.51 per day. Cows lost 0.82 lbs per day and lost 9.77 lbs per acre; accumulated weight loss was 24.60 lbs. Calf weight gain was 0.92 lbs per day and 10.90 lbs per acre; accumulated weight gain was 27.60 lbs. When calf accumulated weight was assumed to have a value of \$0.70 per pound, the gross return was \$19.32 per calf and \$4.75 per acre. The net returns after pasture costs were a loss of \$25.96 per cow-calf pair and a loss of \$6.38 per acre. The cost of calf weight gain was \$1.64 per pound.

Native rangeland forage grazed during the fall lactation production period was high cost forage because the quantity of forage dry matter available per acre was low and the crude protein content of the forage was low. Total forage costs for native rangeland grazed for 30 days during the fall was high, even though the equipment costs, labor costs, land rent per acre, and forage production costs per acre were very low, because the input costs did not directly regulate livestock forage feed cost. The forage dry matter cost (\$79.28/ton) was high because the quantity of forage weight per acre was low. The low forage availability per acre and the low crude protein content in the forage were major causes for the low cow and calf weight performance per acre. The high land area (4.07 acres/month) per cow caused the forage costs per period to be high. The total daily forage feed costs (\$1.51/day) were high. The total feed costs (\$45.28/period) were greater than the low market value of the accumulated calf weight causing a high loss in returns after feed costs (\$-25.96) per cow and a high loss in returns after feed costs (\$-6.38) per acre. The cost per pound of calf weight gain (\$1.64/lb) was high because of the low forage dry matter yield per acre, the low crude protein content in the forage, the low animal weight performance per acre, and the large land area per cow-calf pair.

12-month Season

The 12-month traditional seasonlong management strategy with a summer native rangeland pasture and complementary spring crested wheatgrass and fall native rangeland pastures and harvested forage of mature crested wheatgrass hay and oat forage hay cut late was a typical low profit margin management strategy. The 12-month forage feed costs at $239.76 per year and $0.66 per day was high, the 12-month forage crude protein costs at $0.30 per pound were high, and the 12-month calf weight gain costs at $0.43 per pound were moderate. The 12-month land area per cow at 19.71 acres was large. The 12-month returns after feed costs at $147.79 per cow and at $7.50 per acre were low.

Table 2. Twelve month costs and returns on the Traditional 4.5 Month Seasonlong management strategy for 1200 lb cow with 8 month old calf born mid March.

		Production Period						
		Dry Gestation	Third Trimester	Early Lactation	Spring Lactation	Summer Lactation	Fall Lactation	12-month Season
Days		32	90	45	31	137	30	365
Forage Type		Crested Hay Late	Oat Hay Late	Oat Hay Late	Crested Wheat	Native Range	Native Range	
Forage DM Weight	lbs/ac	1600.0	5667.0	5667.0	495.0	320.0	221.0	506.83
Production Costs	$/ac	28.11	74.53	74.53	8.76	8.76	8.76	12.16
Forage DM Costs	$/ton	35.14	26.40	26.40	35.39	54.75	79.28	47.91
Crude Protein	%	6.4	7.8	7.8	16.8	8.4	4.8	8.1
CP Yield	lbs/ac	102	435	435	83.36	23.68	10.61	40.85
* CP Costs (≤ $0.25)	$/lb	0.28	0.17	0.17	0.11	0.37	0.83	0.30
Forage Allocation	lbs/pp	748.8	2160.0	1215.0	930.0	4110.0	900.0	10063.8
* Land Area	ac	0.47	0.38	0.21	1.88	12.70	4.07	19.71
Roughage Allocation	lbs/pp	19.2	0.0	0.0	0.0	0.0	0.0	19.2
CP Supp.	lbs/pp	0.0	0.0	27.9	0.0	0.0	32.1	60.0
Forage Costs	$/pp	13.21	28.80	16.04	16.47	111.25	35.65	221.42
Roughage Costs	$/pp	0.34	0.0	0.0	0.0	0.0	0.0	0.34
CP Supp. Costs	$/pp	0.0	0.0	8.37	0.0	0.0	9.63	18.00
Total Feed Costs	$/pp	13.55	28.80	24.41	16.47	111.25	45.28	239.76
Feed Cost/Acre	$/ac	28.83	75.79	116.24	8.76	8.76	11.13	12.16
* Cost/Day (≤ $0.62)	$/d	0.42	0.32	0.54	0.52	0.81	1.51	0.66
Accumulated Calf Wt.	lbs	24.92	70.08	85.50	59.21	286.33	27.60	553.64
Weight Value @ $0.70/lb	$	17.44	49.06	59.85	41.45	200.43	19.32	387.55
Gross Return/Acre	$	37.11	129.11	285.00	22.05	15.78	4.75	19.66
Net Return/c-cpr	$	3.89	20.26	35.44	24.98	89.18	-25.96	147.79
* Net Return/acre	$	8.28	53.32	168.76	13.29	7.02	-6.38	7.50
* Cost/lb of Calf Gain (≤ $0.42)	$	0.54	0.41	0.29	0.27	0.39	1.64	0.43

* Factors with diagnostic value in selection of low cost-high return forage types and 12 month management strategies.

Biologically Effective Twice-over Rotation

Dry Gestation

Forage barley hay cut late, at the hard dough stage, has a crude protein content of 9.2%. This forage barley hay has production costs of $70.35 per acre, forage dry matter costs of $27.40 per ton, and crude protein costs of $0.15 per pound. Late-cut forage barley hay would be fed at 16.2 lbs DM/day to provide 1.5 lbs CP/day. An additional 7.8 lbs of roughage per day would need to be provided, at a cost of $4.37 per period. Production of late-cut forage barley hay to feed during the dry gestation production period (table 3) would require 0.10 acres, and the forage would cost $7.04 per production period. Total forage and supplement costs would be $11.41 per period and $114.10 per acre, or $0.36 per day. Calf fetus weight gain was assumed to be 0.78 lbs per day; accumulated weight gain was 24.92 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $17.44 per calf and $174.40 per acre. The net returns after feed costs were $6.03 per cow-calf pair and $60.30 per acre. The cost of calf fetus weight gain was $0.46 per pound.

Forage barley hay cut at the hard dough growth stage and fed during the dry gestation production period was low-cost forage. The production costs per acre were high for late cut forage barley hay because the equipment costs, labor costs, and land rent per acre were high. The forage dry matter cost ($27.40/ton) was low because of the high forage dry matter production. The cost per pound of crude protein ($0.15/lb CP) was low because of the high crude protein weight contained in the forage. The cost per pound of crude protein for late cut forage barley hay was greater than the cost per pound of crude protein for early cut forage barley hay because of the lower crude protein weight harvested per acre in the late cut forage barley hay. The land area (0.10 acres) per cow was very small because of the high crude protein and high forage dry matter yields per acre. The total daily forage and supplemental roughage costs ($0.36/day) were low because of the low cost of crude protein per pound and the high forage dry matter production. The total feed costs were lower than the low market value of the accumulated calf fetus weight resulting in low returns after feed costs ($6.03) per cow and in high returns after feed costs ($60.30) per acre. The returns after feed costs per acre were lower for late cut forage barley hay than for early cut forage barley hay because late cut forage barley hay had slightly higher crude protein cost per pound and slightly larger land area per cow than early cut forage barley hay. The cost per pound of calf fetus weight gain ($0.46/lb) was moderate because growth in weight of the fetus was relatively slow.

Third Trimester

Forage barley hay cut early, at the milk stage, has a crude protein content of 13.0%. This forage barley hay has production costs of $68.21 per acre, forage dry matter costs of $28.80 per ton, and crude protein costs of $0.11 per pound. Early cut forage barley hay would be fed at 14.4 lbs DM/day to provide 1.9 lbs CP/day. An additional 9.6 lbs of roughage per day would need to be provided, at a cost of $14.96 per period. Production of early cut forage barley hay to feed during the third trimester (table 3) would require 0.27 acres, and the forage would cost $18.90 per production period. Total forage and supplement costs would be $33.86 per period and $125.40 per acre, or $0.38 per day. Calf fetus weight gain was assumed to be 0.78 lbs per day; accumulated weight gain was 70.08 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $49.06 per calf and $181.70 per acre. The net returns after feed costs were $15.20 per cow-calf pair and $56.30 per acre. The cost of calf fetus weight gain was $0.48 per pound.

Forage barley hay cut at the milk growth stage and fed during the third trimester production period was low-cost forage. The production costs per acre were high for early cut forage barley hay because the equipment costs, labor costs, and land rent per acre were high. The forage dry matter cost ($28.80/ton) was low because of the high forage dry matter production. The cost per pound of crude protein ($0.11/lb CP) was low because of the high crude protein weight contained in the forage. The land area (0.27 acres) per cow was small because of the high crude protein and high forage dry matter yields per acre. The total daily forage and supplemental roughage costs ($0.38/day) were low because of the low cost of crude protein per pound and the high forage dry matter production. The total forage feed costs for early cut forage barley hay was slightly greater than the total forage feed costs for late cut forage barley hay because of the greater quantity of supplemental roughage in the forage ration for early cut forage barley hay. The total feed costs were lower than the low market value of the accumulated calf fetus weight resulting in moderate returns after feed costs ($15.20) per cow and in high returns after feed costs ($56.30) per acre. The cost per pound of calf fetus weight gain ($0.48/lb) was moderate because growth in weight of the fetus was relatively slow.

Early Lactation

Pea forage hay cut at a late plant stage has a crude protein content of 14.4%. This pea forage hay has production costs of $86.87 per acre, forage dry matter costs of $37.40 per ton, and crude protein costs of $0.13 per pound. Late-cut pea forage hay would be fed at 19.0 lbs DM/day to provide 2.7 lbs CP/day. An additional 8.0 lbs of roughage per day would need to be provided, at a cost of $6.30 per period. Production of late-cut pea forage hay to feed during the early lactation period (table 3) would require 0.18 acres, and the forage would cost $15.75 per production period. Total forage and supplement costs would be $22.05 per period and $122.50 per acre, or $0.49 per day. Calf weight gain was assumed to be 1.90 lbs per day; accumulated weight gain was 85.5 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $59.85 per calf and $332.50 per acre. The net returns after feed costs were $37.80 per cow-calf pair and $210.00 per acre. The cost of calf weight gain was $0.26 per pound.

Pea forage hay cut at a late growth stage and fed during the early lactation production period was low-cost forage. Late cut pea forage hay has lower forage feed costs and greater revenue returns after feed costs than early cut pea forage hay. The production costs per acre were high for late cut pea forage hay because the equipment costs, labor costs, seed costs, and land rent per acre were high. The forage dry matter cost ($37.40/ton) was moderate because of the high forage dry matter production. The cost per pound of crude protein ($0.13/lb CP) was low because of the high crude protein weight contained in the forage. The land area (0.18 acres) per cow was very small because of the high crude protein and high forage dry matter yields per acre. The total daily forage and supplemental roughage costs ($0.49/day) were low because of the low cost of crude protein per pound, the high forage dry matter production per acre, and the very small land area per cow. The total feed costs were lower than the low market value of the accumulated calf weight resulting in high returns after feed costs ($37.80) per cow and in extremely high returns after feed costs ($210.00) per acre. The cost per pound of calf weight gain ($0.26/lb) was low because of the low cost per pound of crude protein, the high forage dry matter production per acre, and the very small land area per cow-calf pairs.

Spring Lactation

Crested wheatgrass seeded domesticated grassland managed as a fertilized complementary spring pasture was evaluated during the spring lactation production period for 31 days between early and late May (table 3). Crested wheatgrass grassland forage had pasture rent value of $8.76 per acre and 50 lbs nitrogen per acre applied during the first week of April had costs of $12.50 per acre; the resulting production costs were $21.26 per acre, and forage dry matter costs were $34.29 per ton. A cow grazing during the spring lactation period was allotted 0.75 acres at a forage cost of $15.95 per production period. Additional roughage or crude protein were not supplemented on this pasture forage type. Total forage feed costs were $15.95 per period and $21.26 per acre, or $0.51 per day. Cow weight gain was 2.68 lbs per day and 110.77 lbs per acre; accumulated weight gain was 83.08 lbs on 0.75 acres. Calf weight gain was 2.18 lbs per day and 90.11 lbs per acre; accumulated weight gain was 67.58 lbs on 0.75 acres. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $47.31 per calf and $63.08 per acre. The net returns after pasture costs were $31.36 per cow-calf pair and $41.82 per acre. The cost of calf weight gain was $0.24 per pound.

Crested wheatgrass grassland grazed as a complementary pasture during the spring lactation production period was low-cost forage because the quantities of crude protein and the quantities of forage dry matter available per acre were seasonally high. The production costs per acre were moderate. The forage dry matter cost ($34.29/ton) was low because of the rapid early season forage dry matter production. The land area (0.75 acres) per cow was small because of the seasonally high forage dry matter yield per acre. The total daily forage feed costs ($0.51/day) were low because of the small land area per cow. The total feed costs were lower than the low market value of the accumulated calf weight resulting in moderate returns after feed costs ($31.36) per cow and in high returns after feed costs ($41.82) per acre. The cost per pound of calf weight gain ($0.24/lb) was very low because of the seasonally high crude protein and seasonally high forage dry matter production and the small land area per cow-calf pair.

Summer Lactation

Native rangeland managed as a three pasture twice-over rotation system was evaluated during the summer lactation production period for 137 days between early June and mid October (table 3). Native rangeland forage had pasture rent value or production costs of $8.76 per acre and forage dry matter costs of $39.02 per ton. A cow grazing during the summer lactation period was allotted 9.00 acres (2.04 acres per month) at a forage cost of $78.84 per production period. Additional roughage or crude protein were not supplemented on this pasture forage type. Total forage feed costs were $78.84 per period and $8.76 per acre, or $0.58 per day. Cow weight gain was 0.62 lbs per day and 9.44 lbs per acre; accumulated weight gain was 84.94 lbs. Calf weight gain was 2.21 lbs per day and 33.64 lbs per acre; accumulated weight gain was 302.77 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $211.94 per calf and $23.55 per acre. The net returns after pasture costs were $133.10 per cow-calf pair and $14.79 per acre. The cost of calf weight gain was $0.26 per pound.

Native rangeland forage grazed as a twice-over rotation system during the summer lactation production period was the lowest-cost native rangeland forage because of the increase in herbage production through vegetative reproduction of grass plants and the crude protein content of the forage met the lactating cows requirements for most of the grazing season. The equipment costs, labor costs, land rent per acre, and forage production costs per acre were low. The forage dry matter cost ($39.02/ton) was low because of the stimulated additional herbage production per acre. The greater quantity of forage dry matter available per acre and the greater crude protein content in the forage were the major causes for the greater cow and calf weight performance per acre. The small land area (2.04 acres/month) per cow-calf pair was achieved because of the stimulated vegetative reproduction and the resulting increases in herbage biomass production. The total daily forage feed costs ($0.58/day) were low. The total feed costs were lower than the low market value of the accumulated calf weight resulting in very high returns after feed costs ($133.10) per cow and in high returns after feed costs ($14.79) per acre. The cost per pound of calf weight gain ($0.26/lb) was low because of the high forage dry matter yields per acre, the high crude protein content in the forage during the grazing season, the high animal weight performance per acre, and the small land area per cow-calf pair.

Fall Lactation

Spring seeded winter cereal (winter rye) managed as a seasonal pasture was evaluated during the fall lactation production period for 30 days between mid October and mid November (table 3). Spring seeded winter cereal forage had production costs of $41.75 per acre and forage dry matter costs of $43.77 per ton. A cow grazing during the fall lactation period was allotted 0.47 acres at a forage cost of $19.70 per production period. Additional roughage or crude protein were not supplemented on this pasture forage type. Total forage feed costs were $19.70 per period and $41.75 per acre, or $0.66 per day. Cow weight gain was 1.05 lbs per day and 67.02 lbs per acre; accumulated weight gain was 31.50 lbs. Calf weight gain was assumed to be 2.00 lbs per day; accumulated weight gain was 60.0 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $42.00 per calf and $89.20 per acre. The net returns after pasture costs were $22.30 per cow-calf pair and $47.45 per acre. The cost of calf weight gain was $0.33 per pound.

Spring seeded winter cereal (winter rye) grazed as a seasonal pasture during the fall lactation production period was moderate-cost forage because a relatively moderate quantity of forage dry matter was produced per acre. The winter cereal is seeded during the spring in order for the plants to develop large enough root systems to survive water stress periods during the growing season. On the average, there are two months with water deficiencies great enough to cause water stress in plants each growing season. Only 6% of the past 114 years have not had growing season months with water deficiency. The quantity of herbage available during fall and winter grazing of spring seeded winter cereal pastures is related to the severity and duration of the water stress conditions during the growing season and to the depth of packed snow and ice during the nongrowing season. The forage dry matter cost ($43.77/ton) was moderate because of the relatively moderate forage dry matter production. The land area (0.47 acres) per cow was relatively small because greater than 70% of the herbage was consumed as forage, however, the total daily forage feed costs ($0.66/day) were moderate because only a modest quantity of herbage biomass was produced as a result of growing season water stress. The total feed costs were lower than the low market value of the accumulated calf weight resulting in moderate returns after feed costs ($22.30) per cow and in high returns after feed costs ($47.45) per acre. The cost per pound of calf weight gain ($0.33/lb) was low because of the high quantity of forage available per acre, the high animal weight performance per acre, and the small land area per cow-calf pair.

12-month Season

The 12-month twice-over rotation management strategy with native rangeland pastures and complementary crested wheatgrass and spring seeded winter cereal pastures and early and late cut forage barley hay and late cut pea hay was a low-cost forage management strategy (table 3). The 12-month forage feed costs at $0.50 per day were low, the 12-month forage crude protein costs at $0.16 per pound were low, and the 12-month calf weight gain costs at $0.30 per pound were very low. The 12-month land area per cow at 10.77 acres was small. The 12-month returns after feed costs at $245.79 per cow was very high and at $22.82 per acre was high. The 12-month twice-over rotation management strategy does have all of the critical diagnostic cost factors below the threshold values and this management strategy does have the greatest returns after feed costs per cow-calf pair and per acre.

Table 3. Twelve month costs and returns on the Biologically Effective Twice-over Rotation management strategy for 1200 lb cow with 8 month old calf born mid March.

		Production Period						
		Dry Gestation	Third Trimester	Early Lactation	Spring Lactation	Summer Lactation	Fall Lactation	12-month Season
Days		32	90	45	31	137	30	365
Forage Type		Barley Hay Late	Barley Hay Early	Pea Hay Late	Crested Wheat	Native Range	Spring Seeded Winter Cereal	
Forage DM Weight	lbs/ac	5133.0	4733.0	4650.0	1240.0	449.0	1908.0	788.86
Production Costs	$/ac	70.35	68.21	86.87	21.26	8.76	41.75	14.50
Forage DM Costs	$/ton	27.40	28.80	37.40	34.29	39.02	43.77	36.76
Crude Protein	%	9.2	13.0	14.4	17.1	9.8	12.2	11.1
CP Yield	lbs/ac	468	606	685	212.6	43.8	109.0	87.2
* CP Costs (≤ $0.25)	$/lb	0.15	0.11	0.13	0.10	0.20	0.18	0.16
Forage Allocation	lbs/pp	518.4	1296.0	855.0	930.0	4110.0	900.0	8609.4
* Land Area	ac	0.10	0.27	0.18	0.75	9.00	0.47	10.77
Roughage Allocation	lbs/pp	249.6	864.0	360.0	0.0	0.0	0.0	1473.6
CP Supp.	lbs/pp	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forage Costs	$/pp	7.04	18.90	15.75	15.95	78.84	19.70	156.18
Roughage Costs	$/pp	4.37	14.96	6.30	0.0	0.0	0.0	25.63
CP Supp. Costs	$/pp	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Feed Costs	$/pp	11.41	33.86	22.05	15.95	78.84	19.70	181.81
Feed Cost/Acre	$/ac	114.10	125.40	122.50	21.26	8.76	41.75	16.88
* Cost/Day (≤ $0.62)	$/d	0.36	0.38	0.49	0.51	0.58	0.66	0.50
Accumulated Calf Wt.	lbs	24.92	70.08	85.50	67.58	302.77	60.00	610.85
Weight Value @ $0.70/lb	$	17.44	49.06	59.85	47.31	211.94	42.00	427.60
Gross Return/Acre	$	174.40	181.70	332.50	63.08	23.55	89.20	39.70
Net Return/c-cpr	$	6.03	15.20	37.80	31.36	133.10	22.30	245.79
* Net Return/acre	$	60.30	56.30	210.00	41.82	14.79	47.45	22.82
* Cost/lb of Calf Gain (≤ $0.42)	$	0.46	0.48	0.26	0.24	0.26	0.33	0.30

* Factors with diagnostic value in selection of low cost-high return forage types and 12 month management strategies.

Value Captured from the Land

The Repeated Seasonal, No Hay, the Traditional Seasonlong, and the Biologically Effective Twice-over Rotation 12-month forage management strategies were implemented on an hypothetical starter ranch that had a land base of 4 sections with 60 acres nonagricultural and 2500 acres of the appropriate forage types for each management strategy to determine the value of new wealth captured from the land natural resources (table 4).

The Repeated Seasonal, No Hay management strategy had 2500 acres of native rangeland divided into 6 pastures for each cow production period. A 1200 pound cow with a calf required 55.44 acres of grazingland; the starter ranch provided forage feed for 45 cows. The pasture forage costs on the 240 acre dry gestation pasture was $2125.35, on the 840 acre third trimester pasture was $7862.85, on the 486 acre early lactation pasture was $4258.80, on the 215 acre spring lactation pasture was $1883.25, on the 510 acre summer lactation pasture was $4438.80, and on the 209 acre fall lactation pasture was $2304.00, for a total 12 month pasture forage feed cost of $22,873.05 and $9.17 per acre. The mean heifer-steer weaning weight was 532.40 pounds, for a total production of 23,958.0 pounds of calf live weight per year. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $16,770.60 per herd year and $6.72 per acre. The net return after pasture forage feed costs was a loss of $6,102.45 per year and a loss of $2.45 per acre. The mean cost of calf weight gain was $0.95 per pound.

The Traditional Seasonlong management strategy had 2500 acres with 80 acres of cropland, 60 acres of hayland, and 2360 acres of pastureland divided into 6 portions for each cow production period. A 1200 pound cow with a calf required 19.71 acres for forage growth; the starter ranch provided forage feed for 126 cows. The forage feed costs on the 60 acre dry gestation hayland was $1707.30, on the 50 acre third trimester cropland hay was $3628.80, on the 30 acre early lactation cropland hay was $3075.66, on the 240 acre spring lactation pasture was $2075.22, on the 1600 acre summer lactation pasture was $14,017.50, and on the 520 acre fall lactation pasture was $5705.28, for a total 12 month pasture-harvested forage feed cost of $30,209.76 and $12.16 per acre. The mean heifer-steer weaning weight was 553.64 pounds, for a total production of 69,758.64 pounds of calf live weight per year. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $48,831.05 per herd year and $19.66 per acre. The net return after pasture forage feed costs was $18,621.29 per year and a net return per acre was $7.50. The mean cost of calf weight gain was $0.43 per pound.

The Biologically Effective Twice-over Rotation management strategy had 2500 acres with 237 acres of cropland, 0 acres of hayland, and 2263 acres of pastureland divided into 6 portions for each cow production period. A 1200 pound cow with a calf required 10.77 acres for forage growth; the starter ranch provided forage feed for 232 cows. The forage feed costs on the 23 acre dry gestation cropland hay was $2647.12, on the 63 acre third trimester cropland hay was $7855.52, on the 42 acre early lactation cropland hay was $5115.60, on the 175 acre spring lactation pasture was $3700.40, on the 2088 acre summer lactation triple pastures was $18,290.88, and on the 109 acre fall lactation cropland pasture was $4570.40, for a total 12 month pasture-harvested forage feed cost of $42,179.92 and $16.88 per acre. The mean heifer-steer weaning weight was 610.85 pounds, for a total production of 141,717.2 pounds of calf live weight per year. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $99,202.04 per herd year and $39.70 per acre. The net return after pasture forage feed costs was $57,022.12 per year and a net return per acre was $22.82. The mean cost of calf weight gain was $0.30 per pound.

The 12-month forage management strategy that captured the greatest quantity of new wealth from the land natural resources was biologically effective and captured the greatest quantity of crude protein per acre and had the lowest cost per pound of crude protein that resulted in the greatest cow and calf weight gain per acre, the lowest land area per cow-calf pair, the lowest total annual feed cost per cow and the lowest feed cost per day per cow, which produced the greatest return after feed costs per cow-calf pair and per acre, and had the lowest cost for calf weight gain per pound.

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Table 4. Summary of twelve month costs and returns of the No Hay, Traditional, and Biologically Effective management strategies on a land base of 4 sections with 60 ac. nonag. and 2500 ac. forage.

		No Hay Repeated Seasonal	Traditional 4.5 month Seasonlong	Biologically Effective Twice-over Rotation
Forage Base	ac	2500	2500	2500
Land/Cow/Yr	ac	55.44	19.71	10.77
No. Cows	hd	45	126	232
Calf Wt./Yr	lbs	23,958.0	69,758.6	141,717.2
Gross Return	$	16,770.60	48,831.05	99,202.04
Feed Costs	$	22,873.05	30,209.76	42,179.92
Return-Feed Costs	$	-6,102.45	18,621.29	57,022.12
Gross Return/acre	$	6.72	19.66	39.70
Feed Costs/acre	$	9.17	12.16	16.88
Return-Feed Costs/acre	$	-2.45	7.50	22.82
Land Area				
Dry Gestation	ac	240	60	23
Third Trimester	ac	840	50	63
Early Lactation	ac	486	30	42
Spring Lactation	ac	215	240	175
Summer Lactation	ac	510	1600	2088
Fall Lactation	ac	209	520	109
Pastureland	ac	2500	2360	2263
Hayland	ac	0	60	0
Cropland	ac	0	80	237

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Diagnostic Examination of the Value Captured from Land Natural Resources by Forage Management Strategies for Range Cows During the Nongrowing Season

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The beef production industry has focused on the improvement in animal performance for several decades and has neglected to simultaneously improve the efficiencies of forage management systems. 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 proportional to the animals greater size. Feeding modern high-performance cattle with traditional pasture and harvested forage management technology developed for the old-style low-performance cattle causes a mismatch in the quantity of forage nutrients needed and the amount of forage nutrients available between the modern cattle with high nutrient requirements and the traditional low quality forage management practices. Traditional forage management practices inhibit the modern beef animal from performing at its genetic capacity, 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 animal production. Modern cattle perform at greater efficiency when their nutritional demands are met during each production period.

Development of low cost-high return forage management strategies for modern high-performance livestock during the nongrowing season presents a huge challenge because few nutritious green forage plants are readily available. The 197 day nongrowing period from mid October to late April includes the 30 day fall lactation, the 32 day dry gestation, the 90 day third trimester, and the 45 day early lactation production periods. Evaluation of pasture forage types and harvested forage types that meet nutrient and dry matter requirements of modern range cows during the production periods that occur in the nongrowing season is complicated. The quantifiable factors that should be included in the evaluation of forage management strategies during the nongrowing season are harvested or grazed forage dry matter weight per acre, captured crude protein weight per acre, land area per cow or 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 acre and 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 per pound, and forage feed costs per acre and per day including the supplemental roughage or crude protein costs directly affect 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.

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 feed types that have forage feed costs of $0.62 or less per day, calf weight gain costs of $0.42 or less per pound, 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.

Forage management strategies are developed by selection of pasture forage types or harvested forage types for use in sequence during the range cow production periods that occur in the nongrowing season. Diagnostic examinations were conducted on three forage management strategies: the Repeated Seasonal, No Hay, the Traditional Seasonlong, and the Biologically Effective Twice-over Rotation; and on forage strategies with three harvested forage types, each cut at two growth stages: crested wheatgrass hay cut at the boot stage and mature stage, oat forage hay cut at the milk stage and the hard dough stage, and forage barley hay cut at the milk stage and the hard dough stage. The beef cattle nutrient requirements were from NRC 1996 and BCRC 1999. The harvested forage data were from Manske and Carr 2000. The pasture forage data and the cow and calf performance data were from Manske 2001, 2002, 2003a, 2003b, 2004, and 2008. The methods used were from Manske 2008.

Repeated Seasonal, No Hay

The Repeated Seasonal, No Hay management strategy (table 1) uses four separate native rangeland pastures during the 197 day nongrowing period from mid October to late April with a total of 39.35 acres allocated per cow. The forage allocation is 30.0 lbs DM/day/cow with a total of 5910.0 lbs DM/pp to provide 343.08 lbs CP/pp, at a cost of $344.81/pp, with an additional 76.6 lbs CP/pp supplemented at a cost of $22.99/pp. Total forage and crude protein costs would be $367.80/pp and $9.35 per acre, or $1.87 per day. Calf accumulated weight gain during the 197 day nongrowing period was estimated to be 230.0 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $161.00 per calf and $4.09 per acre. The net returns after feed costs were a loss of $206.80 per cow-calf pair and a loss of $5.26 per acre. The cost of calf weight gain was $1.60 per pound.

Traditional Seasonlong

The Traditional Seasonlong management strategy (table 1) uses one native rangeland pasture for 30 days and feeds harvested forages for 167 days during the 197 day nongrowing period from mid October to late April with 4.07 acres of pastureland, 0.47 acres of hayland, and 0.59 acres of cropland hay for a total of 5.13 acres allocated per cow. The forage allocation is 900 lbs DM from the pastureland, 748.8 lbs DM from the hayland, and 3375.0 lbs DM from cropland hay for a total of 5023.8 lbs DM/pp from the land to provide 354.37 lbs CP/pp, at a cost of $93.70/pp, with an additional 19.2 lbs roughage/pp at a cost of $0.34/pp, and with an additional 60.0 lbs of supplemental CP at a cost of $18.00/pp. Total forage, roughage, and crude protein costs would be $112.04/pp and $21.84 per acre, or $0.57 per day. Calf accumulated weight gain during the 197 day nongrowing period was estimated to be 208.1 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $145.67 per calf and $28.40 per acre. The net returns after feed costs were $33.63 per cow-calf pair and $6.56 per acre. The cost of calf weight gain was $0.54 per pound.

Twice-over Rotation

The Twice-over Rotation management strategy (table 1) uses spring seeded cropland pasture for 30 days and feeds harvested forages for 167 days during the 197 day nongrowing period from mid October to late April with 0.47 acres of cropland pasture and 0.55 acres of cropland hay for a total of 1.02 acres allocated per cow. The forage allocation is 900 lbs DM from cropland pasture and 2669.4 lbs DM from cropland hay for a total of 3569.4 lbs DM from the land to provide 449.09 lbs CP at a cost of $61.39/pp, with an additional 1473.6 lbs of supplemental roughage at a cost of $25.63/pp. Total forage and roughage costs would be $87.02/pp and $85.31 per acre, or $0.44 per day. Calf accumulated weight gain during the 197 day nongrowing period was estimated to be 240.5 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $168.35 per calf and $165.05 per acre. The net returns after feed costs were $81.33 per cow-calf pair and $79.74 per acre. The cost of calf weight gain was $0.34 per pound.

Table 1. Costs and returns for three management strategies that provide forage fed to 1200 lb cow for 197 days during fall lactation, dry gestation, third trimester, and early lactation periods.

		Repeated Seasonal, No Hay	Traditional Seasonlong	Twice-over Rotation
Days		197	197	197
Forage DM Weight	lbs/ac	150.56	973.68	3455.85
Production Costs	$/ac	8.76	18.10	59.53
Forage DM Costs	$/ton	116.37	37.18	34.45
Crude Protein	%	5.8	7.0	11.00
CP Yield	lbs/ac	8.7	67.79	377.40
* CP Costs (≤ $0.25)	$/lb	1.01	0.27	0.16
Forage Allocation	lbs/p	5910.0	5023.8	3569.4
* Land Area	ac	39.35	5.13	1.02
Roughage Allocation	lbs/p	0.0	19.2	1473.6
CP Supp.	lbs/p	76.6	60.0	0.0
Forage Costs	$/pp	344.81	93.70	61.39
Roughage Costs	$/pp	0.0	0.34	25.63
CP Supp. Costs	$/pp	22.99	18.00	0.0
Total Feed Costs	$/pp	367.80	112.04	87.02
Feed Cost/Acre	$/ac	9.35	21.84	85.31
* Cost/Day (≤ $0.62)	$/d	1.87	0.57	0.44
Accumulated Calf Wt.	lbs	230.00	208.10	240.5
Weight Value @ $0.70/lb	$	161.00	145.67	168.35
Gross Return/Acre	$	4.09	28.40	165.05
Net Return/c-cpr	$	-206.80	33.63	81.33
* Net Return/acre	$	-5.26	6.56	79.74
*Cost/lb of Calf Gain (≤ $0.42)	$	1.60	0.54	0.34

* Factors with diagnostic value in selection of low cost-high return forage types.

Crested Wheatgrass Hay, Boot Stage

Crested wheatgrass hay cut early, at the boot stage, has a crude protein content of 14.5%. This crested wheatgrass hay has production costs of $26.50 per acre, forage dry matter costs of $40.80 per ton, and crude protein costs of $0.14 per pound (table 2). Early cut crested wheatgrass hay would be fed during the fall lactation period at 17.3 lbs DM/day to provide 2.5 lbs CP/day, at a cost of $10.50 per period, with an additional 12.7 lbs of roughage fed per day, at a cost of $6.66 per period. Total forage and roughage costs during the fall lactation would be $17.16 per period, or $0.57 per day. Early cut crested wheatgrass hay would be fed during the dry gestation period at 10.3 lbs DM/day to provide 1.5 lbs CP/day, at a cost of $6.72 per period, with an additional 13.7 lbs of roughage fed per day, at a cost of $7.68 per period. Total forage and roughage costs during the dry gestation would be $14.40 per period, or $0.45 per day. Early cut crested wheatgrass hay would be fed during the third trimester period at 12.9 lbs DM/day to provide 1.9 lbs CP/day, at a cost of $23.40 per period, with an additional 11.1 lbs of roughage per day, at a cost of $17.48 per period. Total forage and roughage costs during the third trimester would be $40.88 per period, or $0.45 per day. Early cut crested wheatgrass hay would be fed during the early lactation period at 18.8 lbs DM/day to provide 2.7 lbs CP/day, at a cost of $17.10 per period, with an additional 8.2 lbs of roughage per day, at a cost of $6.43 per period. Total forage and roughage costs during the early lactation would be $23.53 per period, or $0.52 per day.

Early cut crested wheatgrass hay would be fed during the 197 day nongrowing period from mid October to late April at 2855.6 lbs DM/pp from 2.2 acres to provide 415.5 lbs CP/pp, at a cost of $57.72/pp, with an additional 2187.4 lbs of roughage/pp, at a cost of $38.25/pp. Total forage and roughage costs would be $95.97/pp and $43.62 per acre, or $0.49 per day. Calf accumulated weight gain during the 197 day nongrowing period was estimated to be 240.5 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $168.35 per calf and $76.52 per acre. The net returns after feed costs were $72.38 per cow-calf pair and $32.90 per acre. The cost of calf weight gain was $0.40 per pound (table 2).

Crested Wheatgrass Hay, Mature Stage

Crested wheatgrass hay cut late, at the mature stage, has a crude protein content of 6.4%. This crested wheatgrass hay has production costs of $28.11 per acre, forage dry matter costs of $34.80 per ton, and crude protein costs of $0.28 per pound (table 2). Late cut crested wheatgrass hay would be fed during the fall lactation period at 30.0 lbs DM/day to provide 1.9 lbs CP/day, at a cost of $15.84 per period, with an additional 0.59 lbs of crude protein fed per day, at a cost of $5.31 per period. Total forage and crude protein costs during the fall lactation would be $21.15 per period, or $0.71 per day. Late cut crested wheatgrass hay would be fed during the dry gestation period at 23.4 lbs DM/day to provide 1.5 lbs CP/day, at a cost of $13.12 per period, with an additional 0.6 lbs of roughage fed per day, at a cost of $0.34 per period. Total forage and roughage costs during the dry gestation would be $13.46 per period, or $0.42 per day. Late cut crested wheatgrass hay would be fed during the third trimester period at 24.0 lbs DM/day to provide 1.5 lbs CP/day, at a cost of $38.02 per period, with an additional 0.33 lbs of crude protein per day, at a cost of $9.02 per period. Total forage and crude protein costs during the third trimester would be $47.04 per period, or $0.52 per day. Late cut crested wheatgrass hay would be fed during the early lactation period at 27.0 lbs DM/day to provide 1.7 lbs CP/day, at a cost of $21.38 per period, with an additional 1.0 lbs of crude protein per day, at a cost of $13.50 per period. Total forage and crude protein costs during the early lactation would be $34.88 per period, or $0.78 per day.

Late cut crested wheatgrass hay would be fed during the 197 day nongrowing period from mid October to late April at 5023.8 lbs DM/pp from 3.14 acres at a cost of $88.36/pp, with 19.2 lbs of roughage at a cost of $0.34/pp, and with 92.4 lbs crude protein at a cost of $27.83/pp. Total forage, roughage, and crude protein costs would be $116.53/pp and $37.11 per acre, or $0.59 per day. Calf accumulated weight gain during the 197 day nongrowing period was estimated to be 240.5 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $168.35 per calf and $53.61 per acre. The net returns after feed costs were $51.82 per cow-calf pair and $16.50 per acre. The cost of calf weight gain was $0.48 per pound (table 2).

Oat Forage Hay, Milk Stage

Oat forage hay cut early, at the milk stage, has a crude protein content of 11.5%. This oat forage hay has production costs of $69.17 per acre, forage dry matter costs of $29.60 per ton, and crude protein costs of $0.13 per pound (table 2). Early cut oat forage hay would be fed during the fall lactation period at 21.8 lbs DM/day to provide 2.5 lbs CP/day, at a cost of $9.90 per period, with an additional 8.2 lbs of roughage fed per day, at a cost of $4.31 per period. Total forage and roughage costs during the fall lactation would be $14.21 per period, or $0.47 per day. Early cut oat forage hay would be fed during the dry gestation period at 13.0 lbs DM/day to provide 1.5 lbs CP/day, at a cost of $6.08 per period, with an additional 11.0 lbs of roughage fed per day, at a cost of $6.16 per period. Total forage and roughage costs during the dry gestation would be $12.24 per period, or $0.38 per day. Early cut oat forage hay would be fed during the third trimester period at 16.3 lbs DM/day to provide 1.9 lbs CP/day, at a cost of $21.60 per period, with an additional 7.7 lbs of roughage per day, at a cost of $12.13 per period. Total forage and roughage costs during the third trimester would be $33.73 per period, or $0.37 per day. Early cut oat forage hay would be fed during the early lactation period at 23.7 lbs DM/day to provide 2.7 lbs CP/day, at a cost of $15.75 per period, with an additional 3.3 lbs of roughage per day, at a cost of $2.60 per period. Total forage and roughage costs during the early lactation would be $18.35 per period, or $0.41 per day.

Early cut oat forage hay would be fed during the 197 day nongrowing period from mid October to late April at 3603.5 lbs DM/pp from 0.77 acres to provide 415.5 lbs CP/pp, at a cost of $53.33/pp, with an additional 1439.5 lbs of roughage/pp, at a cost of $25.20/pp. Total forage and roughage costs would be $78.53/pp and $101.99 per acre, or $0.40 per day. Calf accumulated weight gain during the 197 day nongrowing period was estimated to be 240.5 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $168.35 per calf and $218.64 per acre. The net returns after feed costs were $89.82 per cow-calf pair and $116.65 per acre. The cost of calf weight gain was $0.32 per pound (table 2).

Oat Forage Hay, Hard Dough Stage

Oat forage hay cut late, at the hard dough stage, has a crude protein content of 7.8%. This oat forage hay has production costs of $74.53 per acre, forage dry matter costs of $26.40 per ton, and crude protein costs of $0.17 per pound (table 2). Late cut oat forage hay would be fed during the fall lactation period at 30.0 lbs DM/day to provide 2.34 lbs CP/day, at a cost of $11.88 per period, with an additional 0.17 lbs of crude protein fed per day, at a cost of $1.53 per period. Total forage and crude protein costs during the fall lactation would be $13.41 per period, or $0.45 per day. Late cut oat forage hay would be fed during the dry gestation period at 19.1 lbs DM/day to provide 1.5 lbs CP/day, at a cost of $8.00 per period, with an additional 4.9 lbs of roughage fed per day, at a cost of $2.74 per period. Total forage and roughage costs during the dry gestation would be $10.74 per period, or $0.34 per day. Late cut oat forage hay would be fed during the third trimester period at 24.0 lbs DM/day to provide 1.9 lbs CP/day, at a cost of $28.80 per period. Total forage costs during the third trimester would be $28.80 per period, or $0.32 per day. Late cut oat forage hay would be fed during the early lactation period at 27.0 lbs DM/day to provide 2.1 lbs CP/day, at a cost of $16.04 per period, with an additional 0.62 lbs of crude protein per day, at a cost of $8.37 per period. Total forage and crude protein costs during the early lactation would be $24.41 per period, or $0.54 per day.

Late cut oat forage hay would be fed during the 197 day nongrowing period from mid October to late April at 4886.2 lbs DM/pp from 0.86 acres at a cost of $64.72/pp, with 156.8 lbs of roughage at a cost of $2.74/pp, and with 33.0 lbs crude protein at a cost of $9.90/pp. Total forage, roughage, and crude protein costs would be $77.36/pp and $89.95 per acre, or $0.39 per day. Calf accumulated weight gain during the 197 day nongrowing period was estimated to be 240.5 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $168.35 per calf and $195.75 per acre. The net returns after feed costs were $90.99 per cow-calf pair and $105.80 per acre. The cost of calf weight gain was $0.32 per pound (table 2).

Forage Barley Hay, Milk Stage

Forage barley hay cut early, at the milk stage, has a crude protein content of 13.0%. This forage barley hay has production costs of $68.21 per acre, forage dry matter costs of $28.80 per ton, and crude protein costs of $0.11 per pound (table 2). Early cut forage barley hay would be fed during the fall lactation period at 19.3 lbs DM/day to provide 2.5 lbs CP/day, at a cost of $8.40 per period, with an additional 10.7 lbs of roughage fed per day, at a cost of $5.62 per period. Total forage and roughage costs during the fall lactation would be $14.02 per period, or $0.47 per day. Early cut forage barley hay would be fed during the dry gestation period at 11.5 lbs DM/day to provide 1.5 lbs CP/day, at a cost of $5.12 per period, with an additional 12.5 lbs of roughage fed per day, at a cost of $7.00 per period. Total forage and roughage costs during the dry gestation would be $12.12 per period, or $0.38 per day. Early cut forage barley hay would be fed during the third trimester period at 14.4 lbs DM/day to provide 1.9 lbs

CP/day, at a cost of $18.90 per period, with an additional 9.6 lbs of roughage per day, at a cost of $14.96 per period. Total forage and roughage costs during the third trimester would be $33.86 per period, or $0.38 per day. Early cut forage barley hay would be fed during the early lactation period at 21.0 lbs DM/day to provide 2.7 lbs CP/day, at a cost of $13.50 per period, with an additional 6.0 lbs of roughage per day, at a cost of $4.73 per period. Total forage and roughage costs during the early lactation would be $18.23 per period, or $0.41 per day.

Early cut forage barley hay would be fed during the 197 day nongrowing period from mid October to late April at 3188.0 lbs DM/pp from 0.67 acres to provide 415.5 lbs CP/pp, at a cost of $45.92/pp, with an additional 1855.0 lbs of roughage/pp, at a cost of $32.31/pp. Total forage and roughage costs would be $78.23/pp and $116.76 per acre, or $0.40 per day. Calf accumulated weight gain during the 197 day nongrowing period was estimated to be 240.5 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $168.35 per calf and $251.27 per acre. The net returns after feed costs were $90.12 per cow-calf pair and $134.51 per acre. The cost of calf weight gain was $0.32 per pound (table 2).

Forage Barley Hay, Hard Dough Stage

Forage barley hay cut late, at the hard dough stage, has a crude protein content of 9.2%. This forage barley hay has production costs of $70.35 per acre, forage dry matter costs of $27.40 per ton, and crude protein costs of $0.15 per pound (table 2). Late cut forage barley hay would be fed during the fall lactation period at 27.3 lbs DM/day to provide 2.5 lbs CP/day, at a cost of $11.40 per period, with an additional 2.7 lbs of roughage fed per day, at a cost of $1.42 per period. Total forage and roughage costs during the fall lactation would be $12.82 per period, or $0.43 per day. Late cut forage barley hay would be fed during the dry gestation period at 16.2 lbs DM/day to provide 1.5 lbs CP/day, at a cost of $7.04 per period, with an additional 7.8 lbs of roughage fed per day, at a cost of $4.37 per period. Total forage and roughage costs during the dry gestation would be $11.41 per period, or $0.36 per day. Late cut forage barley hay would be fed during the third trimester period at 20.3 lbs DM/day to provide 1.9 lbs CP/day, at a cost of $26.10 per period, with an additional 3.7 lbs of roughage per day, at a cost of $5.83 per period. Total forage and roughage costs during the third trimester would be $31.93 per period, or $0.35 per day. Late cut forage barley hay would be fed during the early lactation period at 27.0 lbs DM/day to provide 2.48 lbs CP/day, at a cost of $16.65 per period, with an additional 0.25 lbs of crude protein per day, at a cost of $3.38 per period. Total forage and crude protein costs during the early lactation would be $20.03 per period, or $0.45 per day.

Late cut forage barley hay would be fed during the 197 day nongrowing period from mid October to late April at 4379.4 lbs DM/pp from 0.86 acres at a cost of $61.19/pp, with 663.6 lbs of roughage at a cost of $11.62/pp, and with 11.25 lbs crude protein at a cost of $3.38/pp. Total forage, roughage, and crude protein costs would be $76.19/pp and $88.59 per acre, or $0.39 per day. Calf accumulated weight gain during the 197 day nongrowing period was estimated to be 240.5 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $168.35 per calf and $195.75 per acre. The net returns after feed costs were $92.16 per cow-calf pair and $107.16 per acre. The cost of calf weight gain was $0.32 per pound (table 2).

Table 2. Costs and returns for three harvested forage types cut at two growth stages fed to 1200 lb cow for 197 days during fall lactation, dry gestation, third trimester, and early lactation production periods.

		Crested Wheatgrass		Oat Forage		Forage Barley	
		Boot Stage	Mature	Milk	Hard Dough	Milk	Hard Dough
Days		197	197	197	197	197	197
Forage DM Weight	lbs/ac	1300	1600	4667	5667	4733	5133
Production Costs	$/ac	26.50	28.11	69.17	74.53	68.21	70.35
Forage DM Costs	$/ton	40.80	34.80	29.60	26.40	28.80	27.40
Crude Protein	%	14.5	6.4	11.5	7.8	13.0	9.2
CP Yield	lbs/ac	189	102	535	435	606	468
*CP Costs (≤ $0.25)	$/lb	0.14	0.28	0.13	0.17	0.11	0.15
Forage Allocation	lbs/pp	2855.6	5023.8	3603.5	4886.2	3188.0	4379.4
*Land Area	ac	2.20	3.14	0.77	0.86	0.67	0.86
Roughage Allocation	lbs/pp	2187.4	19.2	1439.5	156.8	1855.0	663.6
CP Supp.	lbs/pp	0.0	92.4	0.0	33.0	0.0	11.25
Forage Costs	$/pp	57.72	88.36	53.33	64.72	45.92	61.19
Roughage Costs	$/pp	38.25	0.34	25.20	2.74	32.31	11.62
CP Supp. Costs	$/pp	0.0	27.83	0.0	9.90	0.0	3.38
Total Feed Costs	$/pp	95.97	116.53	78.53	77.36	78.23	76.19
Feed Cost/Acre	$/ac	43.62	37.11	101.99	89.95	116.76	88.59
*Cost/Day (≤ $0.62)	$/d	0.49	0.59	0.40	0.39	0.40	0.39
Accumulated Calf Wt.	lbs	240.50	240.50	240.50	240.50	240.50	240.50
Weight Value @ $0.70/lb	$	168.35	168.35	168.35	168.35	168.35	168.35
Gross Return/Acre	$	76.52	53.61	218.64	195.75	251.27	195.75
Net Return/c-cpr	$	72.38	51.82	89.82	90.99	90.12	92.16
*Net Return/acre	$	32.90	16.50	116.65	105.80	134.51	107.16
*Cost/lb of Calf Gain (≤ $0.42)	$	0.40	0.48	0.32	0.32	0.32	0.32

*Factors with diagnostic value in selection of low cost-high return forage types.

Value Captured from the Land

The forage management strategies used to feed range cows during the 197 day nongrowing season were ranked according to the quantity of value captured from the land natural resources (table 3). The top five forage management strategies captured great wealth from the land at $80 to $135 net return per acre after feed costs during low market value for calf weight at weaning (table 3). The generation of great wealth from the land resources requires the capture of great crude protein weight per acre. These five forage strategies produced adequate quantities of forage on small land areas of 1 acre or less to feed a range cow for 6.5 months and captured huge quantities of crude protein from 377 lbs to 606 lbs per acre in the forage feed (table 3), which produced large quantities of beef weight commodities per acre, resulting in great gross returns per acre and high net returns after forage feed costs per acre. The great quantities of crude protein weight captured in the forage per acre also resulted in low crude protein costs from $0.11 to $0.17 per pound, low total forage feed costs from $0.39 to $0.44 per day, and low calf weight gain costs from $0.32 to $0.34 per pound (tables 1 and 2).

The bottom three forage management strategies captured little wealth from the land resources at less than $17 net return per acre to a loss of greater than $5 per acre after feed costs (table 3). These three forage strategies required large land areas from greater than 3 acres to almost 40 acres to grow the forage dry matter for a range cow for 6.5 months and captured low quantities of crude protein from around 100 lbs to less than 10 lbs per acre (table 3), which was not enough. Supplemental crude protein at greater than 92 lbs to around 60 lbs per cow had to be purchased to meet animal nutrient requirements (tables 1 and 2). Low quantities of beef weight commodities were produced per acre because of the low quantities of crude protein weight captured per acre resulting in low gross returns per acre. The large land areas with low amounts of forage dry matter and low crude protein weight per acre resulted in high feed costs from $112 to $368 per cow, high crude protein costs from $0.27 to $1.01 per pound, high forage feed costs from $0.49 to $1.87 per day, and high calf weight gain costs from $0.48 to $1.60 per pound (tables 1 and 2).

The renewable forage nutrients are the primary unit of production in a range cow-calf operation because the nutrients are the source of new wealth generated from livestock agricultural use of land resources. The amount of new wealth generated from land natural resources is related to the quantity of forage crude protein captured per acre, not to the quantity of dry matter weight, so increasing economic wealth from beef production requires a paradigm shift to the use of biologically efficient forage management strategies that focus on capturing great quantities of crude protein weight per acre. Forage dry matter does not have a real economic value because it is not incorporated into the beef weight produced and it is returned to the land in a couple of days after ingestion. The dry matter is simply the carrier of the nutrients it contains.

Cutting forage hay at the plant growth stage when the greatest weight of crude protein can be captured per acre reduces the cost of crude protein per pound and reduces the size of land area needed per cow which decreases the forage feed costs per day. The weight of crude protein harvested per acre is related to the percent nutrient content and the weight of the forage dry matter at the time of cutting. The greatest weight of crude protein captured per acre is not at the growth stage with the highest percent crude protein. The greatest percent crude protein occurs during early plant growth stages when the weight of the forage dry matter is low. As the weight of plant dry matter increases until maximum plant height, the percent crude protein decreases. The flower growth stage is when grass plants, including perennial grasses and annual cereal grasses have the greatest weight of crude protein per acre. While for legumes, the greatest weight of crude protein per acre occurs at a late full growth stage just prior to when the bottom leaves dry from senescence. The later growth stage in legumes results because the rate of growth of dry matter weight accumulation and the rate of decline of percent crude protein are both slower in legumes than in grasses.

Biologically effective forage management strategies are based on increasing production of crude protein per acre, improving the efficiency of capturing produced forage crude protein, and improving the conversion of captured crude protein into a saleable commodity of beef weight that result in low costs for crude protein per pound, reduced land area per cow-calf pair, low total forage feed costs per day, and low costs per pound of accumulated calf weight gain which results in greater new wealth captured from the land natural resources.

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Table 3. Ranking according to the quantity of value captured from land natural resources by forage management strategies for range cows during the nongrowing season.

Forage Management Strategy	Land Area ac	Crude Protein per Acre lbs	Gross Return per Acre $	Feed Cost per Acre $	Net Return per Acre $
Forage Barley Milk Stage	0.67	606	251.27	116.76	134.51
Oat Forage Milk Stage	0.77	535	218.64	101.99	116.65
Forage Barley Hard Dough	0.86	468	195.75	88.59	107.16
Oat Forage Hard Dough	0.86	435	195.75	89.95	105.80
Twice-over Rotation	1.02	377.4	165.05	85.31	79.74
Crested Wheatgrass Boot Stage	2.20	189	76.52	43.62	32.90
Crested Wheatgrass Mature Stage	3.14	102	53.61	37.11	16.50
Traditional Seasonlong	5.13	67.8	28.40	21.84	6.56
Repeated Seasonal No Hay	39.35	8.7	4.09	9.35	-5.26

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