Advanced Harvested Forage Management Technology for the Northern Mixed Grass Prairie

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

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

Shortly after the end of World War II, fattening feeder beef animals to finish changed from a forage based ration to primarily a grain based ration (Hutcheson and Eng 2007). A great deal of research and experimentation was dedicated to the development of new technologies needed to properly feed a high energy grain based ration that can cause digestive problems when fed to ruminant beef animals by reducing rumen pH. Also, in order to increase the rate of gain of the feeder beef animals, the genetic constitution of the North American beef herd needed improvement. As a result, beef cows have been transformed into modern high-performance cattle that are larger and heavier, gain weight more rapidly, produce more milk, deposit less body fat, and require greater nutrient intake than the old-style cows. However, superior forage ration management technologies for the modern high-performance beef cow were not simultaneously developed while the new and improved feeder ration technologies were being developed. Modern stocker and feeder producers are severely encumbered by using slightly modified traditional forage management technologies developed for the old-style low-performance livestock.

Livestock agriculture has a lifelong apprenticeship with the basic foundations passed within families from generation to generation. However, this new problem to overcome has not been solved by traditional practices. The genetic code of the North American beef herd has been changed and the modern cow is quite different from the old-style cow. The forage management technologies that worked with the old-style cow do not effectively work with the modern high-performance cow. Some long held traditional paradigms need to be challenged in order to develop new forage management technologies matched to the nutrient requirements of the modern high-performance cows that will permit them to produce at their genetic potentials.

Most beef producers, agricultural loan agents, and ag economists maintain a traditional paradigm that considers the source of wealth from beef production to be the selling of beef weight at market, the same as the source of wealth from wheat or corn production is the selling of the weight of wheat or corn grain at market. However, there is a biological difference. Green plants are autotrophic and use sunlight as a source of energy to synthesize organic material from acquired inorganic substances. Livestock are heterotrophic and consume grass plants as the source of energy and organic substances which are broke down during digestion and then used to synthesize the required organic material. The source of livestock weight is the renewable nutrients and essential elements from consumed plant material produced on the land natural resources. Livestock weight is not self produced.

As a result from retention of other long held traditional paradigms, almost every beef cow-calf producer still has a staunch assumption that feeding harvested forages is expensive and that these excessive costs are the major cause for the high production costs of beef cows. This traditional paradigm has prompted many beef producers to develop nonconventional practices in order to reduce the quantities of harvested forages used. An example rationale, the cash cost for pasture is lower than that for harvested feeds, therefore, late season pasture is cheaper than feeding hay. These nonconventional practices are generally not properly evaluated for costs and returns and often actually increase production costs for a beef cow.

There is a mismatch of forage nutrients required by modern high-performance cows and the forage nutrients provided by traditional low-performance forage management practices. Modern cattle on traditional forage management treatments based on the technologies 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. Improvement of forage management practices that provide the required quantities of forage nutrients at the time they are needed by the cow can enhance cow and calf weight performance to the level of their genetic potential.

A great deal of difference exists for the quantity of energy (TDN) and crude protein required between a 1000 lb old style cow and a modern 1200 lb cow with average milk production or with high milk production (table 1). The modern high production range cow has greater nutrient demand that is not simply proportional to the cows greater size. A high performance 1200 lb range cow with average milk production at 20 lb/d, is 20% larger than an old style 1000 lb range cow that had milk production at 12 to 6 lb/d, and 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 with high milk production at 30 lb/d requires 43% more energy and 72% more crude protein per day during the lactation periods than the old style range cow (table 1) (Manske 2014a).

The old style range cow could deposit considerable quantities of body fat during June and two or three weeks of July when grass had high levels of crude protein. These large quantities of body fat permitted the old style cows to produce around 6 lb/d of milk during August, September, and two weeks of October. This and other production characteristics of the old style cow gave her the ability to tolerate traditional forage management practices that were negligent in providing forage with adequate amounts of crude protein. Four of the five forage management practices on table 2 are traditional practices that provided forages deficient of crude protein during 45% to 29% of the days in an annual cycle. These traditional forage practices are still being use to provide forage deficient of crude protein to modern cows. However, the modern cow does not have the tolerance characteristics of the old style cow; the modern cow production levels decrease well below her genetic potentials each day when consuming forages deficient of required essential elements. This loss in productivity usually has greater value than the cost savings from low quality forage. The fifth forage strategy on table 2 was designed to provide adequate forage quality to meet the modern cows requirements each day of the year; except for 15 days during 36% of the years, crude protein is deficient. During 64% of the years, crude protein is not deficient (Manske 2018a). The modern cow appears to be able to tolerate one week with gradual decreases from forage deficient of required nutrients, after that her production levels greatly decrease.

Forage management practices with no hay

Raising beef animals without feeding hay is an intriguing proposition to many beef producers and it was actually attempted for a short period during the late 19th century in western North Dakota and eastern Montana. The Northern Pacific Railroad constructed new tracks from Bismarck through Dickinson and into eastern Montana during 1880 and 1881. Buffalo skinners shipped 1.5 million bison hides from the region to eastern markets between 1880 and 1884. Several large herds of light weight 2-4 year old steers and dry cows were trail north from Texas during 1882 and 1883 to be fattened on the open range grasses and then be shipped to eastern markets by rail as live animals or as hanging carcasses. The first regional roundup in western North Dakota was conducted in the spring of 1884 in a district that was 100 by 50 miles with Medora near the center. The population of cattle was estimated to be between 30,000 and 40,000 head at a stocking level of 80 to 100 acres per animal for a year of grazing. During the fall of 1886, the local stockman declared the district to be fully stocked and that no new outfits would be permitted to bring additional cattle or horses onto the range. Then the very severe winter conditions of 1886-1887 occurred with numerous blizzards, very strong winds, and long spells of bitter sub-zero temperatures. By spring, 50% to 75 % of the cattle had been lost. A few outfits had nearly 100% losses. Most of the absentee owned outfits pulled out. A few locally owned and operated outfits remained by maintaining relatively small herd sizes. Financial backers stopped lending money to businesses that engaged in the risky activities of year around grazing to fatten cattle on northern plains open range grasses (Manske 1994).

This five year experimental exploitation of the northern plains grass natural resources ended with a tragic loss of livestock and huge economic losses. The severe weather conditions were not the sole factor responsible for this disaster. These light weight cattle also had to contend with low availability (snow covered) forage having inadequate quantity and quality, frozen water sources, and poor wind breaks. Healthy cattle that are provided an adequate forage ration, liquid water, and protected by good wind breaks can tolerate fairly severe winter weather conditions.

Every winter is not as severe as that of 1886-1887, but some could be. Can modern beef cows and calves be raised profitably in the northern plains on just native rangeland grasses without hay if protected by good wind breaks, and provided access to liquid water and supplemental crude protein? A cooperative producer project evaluation of a 12 month native rangeland management practice with multiple seasonal pastures, without hay, organized as one replication was conducted for most of three years during the early 1980's. A simple data collection protocol included monthly herbage biomass clips, and periodic weights of 20 cows and calves identified by ear tag number.

Even though the data protocol was not followed as planned, the data was significantly complete, with the exception of cow weights, to confidently evaluate a native range forage management practice without hay for costs, returns, and profitability.

Dry Gestation

Reserved native rangeland managed as a repeated seasonal pasture was evaluated during the dry gestation production period for 37 days (table 3). Native rangeland forage during the late fall dormancy period has low crude protein content of around 4.8%. Late-season native rangeland forage has a low pasture rent value or production cost of $8.76 per acre, high forage dry matter cost of $97.33 per ton, and high crude protein cost of $1.01 per pound. A cow grazing during the dry gestation production period requires a large land area of 6.17 acres (5.08 acres per month) at a high forage cost of $54.05 per production period. The crude protein content of mature native rangeland forage is below the requirements of a cow and would need to be supplemented at 1.49 lbs per cow per day at a cost of $16.54 per period. Total feed costs are high at $70.59 per period and $1.91 per day. Calf fetus weight gain was assumed to be 0.73 lbs per day; accumulated weight gain was 27.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00 per pound, the gross return was $27.00 per calf. The net return after pasture forage costs were a high loss of $43.59 per cow-calf pair and a loss of $7.07 per acre. The extremely high cost of calf fetus weight gain was $2.61 per pound.

Third Trimester

Reserved native rangeland managed as a repeated seasonal pasture was evaluated during the third trimester production period for 90 days (table 3). Native rangeland forage during the winter dormancy period has a low crude protein content of around 4.8%. Late-season native rangeland forage has a low pasture rent value or production cost of $8.76 per acre, very high forage dry matter cost of $120.83 per ton, and extremely high crude protein cost of $1.26 per pound. A cow grazing during the third trimester production period requires a large land area of 18.62 acres (6.31 acres per month) at a extremely high forage cost of $163.11 per production period. The crude protein content of mature native rangeland forage is below the requirements of a cow and would need to be supplemented at 0.43 lbs per cow per day at a cost of $11.61 per period. Total feed costs are extremely high at $174.72 per period and $1.94 per day. Calf fetus weight gain was assumed to be 0.76 lbs per day; accumulated weight gain was 68.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00 per pound, the gross return was $68.00 per calf. The net return after pasture forage costs were an extremely high loss of $106.72 per cow-calf pair and a moderate loss of $5.73 per acre. The extremely high cost of calf fetus weight gain was $2.57 per pound.

Early Lactation

Reserved native rangeland managed as a repeated seasonal pasture was evaluated during the early lactation production period for 45 days (table 3). Forage on native rangeland pasture during early spring has a crude protein content of around 9.2%, the grass tillers were activating chlorophyll and starting to regreen portions of the carryover leaves. Early spring native rangeland forage has a low pasture rent value or production cost of $8.76 per acre, extremely high forage dry matter cost of $140.16 per ton, and very high crude protein cost of $0.76 per pound. A cow grazing during the early lactation period requires a large land area of 10.80

acres (7.32 acres per month) at a very high forage cost of $94.61 per production period. The crude protein content of early spring native rangeland forage is below the requirements of a cow, however, crude protein was not supplemented. Total feed costs are very high at $94.61 per period and $2.10 per day. Calf weight gain was 1.24 lbs per day; accumulated weight gain was 56.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00 per pound, the gross return was $56.00 per calf. The net return after pasture forage costs was a very high loss of $38.61 per cow-calf pair and a moderate loss of $3.58 per acre. The very high cost of calf weight gain was $1.69 per pound.

Spring Lactation

Native rangeland managed as a repeated seasonal pasture was evaluated during the spring lactation production period for 28 days (table 3). Native rangeland grass tillers had not reached the three and half new leaf growth stage and were not physiologically ready for grazing during the spring lactation production period in May and grazing during this time will severely degrade the grassland ecosystem. Native rangeland forage during the spring has a crude protein content of around 16.3% because of the regreened portions of carryover leaves and the early growth of some new leaves. Spring native rangeland forage had low pasture rent value or production costs of $8.76 per acre, high forage dry matter cost of $89.85 per ton, and moderate crude protein cost of $0.28 per pound. A cow grazing during the spring lactation period requires a large land area of 4.31 acres (4.69 acres per month) at a high forage cost of $37.76 per production period. No supplementation was needed during this period. Total forage feed costs are high at $37.76 per period and $1.35 per day. Calf weight gain was 1.50 lbs per day; accumulated weight gain was 42.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00 per pound, the gross return was $42.00 per calf. The net return after pasture forage costs was a very low at $4.24 per cow-calf pair and extremely low at $0.98 per acre. The high cost of calf weight gain was $0.90 per pound. The future economic value lost as a result from the ecosystem damage will be much greater than the small return received.

Summer Lactation

Native rangeland managed as a repeated seasonal pasture was evaluated during the summer lactation production period for 135 days (table 3). Native rangeland forage during mid summer has a crude protein content of around 9.6%. Summer native rangeland forage had low pasture rent value or production costs of $8.76 per acre, moderate forage dry matter cost of $48.26 per ton, and acceptable crude protein cost of $0.25 per pound. A cow grazing during the summer lactation period requires a large land area of 11.16 acres (2.52 acres per month) at a forage cost of $97.76 per production period. No supplementation was needed during this period. Total forage feed costs are $97.76 per period and $0.72 per day. Calf weight gain was 1.80 lbs per day; accumulated weight gain was 243.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00 per pound, the gross return was $243.00 per calf. The net return after pasture forage costs were moderate at $145.24 per cow-calf pair and $13.00 per acre. The cost of calf weight gain was $0.40 per pound.

Fall Lactation

Native rangeland managed as a repeated seasonal pasture was evaluated during the fall lactation production period for 30 days (table 3). Native rangeland forage during the fall has a crude protein content of around 4.8%. Fall native rangeland forage had low pasture rent value or production costs of $8.76 per acre, high forage dry matter cost of $88.85 per ton, and high crude protein cost of $0.92 per pound. A cow grazing during the fall lactation period requires a large land area of 4.52 acres at a forage cost of $39.60 per production period. The crude protein content of mature native rangeland forage is below the requirements of a lactating cow during the fall and would need to be supplemented at 1.21 lbs per cow per day at a cost of $10.89 per period. Total forage feed costs are high at $50.49 per period and $1.68 per day. Calf weight gain was 0.59 lbs per day; accumulated weight gain was 17.70 lbs. When calf accumulated weight was assumed to have a low value of $1.00 per pound, the gross return was $17.70 per calf. The net return after pasture forage costs were a high loss of $32.79 per cow-calf pair and a loss of $7.25 per acre. The extremely high cost of calf weight gain was $2.85 per pound.

12-month season

Native rangeland managed as a repeated seasonal pasture system was evaluated during the 12 months of cow production periods for 365 days (table 3). Native rangeland forage had a low average crude protein content of around 8.6%. Native rangeland forage had low pasture rent value of $8.76 per acre, high forage dry matter average cost of $97.55 per ton, and high crude protein average cost of $0.75 per pound. A cow grazing native rangeland for 12 months requires a large land area of 55.58 acres at a pasture forage cost of $486.89 per year. Crude protein was below the requirements of a cow during 273 days (75% of a year) and was supplemented during 157 days (43% of a year) at a cost of $39.04. Total forage feed costs were extremely high at $525.93 per year and $1.44 per day. Calf average weight gain was 1.24 lbs per day; annual accumulated weight gain was 453.70 lbs. When calf accumulated weight was assumed to have a low value of $1.00 per pound, the gross return was $453.70 per calf. The net return after pasture forage costs were a high loss of $72.23 per cow-calf pair and a loss of $1.30 per acre. The high cost of calf weight gain was $1.16 per pound.

The cows and calves did survive. There were no death losses from severe weather conditions nor malnutrition, however, the cows were light weight but not emaciated and the calves were small and had gained weight at much less than their genetic potentials with the average at 454 lbs. The cows did not receive enough nutrients to fully recover from parturition (birth) and to produce milk at peak potential. The study did not have access to the cooperator's records of the number of open cows each year, which was assumed to be at least a few.

This 12 month no hay management practice is not profitable with a loss of $72 per cow-calf pair and a loss of $1.30 per acre. The only production period that showed a profit was during the summer lactation period for 135 days from 1 June to 14 October. The forage feed cost was $97.76 per period and $0.72 per day. The net return was $145.24 per cow-calf pair and $13.00 per acre. The cost of calf weight gain was $0.40 per pound.

During the other five production periods, the mean cost of pasture forage was $107.40/ton, and pasture crude protein was $0.85/pound. The land area of 44.42 acres cost $389.13 and supplemented crude protein cost $39.04. The average stocking rate was 5.58 acres/month. The total forage feed cost was $428.17 for 230 days (7.5 months) ($1.86/day), and the value of calf accumulated weight was $210.70. Net return was a loss of $217.47 per cow-calf pair and a loss of $4.90 per acre. The cost of calf weight gain was $2.03 per pound.

The reason the net returns are negative is that the available grazable pasture forage was an average of only 168.8 lbs/ac containing only 13.7 lbs/ac of crude protein requiring a large land area per cow-calf pair causing the costs of forage per ton and crude protein per pound to be so great. The low calf weight gain per day was not great enough to pay for the high forage feed and crude protein costs.

The low cash cost per acre for late season native rangeland pasture forage does not translate into low forage feed costs. Cowboy math does not identify low cost forage feed practices. Evaluation of forage dry matter cost/ton, crude protein yield per acre and cost per pound, forage feed cost/day, calf weight gain cost/pound, land area per cow-calf pair, and net return/acre need serious scrutiny in order to evaluate and identify low cost forage feed practices.

A study on the effect of grazing management treatments on residuum vegetation cover was conducted in the badlands of western North Dakota with two years of the study including winter grazing treatments. Each pasture in the study was replicated two times. Grazed residuum herbage biomass was collected by the standard clipping method (Cook and Stubbendieck 1986). Clipped herbage material was collected each growing season month with five quarter meter quadrats (frames) every sample date at each replicated site. Residuum vegetation basal cover was determined by the ten-pin point frame method (Cook and Stubbendieck 1986) with 2000 points collected along transect lines at each replicated site during peak vegetation growth.

The live residuum herbage biomass on the winter grazed treatment consisted of 84.6% native grass, 74.3% cool season grass, 10.4% warm season grass, 6.0% upland sedge, and 9.4% forbs (table 4). The live residuum herbage biomass on the seasonlong practice consisted of 89.9% native grass, 38.9% cool season grass, 51.0% warm season grass, 2.7% upland sedge, and 7.4% forbs (table 4). The live residuum herbage biomass on the twice-over system consisted of 89.8% native grass, 76.8% cool season grass, 13.0% warm season grass, 2.5% upland sedge, and 7.7% forbs (table 4). Winter grazing resulted in 14.8% lower native grass and 9.4% lower total live residum herbage biomass than that on the seasonlong practice and winter grazing resulted in 38.5% lower native grass and 34.8% lower total live residuum herbage biomass than that on the twice-over system.

The live residuum basal cover on the winter grazed treatment consisted of 69.7% native grass, 46.9% cool season grass, 22.7% warm season grass, 13.1% upland sedge, and 17.2% forbs (table 5). The live residuum basal cover on the seasonlong practice consisted of 78.3% native grass, 32.7% cool season grass, 45.6% warm season grass, 5.7% upland sedge, and 16.0% forbs (table 5). The live residuum basal cover on the twice-over system consisted of 76.2% native grass, 56.0% cool season grass, 20.2% warm season grass, 5.3% upland sedge, and 18.5% forbs (table 5). Winter grazing resulted in 40.0% lower native grass and 32.6% lower total live residuum basal cover than that on the seasonlong practice and winter grazing resulted in 43.2% lower native grass and 37.9% lower total live residuum basal cover than that on the twice-over system. Winter grazing also resulted in 82.9% greater bare soil than that on the seasonlong practice and 412.0% greater bare soil than that on the twice-over system.

The residuum vegetation structure resulting from the three grazing management treatments were quite different, with the winter grazed practice composed of the lowest herbage biomass (554.99 lbs/ac), the lowest basal cover (16.5%), and the greatest % bare soil (8.1%), with the seasonlong practice composed of about mean herbage biomass (612.77 lbs/ac), basal cover (24.5%), and % bare soil (4.5%), and with the twice-over system composed of the greatest herbage biomass (850.72 lbs/ac) and basal cover (26.6%) and the lowest % bare soil (1.6%) (tables 4 and 5).

Winter grazing removes a high percentage of carryover leaves of the vegetative tillers that would have produced large quantities of carbohydrates needed to develop new leaves the next growing season. And because the internal grass growth mechanisms and the ecosystem biogeochemical processes are not activated from partial defoliation by grazing animals during the period between the three and a half new leaf stage and the flower stage, the surviving grass tillers produce low numbers of vegetative tillers and reduced leaf biomass sending the ecosystem into spiralling degradation. The lost ecosystem productivity has far greater value than any perceived benefits derived from winter grazing native rangeland.

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

Nutrient (lb/d) Difference (%)	Dry Gestation	Third Trimester	Early Lactation	Spring Lactation	Summer Lactation	Fall Lactation
Old Style 1000 lb range cow with 12 to 6 lb/d milk production (lb/d)						
Dry matter	21.0	21.0	21.6	22.3	22.3	22.3
Energy (TDN)	9.64	10.98	12.05	11.98	11.98	11.98
Crude Protein	1.30	1.64	1.88	1.78	1.78	1.78
Modern 1200 lb range cow with 20 lb/d average milk production (lb/d)						
Dry matter	24.0	24.0	27.0	27.0	27.0	27.0
Energy (TDN)	11.02	12.62	15.85	15.23	15.23	15.23
Crude Protein	1.49	1.87	2.73	2.51	2.51	2.51
Percent increase in nutrient requirements for average production 1200 lb cow (%)						
Dry matter	14.29	14.29	25.00	21.08	21.08	21.08
Energy (TDN)	14.32	14.94	31.54	27.13	27.13	27.13
Crude Protein	14.62	14.02	45.21	41.01	41.01	41.01
Modern 1200 lb range cow with 30 lb/d high milk production (lb/d)						
Dry matter	24.1	24.2	29.2	29.08	29.08	29.08
Energy (TDN)	11.07	12.73	18.0	17.17	17.17	17.17
Crude Protein	1.50	1.90	3.36	3.06	3.06	3.06
Percent increase in nutrient requirements for high production 1200 lb cow (%)						
Dry matter	14.76	15.24	35.19	30.40	30.40	30.40
Energy (TDN)	14.83	15.94	49.38	43.32	43.32	43.32
Crude Protein	15.38	15.85	78.72	71.91	71.91	71.91

Data from Manske 2014a.

Table 2. Availability of sufficient crude protein for range cows on 12-month pasture forage management strategies.

12-month Management Strategies	Forage with Adequate Crude Protein		Forage Deficient in Crude Protein		Crude Protein Supplementation Provided		Crude Protein Supplementation Not Provided	
	Days	% of 12-mo	Days	% of 12-mo	Days	% of 12-mo	Days	% of 12-mo
Deferred Grazing	67	18%	298	82%	135	37%	163	45%
6.0-m Seasonlong	77	21%	288	79%	182	50%	106	29%
Repeated Seasonal	92	25%	273	75%	152	42%	121	33%
4.5-m Seasonlong	214	59%	151	41%	45	12%	106	29%
Twice-over Rotation	350	96%	15	4%	0	0%	15	4%

Data from Manske 2014b.

Table 3. Costs and returns for native rangeland, without hay, during cow production periods with 1200 lb cow and calf born in mid March.

Costs/Returns		37 Day Dry Gestation	90 Day Third Trimester	45 Day Early Lactation	28 Day Spring Lactation	135 Day Summer Lactation	30 Day Fall Lactation	12 Month Season
Forage DM Wt	lbs/ac	180.0	145.0	125.0	195.0	363.0	199.0	197.0
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	97.55
Crude Protein	%	4.8	4.8	9.2	16.3	9.6	4.8	8.6
CP Yield	lb/ac	8.6	7.0	11.5	31.8	34.8	9.6	16.9
CP Costs	$/lb	1.01	1.26	0.76	0.28	0.25	0.92	0.75
Forage/day	lbs/d	30	30	30	30	30	30	30
Land Area	ac	6.17	18.62	10.80	4.31	11.16	4.52	55.58
CP supp./day	lbs/d	1.49	0.43	-	-	-	1.21	0.83
Forage Costs	$/pp	54.05	163.11	94.61	37.76	97.76	39.60	486.89
CP supp. Costs	$/pp	16.54	11.61	-	-	-	10.89	39.04
Total Feed Costs	$/pp	70.59	174.72	94.61	37.76	97.76	50.49	525.93
Cost/day	$/d	1.91	1.94	2.10	1.35	0.72	1.68	1.44
Calf Wt Gain	lbs/pp	27.00	68.00	56.00	42.00	243.00	17.70	453.70
Wt. Value @$1.00/lb	$	27.00	68.00	56.00	42.00	243.00	17.70	453.70
Net Return/C-C pr	$	-43.59	-106.72	-38.61	4.24	145.24	-32.79	-72.23
Net Return/Acre	$	-7.07	-5.73	-3.58	0.98	13.00	-7.25	-1.30
Calf Gain Cost	$/lb	2.61	2.57	1.69	0.90	0.40	2.85	1.16

Table 4. Mean growing season herbage biomass (lbs/ac) by biotype categories on the silty ecological sites on three grazed management strategies located in the badlands of western North Dakota, 1993-1994.

Silty Site	Winter Grazed	Seasonlong Grazed	Twice-over Grazed
Cool Season	412.07	238.26	653.50
Warm Season	57.47	312.67	110.39
Upland Sedge	33.23	16.62	21.42
Forbs	52.22	45.23	65.40
Grasses	469.54	550.93	763.89
Graminoids	502.77	567.55	785.31
Total Live	554.99	612.77	850.72

Table 5. Mean growing season basal cover (%) by biotype categories on the silty ecological sites on three grazed management strategies located in the badlands of western North Dakota, 1993-1994.

Silty Site	Winter Grazed	Seasonlong Grazed	Twice-over Grazed
Cool Season	7.76	8.01	14.91
Warm Season	3.76	11.18	5.38
Upland Sedge	2.16	1.39	1.40
Forbs	2.85	3.93	4.93
Grasses	11.52	19.19	20.29
Graminoids	13.68	20.58	21.69
Total Live	16.53	24.51	26.62
Bare Soil	8.14	4.45	1.59

Practical harvested forage techniques

Some producers do provide low cost harvested hay to their cows. Most of this hay is putup late when the forage dry matter yields larger bales per acre, however, the late season forage is usually low in crude protein and energy (TDN), therefore, crude protein and energy (TDN) will need to be supplemental at additional costs. Cutting perennial grass hay between the boot stage and the flower stage, and cutting annual cereal hay between the boot stage and the early milk stage, yields forages with adequate quantities of crude protein and energy (TDN) with no additional cost. The quantity of dry matter would be reduced with little consequence because it has no economic value to livestock production.

Forage dry matter does not have a real economic value because it is not incorporated into the beef weight produced. All of the dry matter consumed by beef cattle is nondigestible and is deposited on the ground as manure in a couple of days. The dry matter component of forage is simply the carrier of the nutrients it contains; therefore, the cost of the forage dry matter is only indirectly related to forage feed costs. The nutrients (major and minor essential elements) are the valuable renewable products produced by forage plants on the land natural resources. The cow processes the forage nutrients and produces milk resulting in calf weight accumulation. This calf weight is the commodity sold at the market, nevertheless, the original source of the income from the sale of beef weight is the forage nutrients. These renewable forage nutrients are the primary unit of production in a cow-calf beef operation, and they are the source of new wealth from agricultural use of grazingland and hayland resources.

Forage nutrients are comprised of essential elements. The essential elements are required for life to exist by ensuring growth and development of organisms and the maintenance of all life functions. Livestock require 21 elements (table 6). Very large amounts of four major essential elements are required: carbon (C), hydrogen (H), nitrogen (N), and oxygen (O). Small amounts of seven macrominerals are required: calcium (Ca), phosphorus (P), potassium (K), magnesium (Mg), sulfur (S), sodium (Na), and chlorine (Cl). Very small amounts of ten microminerals are required: iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), iodine (I), cobalt (Co), selenium (Se), molybdenum (Mo), chromium (Cr), and nickel (Ni). The required quantity of each essential element varies with the cow's production period, body weight, quantity of milk production, and genetic production potential (Manske 2001).

The major forage produced nutrients are energy (TDN) and crude protein. The energy (TDN) produced by forage plants is part of the ecosystem's carbon cycle. Plants capture and fix carbon from atmospheric carbon dioxide with the hydrogen from soil water during the process of photosynthesis which converts energy from the sun into chemical energy. The assimilated carbon is combined in several ways to form various types of sugars and starches that are collectively called carbohydrates (CHO). These carbohydrates can be used as an energy source by the plant or by the herbivore that consumes plant parts. Capturing energy by fixing carbon has a relatively low impact on organisms that possess chlorophyll and on the ecosystem resources.

Feeder beef animals grow rapidly when fed a high energy grain based ration, however, these animals are never asked to go back to a forage based ration. Because of this phenomenon, some beef producers supplement energy to their cow herd in order to improve cow performance on their low cost poor quality forages. Supplements high in energy from nonstructural carbohydrates (NSC) (starches and sugars) causes the ruminal pH to decrease, which reduces growth of fibrolytic bacteria. Low quantities of fibrolytic bacteria result in reduced forage intake, and low forage fiber digestibility (Kunkle et al. 1999, Baublits et al. 2003, Hales et al. 2007). When these cows go back to a forage based ration or to grass pasture, they do not have adequate quantities of fibrolytic bacteria to digest the forage fibers causing a high amount of the nutrients contained in the forage to not be captured in the rumen and thus being lost to the animals. Supplemented energy as nonstructural carbohydrates (NSC) from products containing high amounts of grains or molasses should not be given to the cows that are intended to remain productive in the herd for many years.

Energy supplements that can be fed to a cow herd that have low impact on forage intake and forage digestibility have low nonstructural carbohydrates at less than 30% NSC and still have high total digestible nutrients (TDN) at greater than 75% TDN are the many fibrous coproduct feed stuffs. These include, but are not limited to, soybeans hulls, wheat middlings, corn gluten feed, beet pulp, distillers grains, and brewers grains.

Crude protein becomes deficient in beef cattle forage based rations at earlier forage plant growth stages than does energy. The crude protein produced by forage plants is part of the ecosystem's nitrogen cycle. Inorganic nitrogen is taken up by plant roots from the surrounding rhizosphere microorganisms and, through complex processes, the plant combines the inorganic nitrogen with carbon, hydrogen, and oxygen to synthesize different kinds of amino acids. The amino acids can be used immediately to build complex nitrogenous compounds, or the amino acids can float around inside the plant for later use. Amino acids are building blocks for proteins, nucleotides, and chlorophyll. Proteins are used to form enzymes, hormones, and structural components of cells. Nucleotides build nucleic acids, deoxyribonuclic acid (DNA) and ribonucleic acid (RNA), that are the genetic material that control all cellular functions and heredity (Coyne et al. 1995). About half of the organic nitrogen is in the form of amino compounds (Brady 1974). The large nitrogenous compounds that have been consumed by herbivores and deposited as excreta and the dead plant material are broken down and converted from organic nitrogen into inorganic nitrogen through numerous complex stages by soil microorganisms in the rhizosphere. Transforming nitrogen from inorganic nitrogen to organic nitrogen and back to inorganic nitrogen is complex and has a great impact on many organisms at multiple trophic levels and on the ecosystem resources. 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 quantity of crude protein captured per acre as livestock feed is the factor that has the greatest influence on the cost of pasture forage and harvested forage and on the amount of new wealth generated from the land resources. The weight of crude protein captured per acre is related to the percent crude protein content and the weight of the forage dry matter at the time of grazing or haying. The cost per pound of crude protein is determined by the weight of the crude protein captured per acre prorated against the forage production costs which include the land costs, equipment costs, and labor costs per acre. Reduction in livestock feed costs results from capturing greater quantities of crude protein per acre. Capturing greater quantities of the produced crude protein from a land base causes a reduction in the amount of land area required to feed a cow-calf pair and results in lowering the forage feed costs because the forage production costs per acre are spread over a greater number of pounds of crude protein. The greater quantity of pounds of calf weight gain per acre increases the quantity of new wealth generated per acre of land resources.

The greatest quantity of crude protein and energy (TDN) per acre available to animals with ruminant digestive systems are in the green leaves at the flower stage of perennial and annual grasses and at the full flower stage of legumes. When the seeds fill, nutrient material is moved from the leaves to the seed heads or pods. During the transfer process, half of the material is lost or used and only half reaches the seeds. For example, a field of annual cereal will yield double the weight of crude protein per acre when cut for hay at the flower stage than when harvested for grain at the mature stage.

Perennial and annual grass forages that are grazed or hayed at a mature plant stage, after flowering, are generally high-cost forages. The quantity of dry matter per acre is greater, and the size of the bales per acre are larger, causing a reduction in production costs per ton of forage dry matter. However, the quantity of crude protein per acre is lower causing an increase in cost per pound of crude protein and requiring greater land area to provide adequate feed for a cow-calf pair resulting in an increase in forage feed costs and reducing the pounds of calf weight gain per acre reducing the quantity of captured wealth per acre.

Perennial grass forages that are grazed at an early plant stage, after the three and a half new leaf stage and before the flower stage are low cost forage. Perennial grass and annual cereal forage that are cut for hay early between the boot stage and the early milk stage are low cost forages. The quantity of forage dry matter per acre is less causing an increase in production costs per ton of forage dry matter but the quantity of crude protein captured per acre is greater causing a decrease in cost per pound of crude protein and requiring less land area to provide adequate feed for a cow-calf pair resulting in a decrease of forage feed costs and an increase in the quantity of captured wealth.

Legume forages are different than grass forages and yield the greatest weight of crude protein per acre when the plants are at full growth stage but before the pods start to fill and the leaves start drying from senescence. The cost per pound of crude protein is lower for legume forages when plants are cut one time per year during a late full-growth stage resulting in lower forage feed costs and in greater captured wealth. Legume forages cut at early plant growth stages yield higher percentage of crude protein but because of the lower weight of crude protein per acre, the cost per pound of crude protein is higher and the forage feed costs are higher.

Harvested forage types containing 18% crude protein or greater are generally high-cost forages and have been removed from consideration as forage feed for beef cows during this study because the cost for the large quantity of supplemental roughage needed to balance the ration greatly reduces the amount of net returns per cow-calf pair and per acre.

Advanced Harvested Forage Technology

This report is the synthesis of 25 years of research to identify the factors that affect harvested forage costs for beef cows on the Northern Mixed Grass Prairie and to determine which factors can be controlled by management to improve profit margins from beef cow-calf production and to increase the new wealth generated from the land renewable natural resources without depletion of future production. Harvested forage management strategies will be evaluated for low forage feed costs and high net returns per acre for each of the six range cow production periods.

Evaluation of the production costs of livestock forage management practices is complicated because the various pasture forage types and harvested forage types have complex differences. Traditional livestock practices assume the source of income to be from the sale of animal weight. 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. Under this traditional concept, reduction of livestock production costs require reduction of the labor and equipment costs and the pasture forage and harvested forage costs usually resulting in cow and calf weight performance to be well below their genetic potential.

This traditional paradigm that the wealth comes from the sale of livestock weight causes major problems to provide forage with adequate nutrients to modern beef cows. Grazing native range pastures after mid October has low cash output per acre. However, cost per ton of forage and cost per pound of crude protein are outrageously high because of low forage quantity and low crude protein content per acre (table 3). Late cut grass hay has low cash cost per ton but the cost per pound of crude protein is very high. Modern equipment used for beef production are intended to reduce labor, however, these equipment costs can be greatly reduced to a hand scythe and pitch fork, but then the labor costs become a problem and an additional skilled staff is needed just to feed the workers. The modern equipment is needed, however, the expenditures should remain conservative. Lets change this old paradigm to the source of wealth originates from the renewable forage nutrients produced on the land natural resources.

Actually, reductions in forage dry matter costs, forage production costs, seed costs, land rent costs, equipment operation and depreciation costs, and labor costs all influence livestock feed costs and may cause some reduction in cash expenditures; unfortunately, reductions in these costs do not directly regulate livestock forage feed costs because these costs do not respond proportionally to the variations in quantities of forage needed to provide livestock with adequate amounts of nutrients resulting from the differences in the weight of crude protein captured per acre through the grazing or haying of various forage types at different plant growth stages.

Production of the beef cow herd is the last sector of the meat industry that continues to evaluate feed costs and to make feed management decisions from the cost per unit of dry matter. The swine, poultry, and dairy industries and the feeder sector of the beef industry have switched to efficient feed management systems that evaluate feed costs from the cost per unit of the nutrients.

Traditional evaluation of costs for forage management practices used the criteria of forage dry matter costs, forage production costs, land rent costs, equipment costs, and labor costs which do not identify forage types that provide low forage feed costs because these factors do not fluctuate with forage quality and thus do not directly regulate forage feed costs and have no diagnostic value.

The three most important factors that have diagnostic value in identification of forage management practices with low forage feed costs are the quantitative values of cost per pound of captured crude protein, cost per day of forage feed, and cost per pound of calf weight gain. The two important factors that have diagnostic value in identification of forage management practices that efficiently capture greater new wealth generated from the land renewable natural resources are the quantitative values of size of land area per cow-calf pair (which affects pounds of calf gain per acre) and net returns after feed costs per acre.

Procedure

The quantifiable factors that should be included in evaluations of forage types are harvested forage dry matter weight per acre, production cost per acre including land rent cost, equipment cost, labor cost, and seed cost; percent crude protein, captured crude protein weight per acre, crude protein cost per pound, cow size, forage allocation per day, land area per cow-calf pair, supplemental roughage cost, total forage feed cost, forage feed cost per day, calf weight gain performance, low market value of calf weight, returns after feed cost per cow-calf pair, returns after feed cost per acre, and calf weight gain cost per pound.

Production cost per acre was determined by adding land rent per acre, custom farm work cost per acre, seed cost per acre, and baling cost at per half ton rate.

Cost per ton of forage dry matter (DM) was determined by dividing production costs per acre by pounds of forage dry matter yield per acre and multiplying the quotient by 2000 pounds.

Cost per pound of crude protein (CP) was determined from the pounds of forage dry matter per acre multiplied by percentage of crude protein to derive pounds of captured crude protein per acre; then production cost per acre was divided by pounds of captured crude protein per acre.

Cow weight of 1200 lbs, average potential milk production, calf born in mid March, and cow production period on table 7 determined pounds of daily crude protein requirement.

Pounds of forage dry matter to provide as feed per cow-calf pair per day was determined from the pounds of crude protein required per cow per day during the production period divided by the percent crude protein of the forage type. Pounds of forage dry matter per day was multiplied by the number of days per production period to determine total weight of forage per period. The production cost per acre was divided by the forage dry matter yield per acre to determine cost per pound of forage dry matter. Forage cost per production period was determined by the total pounds of forage feed per period multiplied by the forage cost per pound.

Pounds of supplemental roughage to provide per cow-calf pair per day was determined from the total dry matter allocation per day from table 7 or 8 and subtracting the pounds of forage to provide per day. The source of roughage was year old crested wheatgrass hay valued at $35 per ton or $0.0175/lb and was considered to contain no available nutrients. Roughage cost was determined from the pounds of roughage provided per day multiplied by the number of day per production period and then multiplied by the roughage cost per pound ($0.0175).

Pounds of supplemental crude protein to provide was not determined for harvested forage types because any forage types that were low in crude protein for a cow production period were not used as forage feed during that production period. The source of wealth generated from the land resources depends on the quantity of crude protein captured per acre. A forage type low in crude protein generates low wealth from the land and thus not considered for use as forage feed.

Total feed cost per production period were determined by the sum of the harvested forage cost and the supplemented roughage cost per production period. The total feed cost per production period was divided by the number of days to determine the total feed cost per day.

Dollar value of calf accumulated weight gain per production period was determined by multiplying an assumed low market value of $1.00 per pound. A low market value was used to evaluate and identify harvested forage types that would produce positive returns after feed costs during low portions of the cattle cycle. Calf fetus weight gain was estimated to be 0.68 lbs/day during the dry gestation and to be 0.78 lbs/day during the third trimester production periods, based on an average birth weight of 95 pounds. Live calf accumulated weight gain was determined by subtracting calf live weight at the beginning of the growth period from calf live weight at the end of the growth period. The accumulated calf weight gains determined for the selected harvested forage types were averaged for each production period because the rations for the harvested forage types were designed to provide the same required quantity of crude protein during each production period and these forage types were evaluated over several years with only a few types analyzed each year.

Net return after feed costs per cow-calf pair was determined by subtracting the total feed cost per production period from the dollar value of the accumulated calf weight gain per production period. Net return after feed cost per acre was determined by dividing the net return per cow-calf pair by the number of acres of land area needed to feed a cow-calf pair per production period.

Cost per pound of calf weight gain per production period was determined by dividing the total feed cost per period by the pounds of calf weight accumulated per period.

This study evaluates four common harvested forage types with swathing occurring at two different plant growth stages. Perennial crested wheatgrass hay was cut early during the boot stage, and was cut late at the mature stage. Annual late maturing type oat forage hay was cut early at the beginning of the milk stage and was cut late at the hard dough stage. Annual forage barley hay was cut early at the beginning of the milk stage, and was cut late at the hard dough stage. Annual field pea forage hay was cut late at the full growth stage before pods started to fill. Annual field pea hay was also cut early, however, this hay was not included in the study because forage dry matter yield/ac was 66% lower than that for late cut pea forage, the crude protein content was greater than 18% with a 30% lower yield/ac than that for late cut pea forage, the forage feed ration had a high roughage cost with 28.6% more roughage than pea forage, the total feed cost was relatively high, and the returns/ac were the lowest of the annual forage feeds.

The mean forage dry matter yield per acre and percent crude protein for annual forage crop varieties cut for hay were taken from a five year agronomic forage crop study at the Dickinson Research Extension Center conducted and reported by Carr (1995-1999). Data for pasture forage types used during the spring, summer, and fall production periods were from Manske (2018b).

North Dakota State University agronomists at the Carrington, Dickinson, Hettinger, Minot, and Williston Research Extension Center (REC) conducted investigations on alternative use of cropland for the production of annual forages that can be used as harvested hay or silage during 1994 to 1999. Beef producers should consult the annual forage production reports from the REC nearest their locations for adapted varieties, forage dry matter yield per acre, and percent crude protein data to assist in selection of annual harvested forage types suitable for their operation.

The nutrient requirements for a 1200 lb range cow with a calf born in mid March and with average milk production was met each day during six cow production periods in accordance with recommendations from NRC 1996 (table 7). During the spring, summer, and fall lactation production periods, dry matter forage allocation followed pasture grazing quantities (table 8). The daily minor essential element requirements for a 1200 lb cow with average milk production are reported for macrominerals (lbs/day) and microminerals (g/day) on table 9. Research data has not determined the daily requirements for one macromineral and three microminerals nor ascertained evidence of deficiencies under practical conditions. The nutrient requirements and forage allocation will be described separately for each cow production period.

Table 6. Essential Elements Required by Animals.

Essential Nutrients
Crude Protein, Energy, Water, Vitamins
Major Essential Elements
Carbon (C), Hydrogen (H), Nitrogen (N), and Oxygen (O).
Minor Essential Elements
Macrominerals
Calcium (Ca), Phosphorus (P), Potassium (K),
Magnesium (Mg), Sulfur (S), Sodium (Na), Chlorine (Cl)
Microminerals
Iron (Fe), Manganese (Mn), Zinc (Zn), Copper (Cu),
Iodine (I), Cobalt (Co), Selenium (Se),
Molybdenum (Mo), Chromium (Cr), Nickel (Ni)

Table 7. Intake nutrient requirements (lb/d) for modern range cows with average milk production during cow production periods.

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

Data from NRC 1996.

Table 8. Daily dry matter allocation (lb/d) for modern range cows grazing pasture forage.

DM lb/d	1000 lb cow	1200 lb cow	1400 lb cow
Dry matter allocation	26	30	33

Date from Manske 2012.

Table 9. Daily minor essential element requirements of macrominerals (lbs/day) and microminerals (g/day) during six production periods for 1200 lb beef cows with average milk production.

Minor Essential Elements	Dry Gestation	Third Trimester	Early Lactation	Spring Lactation	Summer Lactation	Fall Lactation
Macrominerals (lbs/day)						
Calcium	0.04	0.06	0.08	0.07	0.07	0.07
Phosphorous	0.03	0.04	0.05	0.05	0.05	0.05
Potassium	0.14	0.14	0.19	0.19	0.19	0.19
Magnesium	0.03	0.03	0.05	0.045	0.045	0.045
Sulfur	0.04	0.04	0.04	0.04	0.04	0.04
Sodium	0.01	0.02	0.03	0.03	0.03	0.03
Chlorine	-	-	-	-	-	-
Microminerals (g/day)						
Iron	0.5443	0.5443	0.6124	0.6124	0.6124	0.6124
Manganese	0.4355	0.4355	0.4899	0.4899	0.4899	0.4899
Zinc	0.3266	0.3266	0.3674	0.3674	0.3674	0.3674
Copper	0.1089	0.1089	0.1225	0.1225	0.1225	0.1225
Iodine	0.0054	0.0054	0.0061	0.0061	0.0061	0.0061
Cobalt	0.0011	0.0011	0.0012	0.0012	0.0012	0.0012
Selenium	0.0011	0.0011	0.0012	0.0012	0.0012	0.0012
Molybdenum	-	-	-	-	-	-
Chromium	-	-	-	-	-	-
Nickel	-	-	-	-	-	-

Data from NRC 1996.

Results

Forage feed cost is affected by the quantity of forage dry matter harvested per acre, the production cost per acre, the forage dry matter cost per ton, the percent crude protein, the crude protein yield in pounds per acre, and the crude protein cost per pound. Four common forage types were included in this study, three forage types were cut at two different growth stages and one forage type was cut at one growth stage.

The early and late cut perennial crested wheatgrass hays had significantly lower forage yield per acre than the five annual forage types. The forage yield per acre for the five annual forage types were not significantly different. The late cut crested wheatgrass hay yielded 300 pounds per acre greater forage dry matter than the early cut crested wheatgrass hay. The production cost per acre for the early and late cut crested wheatgrass were significantly lower than those for the five annual forage types. The production cost per acre for the late pea forage hay was significantly greater than those for the other harvested types. The forage dry matter cost per ton was significantly lower for the late oat forage hay and was significantly greater for the early crested wheatgrass hay.

The percent crude protein was significantly higher for the early crested wheatgrass hay and the late pea forage hay and was significantly lower for the late crested wheatgrass hay. The crude protein yield in pounds per acre was significantly greater for the late pea forage hay and was significantly lower for the late crested wheatgrass hay. The cost per pound of captured crude protein was significantly greater for the late crested wheatgrass hay and was not significantly different for the other harvested types.

Net return per cow-calf pair is affected by the quantity of calf weight gain during a production period related to the total forage feed cost during that period. Net return per cow-calf pair increases when the cow has adequate quality of forage to milk at the genetic potential permitting the calf to grow at the genetic potential. Net return per acre is affected by the land area size used to produce the amount of forage with adequate quantities of crude protein required by a cow-calf pair during a production period. Net return per acre increases when the land area per cow-calf pair decreases.

Dry Gestation

The dry gestation production period was 37 days during late fall from 13 November to 20 December. The dry gestation period has the lowest nutrient requirements because there is no nursing calf or milk production and the developing fetus is 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. During the 37 days dry gestation period, a 1200 lb cow requires 888 lbs of forage dry matter, 407.74 lbs of energy (TDN), and 55.13 lbs of crude protein, with daily intake of 24 lbs dry matter, 1.49 lbs crude protein (table 7), and adequate amounts of minor essential elements (table 9).

Early Crested Wheatgrass Hay

Crested wheatgrass hay cut early during the boot stage was evaluated during the 37 day dry gestation production period (table 10). The crude protein content was 14.5%. Early cut crested wheatgrass hay had production costs of $26.50/ac, forage dry matter costs of $40.80/ton, and crude protein costs of $0.14/lb. Early cut crested wheatgrass hay would be fed at 10.3 lbs/day to provide 1.5 lbs CP/day, with 13.7 lbs/day of roughage added to the ration. Production of 381.10 lbs of early cut crested wheatgrass hay would require 0.29 acres at a cost of $7.77/period, with roughage costs at $8.87/period, the total feed cost was $16.64/period, or $0.45/day. Calf fetus weight gain was assumed to be 0.68lbs/day and accumulated weight gain was 25.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $25.00 per calf. The net returns after feed costs were a low of $8.36/cow-calf pair and a moderate gain of $28.83/acre. The high cost of calf fetus weight gain was $0.67/lb.

Late Crested Wheatgrass Hay

Crested wheatgrass hay cut late at the mature stage was evaluated during the 37 day dry gestation production period (table 10). The crude protein content was 6.4%. Late cut crested wheatgrass hay had production costs of $28.11/ac, forage dry matter costs of $34.80/ton, and crude protein costs of

$0.28/lb. Late cut crested wheatgrass hay would be fed at 24.0 lbs/day to provide 1.5 lbs CP/day, with no roughage added. Production of 888 lbs of late cut crested wheatgrass hay would require 0.56 acres at a cost of $15.74/period, with no roughage, the total feed cost was $15.74/period, or $0.43/day. Calf fetus weight gain was assumed to be 0.68lbs/day and accumulated weight gain was 25.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $25.00 per calf. The net returns after feed costs were a low of $9.26/cow-calf pair and a low of $16.54/acre. The high cost of calf fetus weight gain was $0.63/lb.

Early Forage Barley Hay

Forage barley hay cut early at the beginning of the milk stage was evaluated during the 37 day dry gestation production period (table 10). The crude protein content was 13.0%. Early cut forage barley hay had production costs of $68.21/ac, forage dry matter costs of $28.80/ton, and crude protein costs of $0.11/lb. Early cut forage barley hay would be fed at 11.5 lbs/day to provide 1.5 lbs CP/day, with 12.5 lbs/day of roughage added to the ration. Production of 425.50 lbs of early cut forage barley hay would require 0.09 acres at a cost of $6.14/period, with roughage costs at $8.09/period, the total feed cost was $14.23/period, or $0.38/day. Calf fetus weight gain was assumed to be 0.68lbs/day and accumulated weight gain was 25.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $25.00 per calf. The net returns after feed costs were a low of $10.77/cow-calf pair and a high gain of $119.67/acre. The cost of calf fetus weight gain was $0.57/lb.

Late Forage Barley Hay

Forage barley hay cut late at the hard dough stage was evaluated during the 37 day dry gestation production period (table 10). The crude protein content was 9.2%. Late cut forage barley had production costs of $70.35/ac, forage dry matter costs of $27.40/ton, and crude protein costs of $0.15/lb. Late cut forage barley hay would be fed at 16.2 lbs/day to provide 1.5 lbs CP/day, with 7.8 lbs/day of roughage added to the ration. Production of 599.40 lbs of late cut forage barley hay would require 0.12 acres at a cost of $8.44/period, with roughage costs at $5.05/period, the total feed cost was $13.49/period, or $0.36/day. Calf fetus weight gain was assumed to be 0.68lbs/day and accumulated weight gain was 25.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $25.00 per calf. The net returns after feed costs were $11.51/cow-calf pair and $95.92/acre. The cost of calf fetus weight gain was $0.54/lb.

Early Oat Forage Hay

Oat forage hay cut early at the beginning of the milk stage was evaluated during the 37 day dry gestation production period (table 10). The crude protein content was 11.5%. Early cut oat forage hay had production costs of $69.17/ac, forage dry matter costs of $29.60/ton, and crude protein costs of $0.13/lb. Early cut oat forage hay would be fed at 13.0 lbs/day to provide 1.5 lbs CP/day, with 11.0 lbs/day of roughage added to the ration. Production of 481.00 lbs of early cut oat forage hay would require 0.10 acres at a cost of $6.92/period, with roughage costs at $7.12/period, the total feed cost was $14.04/period, or $0.38/day. Calf fetus weight gain was assumed to be 0.68lbs/day and accumulated weight gain was 25.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $25.00 per calf. The net returns after feed costs were $10.96/cow-calf pair and a high gain of $109.60/acre. The cost of calf fetus weight gain was $0.56/lb.

Late Oat Forage Hay

Oat forage hay cut late at the hard dough stage was evaluated during the 37 day dry gestation production period (table 10). The crude protein content was 7.8%. Late cut oat forage hay had production costs of $74.53/ac, forage dry matter costs of $26.40/ton, and crude protein costs of $0.17/lb. Late cut oat forage hay would be fed at 19.1 lbs/day to provide 1.5 lbs CP/day, with 4.9 lbs/day of roughage added to the ration. Production of 706.70 lbs of late cut oat forage hay would require 0.13 acres at a cost of $9.69/period, with roughage costs at $3.17/period, the total feed cost was $12.86/period, or $0.35/day. Calf fetus weight gain was assumed to be 0.68lbs/day and accumulated weight gain was 25.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $25.00 per calf. The net returns after feed costs were $12.14/cow-calf pair and $93.38/acre. The cost of calf fetus weight gain was $0.51/lb.

Late Pea Forage Hay

Pea forage hay cut late at the full growth stage before pods start to fill was evaluated during the 37 day dry gestation production period (table 10). The crude protein content was 14.4%. Late cut pea forage hay had production costs of $86.87/ac, forage dry matter costs of \$37.40/ton, and crude protein costs of \$0.13/lb. Late cut pea forage hay would be fed at 10.3 lbs/day to provide 1.5 lbs CP/day, with 13.7 lbs/day of roughage added to the ration. Production of 381.10 lbs of late cut pea forage hay would require 0.08 acres at a cost of \$6.95/period, with roughage costs at \$8.87/period, the total feed cost was \$15.82/period, or \$0.43/day. Calf fetus weight gain was assumed to be 0.68lbs/day and accumulated weight gain was 25.00 lbs. When calf accumulated weight was assumed to have a low value of \$1.00/lb, the gross return was \$25.00 per calf. The net returns after feed costs were \$9.18/cow-calf pair and a high gain of \$114.75/acre. The cost of calf fetus weight gain was \$0.63/lb.

During the dry gestation period the total feed cost was significantly low for the late oat forage hay at \$12.86 per period, and \$0.35 per day, and was significantly high for the early cut crested wheatgrass hay at \$16.64 per period, and \$0.45 per day. Net return per cow-calf pair were all very low because the fetal calf weight gain was low, however, these values were all positive; most forage feed types fed during the dry gestation have negative net returns. Net return per acre were not significantly different for the five annual forage types which were all significantly greater than the early and late perennial crested wheatgrass hays.

Table 10. Costs and returns for forage types during 37 day dry gestation production period with 1200 lb cow.

Costs/Returns		Early Crested Wheat Hay	Late Crested Wheat Hay	Early Forage Barley Hay	Late Forage Barley Hay	Early Oat Forage Hay	Late Oat Forage Hay	Late Pea Forage Hay
Forage DM Wt	lbs/ac	1300.0	1600.0	4733.0	5133.0	4667.0	5667.0	4650.0
Production Costs	$/ac	26.50	28.11	68.21	70.35	69.17	74.53	86.87
Forage DM Costs	$/ton	40.80	34.80	28.80	27.40	29.60	26.40	37.40
Crude Protein	%	14.5	6.4	13.0	9.2	11.5	7.8	14.4
CP Yield	lb/ac	189	102	606	468	535	435	685
CP Costs	$/lb	0.14	0.28	0.11	0.15	0.13	0.17	0.13
Forage/day	lbs/d	10.3	24.0	11.5	16.2	13.0	19.1	10.3
Land Area	ac	0.29	0.56	0.09	0.12	0.10	0.13	0.08
Roughage/day	lbs/d	13.7	-	12.5	7.8	11.0	4.9	13.7
Forage Costs	$/pp	7.77	15.74	6.14	8.44	6.92	9.69	6.95
Roughage Costs	$/pp	8.87	-	8.09	5.05	7.12	3.17	8.87
Total Feed Costs	$/pp	16.64	15.74	14.23	13.49	14.04	12.86	15.82
Cost/day	$/d	0.45	0.43	0.38	0.36	0.38	0.35	0.43
Calf Wt Gain	lbs/pp	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Wt. Value @$1.00/lb	$	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Net Return/C-C pr	$	8.36	9.26	10.77	11.51	10.96	12.14	9.18
Net Return/Acre	$	28.83	16.54	119.67	95.92	109.60	93.38	114.75
Calf Gain Cost	$/lb	0.67	0.63	0.57	0.54	0.56	0.51	0.63

Third Trimester

The third trimester production period was 90 days during winter from 20 December to 20 March. The third trimester 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 to 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. During the 90 day third trimester period, a 1200 lb cow requires 2160 lbs of forage dry matter, 1135.8 lbs of energy (TDN), and 168.3 lbs of crude protein, with daily intake of 24 lbs dry matter, 1.87 lbs crude protein (table 7), and adequate amounts of minor essential elements (table 9).

Early Crested Wheatgrass Hay

Crested wheatgrass hay cut early during the boot stage was evaluated during the 90 day third trimester production period (table 11). The crude protein content was 14.5%. Early cut crested wheatgrass hay had production costs of $26.50/ac, forage dry matter costs of $40.80/ton, and crude protein costs of $0.14/lb. Early cut crested wheatgrass hay would be fed at 12.9 lbs/day to provide 1.9 lbs CP/day, with 11.1 lbs/day of roughage added to the ration. Production of 1161.00 lbs of early cut crested wheatgrass hay would require 0.89 acres at a cost of $23.59/period, with roughage costs at $17.48/period, the total feed cost was $41.07/period, or $0.46/day. Calf fetus weight gain was assumed to be 0.78lbs/day and accumulated weight gain was 70.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $70.00 per calf. The net returns after feed costs were $28.93/cow-calf pair and $35.51/acre. The high cost of calf fetus weight gain was $0.59/lb.

Early Forage Barley Hay

Forage barley hay cut early at the beginning of the milk stage was evaluated during the 90 day third trimester production period (table 11). The crude protein content was 13.0%. Early cut forage barley hay had production costs of $68.21/ac, forage dry matter costs of $28.80/ton, and crude protein costs of $0.11/lb. Early cut forage barley hay would be fed at 14.4 lbs/day to provide 1.9 lbs CP/day, with 9.6 lbs/day of roughage added to the ration. Production of 1296.00 lbs of early cut forage barley hay would require 0.27 acres at a cost of $18.42/period, with roughage costs at $15.12/period, the total feed cost was $33.54/period, or $0.37/day. Calf fetus weight gain was assumed to be 0.78lbs/day and accumulated weight gain was 70.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $70.00 per calf. The net returns after feed costs were $36.46/cow-calf pair and a high gain of $135.04/acre. The cost of calf fetus weight gain was $0.48/lb.

Late Forage Barley Hay

Forage barley hay cut late at the hard dough stage was evaluated during the 90 day third trimester production period (table 11). The crude protein content was 9.2%. Late cut forage barley hay had production costs of $70.35/ac, forage dry matter costs of $27.40/ton, and crude protein costs of $0.15/lb. Late cut forage barley hay would be fed at 20.3 lbs/day to provide 1.9 lbs CP/day, with 3.7 lbs/day of roughage added to the ration. Production of 1827.00 lbs of late cut forage barley hay would require 0.36 acres at a cost of $25.33/period, with roughage costs at $5.83/period, the total feed cost was $31.16/period, or $0.35/day. Calf fetus weight gain was assumed to be 0.78lbs/day and accumulated weight gain was 70.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $70.00 per calf. The net returns after feed costs were $38.84/cow-calf pair and $107.89/acre. The cost of calf fetus weight gain was $0.45/lb.

Early Oat Forage Hay

Oat forage hay cut early at the beginning of the milk stage was evaluated during the 90 day third trimester production period (table 11). The crude protein content was 11.5%. Early cut oat forage hay had production costs of $69.17/ac, forage dry matter costs of $29.60/ton, and crude protein costs of $0.13/lb. Early cut oat forage hay would be fed at 16.3 lbs/day to provide 1.9 lbs CP/day, with 7.7 lbs/day of roughage added to the ration. Production of 1467.00 lbs of early cut oat forage hay would require 0.31 acres at a cost of $21.44/period, with roughage costs at $12.13/period, the total feed cost was $33.57/period, or $0.37/day. Calf fetus weight gain was assumed to be 0.78lbs/day and accumulated weight gain was 70.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $70.00 per calf. The net returns after feed costs were $36.43/cow-calf pair and a high gain of $117.52/acre. The cost of calf fetus weight gain was $0.48/lb.

Late Oat Forage Hay

Oat forage hay cut late at the hard dough stage was evaluated during the 90 day third trimester production period (table 11). The crude protein content was 7.8%. Late cut oat forage hay had production costs of $74.53/ac, forage dry matter costs of $26.40/ton, and crude protein costs of $0.17/lb. Late cut oat forage hay would be fed at 24.0 lbs/day to provide 1.9 lbs CP/day, with no roughage added. Production of 2160.00 lbs of late cut oat forage hay would require 0.38 acres at a cost of $28.32/period, with no roughage, the total feed cost was $28.32/period, or $0.32/day. Calf fetus weight gain was assumed to be 0.78lbs/day and accumulated weight gain was 70.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $70.00 per calf. The net returns after feed costs were $41.68/cow-calf pair and a high gain of $109.68/acre. The cost of calf fetus weight gain was $0.41/lb.

Late Pea Forage Hay

Pea forage hay cut late at the full growth stage before pods start to fill was evaluated during the 90 day third trimester production period (table 11). The crude protein content was 14.4%. Late cut pea forage hay had production costs of $86.87/ac, forage dry matter costs of $37.40/ton, and crude protein costs of $0.13/lb. Late cut pea forage hay would be fed at 13.0 lbs/day to provide 1.9 lbs CP/day, with 11.0 lbs/day of roughage added to the ration. Production of 1170.00 lbs of late cut pea forage hay would require 0.25 acres at a cost of $21.72/period, with roughage costs at $17.33/period, the total feed cost was $39.05/period, or $0.43/day. Calf fetus weight gain was assumed to be 0.78lbs/day and accumulated weight gain was 70.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $70.00 per calf. The net returns after feed costs were $30.95/cow-calf pair and a high gain of $123.80/acre. The cost of calf fetus weight gain was $0.56/lb.

During the third trimester period the total feed cost was significantly low for the late oat forage hay at $28.32 per period, and $0.32 per day, and was significantly high for the early crested wheatgrass hay at $41.07 per period, and $0.46 per day. Net return per cow-calf pair was significantly high for the late oat forage hay at $41.68 per period and was significantly low for the early crested wheatgrass hay at $28.93 per period. Net return per acre were significantly high for all the five annual forage types at a mean $118.79 per period and was significantly low for the early crested wheatgrass hay at $35.51 per period.

Table 11. Costs and returns for forage types during 90 day third trimester production period with 1200 lb cow.

Costs/Returns		Early Crested Wheat Hay	Early Forage Barley Hay	Late Forage Barley Hay	Early Oat Forage Hay	Late Oat Forage Hay	Late Pea Forage Hay
Forage DM Wt	lbs/ac	1300.0	4733.0	5133.0	4667.0	5667.0	4650.0
Production Costs	$/ac	26.50	68.21	70.35	69.17	74.53	86.87
Forage DM Costs	$/ton	40.80	28.80	27.40	29.60	26.40	37.40
Crude Protein	%	14.5	13.0	9.2	11.5	7.8	14.4
CP Yield	lb/ac	189	606	468	535	435	685
CP Costs	$/lb	0.14	0.11	0.15	0.13	0.17	0.13
Forage/day	lbs/d	12.9	14.4	20.3	16.3	24.0	13.0
Land Area	ac	0.89	0.27	0.36	0.31	0.38	0.25
Roughage/day	lbs/d	11.1	9.6	3.7	7.7	-	11.0
Forage Costs	$/pp	23.59	18.42	25.33	21.44	28.32	21.72
Roughage Costs	$/pp	17.48	15.12	5.83	12.13	-	17.33
Total Feed Costs	$/pp	41.07	33.54	31.16	33.57	28.32	39.05
Cost/day	$/d	0.46	0.37	0.35	0.37	0.32	0.43
Calf Wt Gain	lbs/pp	70.00	70.00	70.00	70.00	70.00	70.00
Wt. Value @$1.00/lb	$	70.00	70.00	70.00	70.00	70.00	70.00
Net Return/C-C pr	$	28.93	36.46	38.84	36.43	41.68	30.95
Net Return/Acre	$	35.51	135.04	107.89	117.52	109.68	123.80
Calf Gain Cost	$/lb	0.59	0.48	0.45	0.48	0.41	0.56

Early Lactation

The early lactation production period was 45 days during early spring from 20 March to 4 May. The early lactation period has the greatest nutritional requirements of the six production periods because the birth of the calf initiates production of increasing amounts of milk and the reproductive organs require repair and preconditioning 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. During the 45 day early lactation period, a 1200 lb cow with calf born in mid March requires 1215 lbs of forage dry matter, 713.25 lbs of energy (TDN), and 122.85 lbs of crude protein, with daily intake of 27 lbs dry matter, 2.37 lbs crude protein (table 7), and adequate amounts of minor essential elements (table 9).

Early Crested Wheatgrass Hay

Crested wheatgrass hay cut early during the boot stage was evaluated during the 45 day early lactation production period (table 12). The crude protein content was 14.5%. Early cut crested wheatgrass hay had production costs of $26.50/ac, forage dry matter costs of $40.80/ton, and crude protein costs of $0.14/lb. Early cut crested wheatgrass hay would be fed at 18.8 lbs/day to provide 2.7 lbs CP/day, with 8.2 lbs/day of roughage added to the ration. Production of 846.00 lbs of early cut crested wheatgrass hay would require 0.65 acres at a cost of $17.23/period, with roughage costs at $6.46/period, the total feed cost was $23.69/period, or $0.53/day. Calf weight gain was 1.90lbs/day and accumulated weight gain was 85.50 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $85.50 per calf. The net returns after feed costs were $61.81/cow-calf pair and $95.09/acre. The cost of calf weight gain was $0.28/lb.

Early Forage Barley Hay

Forage barley hay cut early at the beginning of the milk stage was evaluated during the 45 day early lactation production period (table 12). The crude protein content was 13.0%. Early cut forage barley hay had production costs of $68.21/ac, forage dry matter costs of $28.80/ton, and crude protein costs of $0.11/lb. Early cut forage barley hay would be fed at 21.0 lbs/day to provide 2.7 lbs CP/day, with 6.0 lbs/day of roughage added to the ration. Production of 945.00 lbs of early cut forage barley hay would require 0.20 acres at a cost of $13.64/period, with roughage costs at $4.73/period, the total feed cost was $18.37/period, or $0.41/day. Calf weight gain was 1.90lbs/day and accumulated weight gain was 85.50 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $85.50 per calf. The net returns after feed costs were $67.31/cow-calf pair and a very high gain of $335.65/acre. The cost of calf weight gain was $0.21/lb.

Early Oat Forage Hay

Oat forage hay cut early at the beginning of the milk stage was evaluated during the 45 day early lactation production period (table 12). The crude protein content was 11.5%. Early cut oat forage hay had production costs of $69.17/ac, forage dry matter costs of $29.60/ton, and crude protein costs of $0.13/lb. Early cut oat forage hay would be fed at 23.7 lbs/day to provide 2.7 lbs CP/day, with 3.3 lbs/day of roughage added to the ration. Production of 1066.50 lbs of early cut oat forage hay would require 0.23 acres at a cost of $15.91/period, with roughage costs at $2.60/period, the total feed cost was $18.51/period, or $0.41/day. Calf weight gain was 1.90lbs/day and accumulated weight gain was 85.50 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $85.50 per calf. The net returns after feed costs were $66.99/cow-calf pair and a high gain of $291.26/acre. The cost of calf weight gain was $0.22/lb.

Late Pea Forage Hay

Pea forage hay cut late at the full growth stage before pods start to fill was evaluated during the 45 day early lactation production period (table 12). The crude protein content was 14.4%. Late cut pea forage hay had production costs of $86.87/ac, forage dry matter costs of $37.40/ton, and crude protein costs of $0.13/lb. Late cut pea forage hay would be fed at 19.0 lbs/day to provide 2.7 lbs CP/day, with 8.0

lbs/day of roughage added to the ration. Production of 855.00 lbs of late cut pea forage hay would require 0.18 acres at a cost of $15.64/period, with roughage costs at $6.30/period, the total feed cost was $21.94/period, or $0.49/day. Calf weight gain was 1.90lbs/day and accumulated weight gain was 85.50 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $85.50 per calf. The net returns after feed costs were $63.56/cow-calf pair and a very high gain of $353.11/acre. The cost of calf weight gain was $0.26/lb.

During the early lactation period the total feed cost were significantly low for the three annual forage hay types at a mean $19.61 per period, and $0.44 per day and was significantly high for the early crested wheatgrass hay at $23.69 per period, and $0.53 per day. Net return per cow-calf pair was significantly high for the three annual forage hay types at a mean $65.89 per period and was significantly low for the early crested wheatgrass hay at $61.81 per period. Net return per acre were significantly high for the three annual forage hay types at a mean $326.67 per period and was significantly low for the early crested wheatgrass hay at $95.09 per period.

Table 12. Costs and returns for forage types during 45 day early lactation production period with 1200 lb cow and calf born in mid March.

Costs/Returns		Early Crested Wheat Hay	Early Forage Barley Hay	Early Oat Forage Hay	Late Pea Forage Hay
Forage DM Wt	lbs/ac	1300.0	4733.0	4667.0	4650.0
Production Costs	$/ac	26.50	68.21	69.17	86.87
Forage DM Costs	$/ton	40.80	28.80	29.60	37.40
Crude Protein	%	14.5	13.0	11.5	14.4
CP Yield	lb/ac	189	606	535	685
CP Costs	$/lb	0.14	0.11	0.13	0.13
Forage/day	lbs/d	18.8	21.0	23.7	19.0
Land Area	ac	0.65	0.20	0.23	0.18
Roughage/day	lbs/d	8.2	6.0	3.3	8.0
Forage Costs	$/pp	17.23	13.64	15.91	15.64
Roughage Costs	$/pp	6.46	4.73	2.60	6.30
Total Feed Costs	$/pp	23.69	18.37	18.51	21.94
Cost/day	$/d	0.53	0.41	0.41	0.49
Calf Wt Gain	lbs/pp	85.50	85.50	85.50	85.50
Wt. Value @$1.00/lb	$	85.50	85.50	85.50	85.50
Net Return/C-C pr	$	61.81	67.13	66.99	63.56
Net Return/Acre	$	95.09	335.65	291.26	353.11
Calf Gain Cost	$/lb	0.28	0.21	0.22	0.26

Spring Lactation

The spring lactation production period was 28 days during spring from 4 May to 1 June. The spring lactation 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. Cows not gaining weight produce less than their 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. During the 28 day spring lactation period, a 1200 lb cow with calf born in mid March requires 840 lbs of forage dry matter, 426.44 lbs of energy (TDN), and 70.28 lbs of crude protein, with daily intake of 30 lbs dry matter, 2.51 lbs crude protein (tables 7 and 8), and adequate amounts of minor essential elements (table 9).

Early Crested Wheatgrass Hay

Crested wheatgrass hay cut early during the boot stage was evaluated during the 28 day spring lactation production period (table 13). The crude protein content was 14.5%. Early cut crested wheatgrass hay had production costs of \$26.50/ac, forage dry matter costs of \$40.80/ton, and crude protein costs of \$0.14/lb. Early cut crested wheatgrass hay would be fed at 17.3 lbs/day to provide 2.5 lbs CP/day, with 12.7 lbs/day of roughage added to the ration. Production of 484.40 lbs of early cut crested wheatgrass hay would require 0.37 acres at a cost of \$9.81/period, with roughage costs at \$6.22/period, the total feed cost was \$16.03/period, or \$0.57/day. Calf weight gain was 2.00lbs/day and accumulated weight gain was 56.00 lbs. When calf accumulated weight was assumed to have a low value of \$1.00/lb, the gross return was \$56.00 per calf. The net returns after feed costs were \$39.97/cow-calf pair and \$108.03/acre. The cost of calf weight gain was \$0.29/lb.

Early Forage Barley Hay

Forage barley hay cut early at the beginning of the milk stage was evaluated during the 28 day spring lactation production period (table 13). The crude protein content was 13.0%. Early cut forage barley hay had production costs of \$68.21/ac, forage dry matter costs of \$28.80/ton, and crude protein costs of \$0.11/lb. Early cut forage barley hay would be fed at 19.3 lbs/day to provide 2.5 lbs CP/day, with 10.7 lbs/day of roughage added to the ration. Production of 540.40 lbs of early cut forage barley hay would require 0.11 acres at a cost of \$7.50/period, with roughage costs at \$5.24/period, the total feed cost was \$12.74/period, or \$0.46/day. Calf weight gain was 2.00 lbs/day and accumulated weight gain was 56.00 lbs. When calf accumulated weight was assumed to have a low value of \$1.00/lb, the gross return was \$56.00 per calf. The net returns after feed costs were \$43.26/cow-calf pair and a very high gain of \$393.27/acre. The cost of calf weight gain was \$0.23/lb.

Early Oat Forage Hay

Oat forage hay cut early at the beginning of the milk stage was evaluated during the 28 day spring lactation production period (table 13). The crude protein content was 11.5%. Early cut oat forage hay had production costs of \$69.17/ac, forage dry matter costs of \$29.60/ton, and crude protein costs of \$0.13/lb. Early cut oat forage hay would be fed at 21.8 lbs/day to provide 2.5 lbs CP/day, with 8.2 lbs/day of roughage added to the ration. Production of 610.40 lbs of early cut oat forage hay would require 0.13 acres at a cost of \$8.99/period, with roughage costs at \$4.02/period, the total feed cost was \$13.01/period, or \$0.46/day. Calf weight gain was 2.00lbs/day and accumulated weight gain was 56.00 lbs. When calf accumulated weight was assumed to have a low value of \$1.00/lb, the gross return was \$56.00 per calf. The net returns after feed costs were \$42.99/cow-calf pair and a high gain of \$330.69/acre. The cost of calf weight gain was \$0.23/lb.

Late Pea Forage Hay

Pea forage hay cut late at the full growth stage before pods start to fill was evaluated during the 28 day spring lactation production period (table 13). The crude protein content was 14.4%. Late cut pea forage hay had production costs of \$86.87/ac, forage dry matter costs of \$35.39/ton, and crude protein costs of \$0.13/lb. Late cut pea forage hay would be fed at 17.4 lbs/day to provide 2.5 lbs CP/day, with

12.6 lbs/day of roughage added to the ration. Production of 487.20 lbs of late cut pea forage hay would require 0.11 acres at a cost of $9.56/period, with roughage costs at $6.17/period, the total feed cost was $15.73/period, or $0.56/day. Calf weight gain was 2.00lbs/day and accumulated weight gain was 56.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $56.00 per calf. The net returns after feed costs were $40.27/cow-calf pair and a high gain of $366.09/acre. The cost of calf weight gain was $0.28/lb.

Crested Wheatgrass One Pasture

Crested wheatgrass spring complementary traditional one pasture treatment was grazed from 4 May to 1 June and was evaluated during the 28 day spring lactation production period (table 13). The crude protein content was 16.8%. Crested wheatgrass one pasture had rent costs of $8.76/ac, forage dry matter costs of $35.39/ton, and crude protein costs of $0.11/lb. Traditional crested wheatgrass pasture was stocked at 2.33 ac/AUM (2.14 ac/AU). Allocation of 30 lbs/d provided 840 lbs forage/period and 5.0 lbs/d crude protein/cow-calf pair. Forage removal rate was 993 lbs or 35.5 lbs/d/cow-calf pair. Total feed cost was $18.75/period, or $0.67/day. Calf weight gain was 2.57 lbs/d, 32.9 lbs/ac, accumulated weight gain was 72.67 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $72.67 per calf. The net returns after feed costs were $53.92/cow-calf pair and $25.20/acre. The cost of calf weight gain was $0.26/lb.

Crested Wheatgrass Two Pasture

Crested wheatgrass spring complementary biologically effective two pasture switchback treatment was grazed from 4 May to 1 June and was evaluated during the 28 day spring lactation production period (table 13). The crude protein content was 17.1%. Crested wheatgrass two pasture switchback had rent costs of $8.76/ac, forage dry matter costs of $32.11/ton, and crude protein costs of $0.09/lb. Biologically effective crested wheatgrass pastures were stocked at 1.30 ac/AUM (1.20 ac/AU). Allocation of 30 lbs/d provided 840 lbs forage/period and 5.0 lbs/d crude protein/cow-calf pair. Forage removal rate was 1372 lbs or 49.0 lbs/d/cow-calf pair. Total feed cost was $10.51/period, or $0.38/day. Calf weight gain was 2.61 lbs/d, 66.6 lbs/ac, accumulated weight gain was 76.45 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $76.45 per calf. The net returns after feed costs were $65.94/cow-calf pair and $54.95/acre. The cost of calf weight gain was $0.14/lb.

During the spring lactation period the total feed cost were not significantly different among the harvested forage hay types at a mean $14.38 per period, and $0.51 per day. The total feed cost was significantly low for the crested wheatgrass two pasture switchback strategy at $10.51 per period, and $0.38 per day and was significantly high for the crested wheatgrass one pasture strategy at $18.75 per period, and $0.67 per day. Net return per cow-calf pair was significantly high for the crested wheatgrass two pasture switchback strategy at $65.94 per period and was not significantly different for the four harvested forage hay types at a mean $41.62 per period. Net return per acre was significantly high for the early forage barley hay at $393.27 per period and was significantly low for the crested wheatgrass one pasture strategy at $25.20 per period. The net return per acre was significantly lower for the early crested wheatgrass hay at $108.03 per period than those for the other three harvested forage hay types.

Table 13. Costs and returns for forage types during 28 day spring lactation production period with 1200 lb cow and calf born in mid March.

Costs/Returns		Early Crested Wheat Hay	Early Forage Barley Hay	Early Oat Forage Hay	Late Pea Forage Hay	Crested Wheat One Pasture	Crested Wheat Two Pasture
Forage DM Wt	lbs/ac	1300.0	4733.0	4667.0	4650.0	495.0	545.6
Production Costs	$/ac	26.50	68.21	69.17	86.87	8.76	8.76
Forage DM Costs	$/ton	40.80	28.80	29.60	35.39	35.39	32.11
Crude Protein	%	14.5	13.0	11.5	14.4	16.8	17.1
CP Yield	lb/ac	189	606	535	685	54	93
CP Costs	$/lb	0.14	0.11	0.13	0.13	0.11	0.09
Forage/day	lbs/d	17.3	19.3	21.8	17.4	30	30
Land Area	ac	0.37	0.11	0.13	0.11	2.14	1.20
Roughage/day	lbs/d	12.7	10.7	8.2	12.6	-	-
Forage Costs	$/pp	9.81	7.50	8.99	9.56	18.75	10.51
Roughage Costs	$/pp	6.22	5.24	4.02	6.17	-	-
Total Feed Costs	$/pp	16.03	12.74	13.01	15.73	18.75	10.51
Cost/day	$/d	0.57	0.46	0.46	0.56	0.67	0.38
Calf Wt Gain	lbs/pp	56.00	56.00	56.00	56.00	72.67	76.45
Wt. Value @$1.00/lb	$	56.00	56.00	56.00	56.00	72.67	76.45
Net Return/C-C pr	$	39.97	43.26	42.99	40.27	53.92	65.94
Net Return/Acre	$	108.03	393.27	330.69	366.09	25.20	54.95
Calf Gain Cost	$/lb	0.29	0.23	0.23	0.28	0.26	0.14

Summer Lactation

The summer lactation production period was 135 days during summer from 1 June to 14 October. The summer lactation period has nutritional requirements 41% to 72% 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 critical 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, however, the nutritional quality of the forage affects the rate of decline. 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 cost per pound of weight gained. During the 135 day summer lactation period, a 1200 lb cow with calf born in mid March requires 4050 lbs of forage dry matter, 2056.05 lbs of energy (TDN), and 338.85 lbs of crude protein, with daily intake of 30 lbs dry matter, 2.51 crude protein (tables 7 and 8), and adequate amounts of minor essential elements (table 9).

Early Crested Wheatgrass Hay

Crested wheatgrass hay cut early during the boot stage was evaluated during the 135 day summer lactation production period (table 14). The crude protein content was 14.5%. Early cut crested wheatgrass hay had production costs of $26.50/ac, forage dry matter costs of $40.80/ton, and crude protein costs of $0.14/lb. Early cut crested wheatgrass hay would be fed at 17.3 lbs/day to provide 2.5 lbs CP/day, with 12.7 lbs/day of roughage added to the ration. Production of 2335.50 lbs of early cut crested wheatgrass hay would require 1.80 acres at a cost of $47.70/period, with roughage costs at $30.00/period, the total feed cost was $77.70/period, or $0.58/day. Calf weight gain was 2.00lbs/day and accumulated weight gain was 270.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $270.00 per calf. The net returns after feed costs were $192.30/cow-calf pair and $106.83/acre. The cost of calf weight gain was $0.29/lb.

Early Forage Barley Hay

Forage barley hay cut early at the beginning of the milk stage was evaluated during the 135 day summer lactation production period (table 14). The crude protein content was 13.0%. Early cut forage barley hay had production costs of $68.21/ac, forage dry matter costs of $28.80/ton, and crude protein costs of $0.11/lb. Early cut forage barley hay would be fed at 19.3 lbs/day to provide 2.5 lbs CP/day, with 10.7 lbs/day of roughage added to the ration. Production of 2605.50 lbs of early cut forage barley hay would require 0.55 acres at a cost of $37.52/period, with roughage costs at $25.28/period, the total feed cost was $62.80/period, or $0.47/day. Calf weight gain was 2.00 lbs/day and accumulated weight gain was 270.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $270.00 per calf. The net returns after feed costs were $207.20/cow-calf pair and a very high gain of $376.73/acre. The cost of calf weight gain was $0.23/lb.

Early Oat Forage Hay

Oat forage hay cut early at the beginning of the milk stage was evaluated during the 135 day summer lactation production period (table 14). The crude protein content was 11.5%. Early cut oat forage hay had production costs of $69.17/ac, forage dry matter costs of $29.60/ton, and crude protein costs of $0.13/lb. Early cut oat forage hay would be fed at 21.8 lbs/day to provide 2.5 lbs CP/day, with 8.2 lbs/day of roughage added to the ration. Production of 2943.00 lbs of early cut oat forage hay would require 0.63 acres at a cost of $43.58/period, with roughage costs at $19.37/period, the total feed cost was $62.95/period, or $0.47/day. Calf weight gain was 2.00lbs/day and accumulated weight gain was 270.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $270.00 per calf. The net returns after feed costs were $207.05/cow-calf pair and a high gain of $328.65/acre. The cost of calf weight gain was $0.23/lb.

Late Pea Forage Hay

Pea forage hay cut late at the full growth stage before pods start to fill was evaluated during the 135 day summer lactation production period (table 14). The crude protein content was 14.4%. Late cut pea forage hay had production costs of $86.87/ac, forage dry matter costs of $35.39/ton, and crude protein costs of $0.13/lb. Late cut pea forage hay would be fed at 17.4 lbs/day to provide 2.5 lbs CP/day, with 12.6 lbs/day of roughage added to the ration. Production of 2349.00 lbs of late cut pea forage hay would require 0.51 acres at a cost of $44.30/period, with roughage costs at $29.77/period, the total feed cost was $74.07/period, or $0.55/day. Calf weight gain was 2.00lbs/day and accumulated weight gain was 270.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $270.00 per calf. The net returns after feed costs were $195.93/cow-calf pair and a high gain of $384.18/acre. The cost of calf weight gain was $0.27/lb.

Native Range Seasonlong Pasture

Native range traditional seasonlong pasture treatment was grazed from 1 June to 14 October and was evaluated during the 135 day summer lactation production period (table 14). The crude protein content was 8.4%. Native range seasonlong pasture had rent costs of $8.76/ac, forage dry matter costs of $58.33/ton, and crude protein costs of $0.35/lb. Traditional native range seasonlong pasture was stocked at 2.58 ac/AUM (11.43 ac/AU). Allocation of 30 lbs/d provided 4050.00 lbs forage/period and 2.5 lbs/d crude protein/cow-calf pair. Total feed cost was $100.13/period, or $0.74/day. Calf weight gain was 2.65 lbs/d, 30.61 lbs/ac, accumulated weight gain was 354.37 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $354.37 per calf. The net returns after feed costs were $254.24/cow-calf pair and $22.24/acre. The cost of calf weight gain was $0.28/lb.

Native Range Twice-over Pasture

Native range biologically effective twice-over pasture system was grazed from 1 June to 14 October and was evaluated during the 135 day summer lactation production period (table 14). The crude protein content was 9.8%. Native range twice-over pasture system had rent costs of $8.76/ac, forage dry matter costs of $51.92/ton, and crude protein costs of $0.26/lb. Biologically effective native range twice-over pastures were stocked at 2.26 ac/AUM (10.22 ac/AU). Allocation of 30 lbs/d provided 4050.00 lbs forage/period and 2.9 lbs/d crude protein/cow-calf pair. Total feed cost was $89.53/period, or $0.66/day. Calf weight gain was 2.89 lbs/d, 37.66 lbs/ac, accumulated weight gain was 380.47 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $380.47 per calf. The net returns after feed costs were $290.94/cow-calf pair and $28.47/acre. The cost of calf weight gain was $0.24/lb.

During the summer lactation period the total feed cost were significantly low for the early forage barley hay at $62.80 per period, and $0.47 per day and the early oat forage hay at $62.95 per period, and $0.47per day and was significantly high for the native range seasonlong pasture strategy at $100.13 per period, and $0.74 per day. Net return per cow-calf pair was significantly high for the native range twice-over strategy at $290.94 per period and was significantly low for the early crested wheatgrass hay at $192.30 per period. Net return per acre was significantly high for the late pea forage barley hay at $384.18 per period and was significantly low for the native range seasonlong pasture strategy at $22.24 per period.

Table 14. Costs and returns for forage types during 135 day summer lactation production period with 1200 lb cow and calf born in mid March.

Costs/Returns		Early Crested Wheat Hay	Early Forage Barley Hay	Early Oat Forage Hay	Late Pea Forage Hay	Native Range Seasonlong Pasture	Native Range Twice-over Pasture
Forage DM Wt	lbs/ac	1300.0	4733.0	4667.0	4650.0	300.4	337.4
Production Costs	$/ac	26.50	68.21	69.17	86.87	8.76	8.76
Forage DM Costs	$/ton	40.80	28.80	29.60	35.39	58.33	51.92
Crude Protein	%	14.5	13.0	11.5	14.4	8.4	9.8
CP Yield	lb/ac	189	606	535	685	25	33
CP Costs	$/lb	0.14	0.11	0.13	0.13	0.35	0.26
Forage/day	lbs/d	17.3	19.3	21.8	17.4	30	30
Land Area	ac	1.80	0.55	0.63	0.51	11.43	10.22
Roughage/day	lbs/d	12.7	10.7	8.2	12.6	-	-
Forage Costs	$/pp	47.70	37.52	43.58	44.30	100.13	89.53
Roughage Costs	$/pp	30.00	25.28	19.37	29.77	-	-
Total Feed Costs	$/pp	77.70	62.80	62.95	74.07	100.13	89.53
Cost/day	$/d	0.58	0.47	0.47	0.55	0.74	0.66
Calf Wt Gain	lbs/pp	270.00	270.00	270.00	270.00	354.37	380.47
Wt. Value @$1.00/lb	$	270.00	270.00	270.00	270.00	354.37	380.47
Net Return/C-C pr	$	192.30	207.20	207.05	195.93	254.24	290.94
Net Return/Acre	$	106.83	376.73	328.65	384.18	22.24	28.47
Calf Gain Cost	$/lb	0.29	0.23	0.23	0.27	0.28	0.24

Fall Lactation

The fall lactation production period was 30 days during fall from 14 October to 13 November. The fall lactation period has nutritional requirements unchanged from the summer lactation period. The greater part of the required nutrient above maintenance 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 quantity 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 quantity 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 harvested 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 were low; the result is higher costs per pound of calf weight gained. During the 30 day fall lactation period, a 1200 lb cow with calf born in mid March requires 900 lbs of forage dry matter, 456.9 lbs of energy (TDN), and 75.3 lbs of crude protein, with daily intake of 30 lbs dry matter, 2.51 lbs crude protein (tables 7 and 8), and adequate amounts of minor essential elements (table 9).

Early Crested Wheatgrass Hay

Crested wheatgrass hay cut early during the boot stage was evaluated during the 30 day fall lactation production period (table 15). The crude protein content was 14.5%. Early cut crested wheatgrass hay had production costs of $26.50/ac, forage dry matter costs of $40.80/ton, and crude protein costs of $0.14/lb. Early cut crested wheatgrass hay would be fed at 17.3 lbs/day to provide 2.5 lbs CP/day, with 12.7 lbs/day of roughage added to the ration. Production of 519.00 lbs of early cut crested wheatgrass hay would require 0.40 acres at a cost of $10.60/period, with roughage costs at $6.67/period, the total feed cost was $17.27/period, or $0.58/day. Calf weight gain was 2.00lbs/day and accumulated weight gain was 60.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $60.00 per calf. The net returns after feed costs were $42.73/cow-calf pair and $106.83/acre. The cost of calf weight gain was $0.29/lb.

Early Forage Barley Hay

Forage barley hay cut early at the beginning of the milk stage was evaluated during the 30 day fall lactation production period (table 15). The crude protein content was 13.0%. Early cut forage barley hay had production costs of $68.21/ac, forage dry matter costs of $28.80/ton, and crude protein costs of $0.11/lb. Early cut forage barley hay would be fed at 19.3 lbs/day to provide 2.5 lbs CP/day, with 10.7 lbs/day of roughage added to the ration. Production of 579.00 lbs of early cut forage barley hay would require 0.12 acres at a cost of $8.19/period, with roughage costs at $5.62/period, the total feed cost was $13.81/period, or $0.46/day. Calf weight gain was 2.00 lbs/day and accumulated weight gain was 60.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $60.00 per calf. The net returns after feed costs were $46.19/cow-calf pair and a very high gain of $384.92/acre. The cost of calf weight gain was $0.23/lb.

Late Forage Barley Hay

Forage barley hay cut late at the hard dough stage was evaluated during the 30 day fall lactation production period (table 15). The crude protein content was 9.2%. Late cut forage barley hay had production costs of $70.35/ac, forage dry matter costs of $27.40/ton, and crude protein costs of $0.15/lb. Late cut forage barley hay would be fed at 27.3 lbs/day to provide 2.5 lbs CP/day, with 2.7 lbs/day of roughage added to the ration. Production of 819.00 lbs of late cut forage barley hay would require 0.16 acres at a cost of $11.26/period, with roughage costs at $1.42/period, the total feed cost was $12.68/period, or $0.42/day. Calf weight gain was 2.00 lbs/day and accumulated weight gain was 60.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $60.00 per calf. The net returns after feed costs were $47.32/cow-calf pair and a high gain of $295.75/acre. The cost of calf weight gain was $0.21/lb.

Early Oat Forage Hay

Oat forage hay cut early at the beginning of the milk stage was evaluated during the 30 day fall lactation production period (table 15). The crude protein content was 11.5%. Early cut oat forage hay had production costs of $69.17/ac, forage dry matter costs of $29.60/ton, and crude protein costs of $0.13/lb. Early cut oat forage hay would be fed at 21.8 lbs/day to provide 2.5 lbs CP/day, with 8.2 lbs/day of roughage added to the ration. Production of 654.00 lbs of early cut oat forage hay would require 0.14 acres at a cost of $9.68/period, with roughage costs at $4.31/period, the total feed cost was $14.00/period, or $0.47/day. Calf weight gain was 2.00lbs/day and accumulated weight gain was 60.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $60.00 per calf. The net returns after feed costs were $46.00/cow-calf pair and a high gain of $328.65/acre. The cost of calf weight gain was $0.23/lb.

Late Pea Forage Hay

Pea forage hay cut late at the full growth stage before pods start to fill was evaluated during the 30 day fall lactation production period (table 15). The crude protein content was 14.4%. Late cut pea forage hay had production costs of $86.87/ac, forage dry matter costs of $37.40/ton, and crude protein costs of $0.13/lb. Late cut pea forage hay would be fed at 17.4 lbs/day to provide 2.5 lbs CP/day, with 12.6 lbs/day of roughage added to the ration. Production of 522.00 lbs of late cut pea forage hay would require 0.11 acres at a cost of $9.56/period, with roughage costs at $6.62/period, the total feed cost was $16.18/period, or $0.54/day. Calf weight gain was 2.00lbs/day and accumulated weight gain was 60.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $60.00 per calf. The net returns after feed costs were $43.82/cow-calf pair and a very high gain of $398.36/acre. The cost of calf weight gain was $0.27/lb.

Spring Seeded Winter Cereal Pasture

Winter rye was seeded during the spring planting period, separated by electric fence in four units that contained forage for one week of grazing each, for a total treatment from 14 October to 13 November and was evaluated during the 30 day fall lactation production period (table 15). The crude protein content was 12.2%. Spring seeded winter cereal pastures had production costs of $41.75/ac, forage dry matter costs of $43.77/ton, and crude protein costs of $0.18/lb. Winter cereal pastures were stocked at 0.48 ac/AUM (0.47 ac/AU). Allocation of 30 lbs/d provided 900 lbs forage/period and 3.7 lbs/d crude protein/cow-calf pair. Total feed cost was $19.70/period, or $0.66/day. Calf weight gain was 2.00 lbs/d, 127.66 lbs/ac, accumulated weight gain was 60.00 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $60.00 per calf. The net returns after feed costs were $40.30/cow-calf pair and $85.74/acre. The cost of calf weight gain was $0.33/lb.

Winter rye is not the only annual winter cereal that would provide forage during the fall lactation production period, however, it was one of the desired winter cereals that had seed available in western North Dakota. Winter wheat and winter triticale seed was also available, however, livestock prefer winter rye forage to winter wheat or winter triticale forage. The winter triticale would produce greater forage weight per acre, the winter wheat would produce mid range forage weight per acre, and the winter rye would produce the lowest forage weight per acre. However, when all three winter cereal types are available, cattle will walk past winter triticale and winter wheat to get to the winter rye.

Other winter cereals that have promise as a fall forage source but still have problems of seed availability in the northern plains is winter barley and winter oat. The desired winter oat is Cosaque black oat (Avena sativa) which should not be confused with old European black winter oat (Avena strigosa) which has ergot and fusarium head blight problems. Until seed dealers supply winter barley and winter oat seed to the northern plains region, acquisition of seeds of winter barley and winter oat will require travel to the region where they are produced during the normal harvest time.

Altai Wildrye Pasture

Altai widrye pasture was grazed from 14 October to 13 November and was evaluated during the 30 day fall lactation production period (table 15). The crude protein content was 10.2%. Altai wildrye pastures had rent costs of $8.76/ac, forage dry matter costs of $22.31/ton, and crude protein costs of $0.11/lb. Altai wildrye pastures were stocked at 1.41 ac/AUM (1.39 ac/AU). Allocation of 30 lbs/d provided 900 lbs forage/period and 3.1 lbs/d crude protein/cow-calf pair. Total feed cost was $12.18/period, or $0.41/day. Calf weight gain was 1.82 lbs/d, 37.12 lbs/ac, accumulated weight gain was 50.34 lbs. When calf accumulated weight was assumed to have a low value of $1.00/lb, the gross return was $50.34 per calf. The net returns after feed costs were $38.16/cow-calf pair and $27.45/acre. The cost of calf weight gain was $0.24/lb.

During the fall lactation period the total feed cost were significantly low for the Altai wildrye pasture at $12.18 per period, and $0.41 per day and for the late forage barley hay at $12.68 per period, and $0.42 per day and were significantly high for the spring seeded winter cereal pasture at $19.70 per period, and $0.66 per day and for the early crested wheatgrass hay at $17.27 per period, and $0.58 per day. Net return per cow-calf pair was significantly high for the late forage barley hay at $47.32 per period and was significantly low for the Altai wildrye pasture at $38.16 per period. Net return per acre was significantly high for the late pea forage hay at $398.36 per period and was significantly low for the Altai wildrye pasture at $27.45. The net return per acre for the late forage barley hay was significantly lower than that for the other annual forage hay types.

Late crested wheatgrass hay had the lowest content of crude protein at 6.4%, the lowest yield at 102 lbs/ac, and the highest cost at $0.28/lb and was deficient of crude protein during all cow production periods except the dry gestation period.

Late oat forage hay had the second lowest content of crude protein at 7.8%, and the second highest cost at $0.17/lb, and was deficient of crude protein during all cow production periods except the dry gestation and third trimester periods.

Late forage barley hay had the third lowest content of crude protein at 9.2%, and was deficient of crude protein during the early lactation period and was borderline deficient of crude protein during the other three lactation periods, however, late forage barley hay was fed during the fall lactation period because it had a low total forage feed cost.

Early forage barley hay, early oat forage hay, and late pea forage hay were excellent annual forage hay types with consistently low total feed cost and high net return per cow-calf pair and net return per acre.

Table 15. Costs and returns for forage types during 30 day fall lactation production period with 1200 lb cow and calf born in mid March.

Costs/Returns		Early Crested Wheat Hay	Early Forage Barley Hay	Late Forage Barley Hay	Early Oat Forage Hay	Late Pea Forage Hay	Spring Seeded Winter Cereal Pasture	Altai Wildrye Pasture
Forage DM Wt	lbs/ac	1300.0	4733.0	5133.0	4667.0	4650.0	1908.0	785.25
Production Costs	$/ac	26.50	68.21	70.35	69.17	86.87	41.75	8.76
Forage DM Costs	$/ton	40.80	28.80	27.40	29.60	37.40	43.77	22.31
Crude Protein	%	14.5	13.0	9.2	11.5	14.4	12.2	10.2
CP Yield	lb/ac	189	606	468	535	685	233	80
CP Costs	$/lb	0.14	0.11	0.15	0.13	0.13	0.18	0.11
Forage/day	lbs/d	17.3	19.3	27.3	21.8	17.4	30	30
Land Area	ac	0.40	0.12	0.16	0.14	0.11	0.47	1.39
Roughage/day	lbs/d	12.7	10.7	2.7	8.2	12.6	-	-
Forage Costs	$/pp	10.60	8.19	11.26	9.68	9.56	19.70	12.18
Roughage Costs	$/pp	6.67	5.62	1.42	4.31	6.62	-	-
Total Feed Costs	$/pp	17.27	13.81	12.68	14.00	16.18	19.70	12.18
Cost/day	$/d	0.58	0.46	0.42	0.47	0.54	0.66	0.41
Calf Wt Gain	lbs/pp	60.00	60.00	60.00	60.00	60.00	60.00	50.34
Wt. Value @$1.00/lb	$	60.00	60.00	60.00	60.00	60.00	60.00	50.34
Net Return/C-C pr	$	42.73	46.19	47.32	46.00	43.82	40.30	38.16
Net Return/Acre	$	106.83	384.92	295.75	328.57	398.36	85.74	27.45
Calf Gain Cost	$/lb	0.29	0.23	0.21	0.23	0.27	0.33	0.24

Harvested Forage Management Strategies

Twelve-month forage management strategies were developed by using selected harvested forage types evaluated during the six range cow production periods. Four of these forage management strategies use single harvested forage types to demonstrate that harvested forages are not always the high cost forage they are assumed to be and to show that substantial revenue can be captured per acre by feeding harvested forage types.

Early Forage Barley Hay

The 12-month early forage barley hay strategy required a small total land area of 1.34 acres (table 16). The total forage costs were low at $91.40 per cow-calf pair, even with production costs at $68.21 per acre. The forage contained 13% crude protein, yielding a total of 830.88 lbs CP, meeting the cow requirements during each production period at a cost of $0.11 per pound CP. Roughage composed 36% of the total ration at a cost of $64.08. The total feed cost was $155.49 at a low rate of $30.93 per ton of the ration feed and $0.43 per day. The calf accumulated weight was a mean of all harvested forages evaluated at 566.50 pounds at a cost of $0.27 per pound. Net return per cow-calf pair was relatively high at $411.01 and net return per acre was extremely high at $306.72. Early cut forage barley hay would be an excellent harvested forage that would help modern high-performance cows produce at their genetic potential and that would improve the value captured from the land natural resources.

Early Oat Forage Hay

The 12-month early oat forage hay strategy required a small total land area of 1.54 acres (table 17). The total forage costs were low at $106.52 per cow-calf pair, even with production costs at $69.17 per acre. The forage contained 11.5% crude protein, yielding a total of 830.52 lbs CP, meeting the cows requirements during each production period at a cost of $0.13 per pound CP. Roughage composed 28% of the total ration at a cost of $49.55. The total feed cost was $156.08 at a low rate of $31.05 per ton of the ration feed and $0.43 per day. The calf accumulated weight was a mean of all harvested forages evaluated at 566.50 pounds at a cost of $0.28 per pound. Net return per cow-calf pair was relatively high at $410.42 and net return per acre was very high at $266.51. Early cut oat forage hay would be a very good harvested forage that would help modern high-performance cows produce at their genetic potential and that would improve the value captured from the land natural resources.

Late Pea Forage Hay

The 12-month late pea forage hay strategy required a very small total land are of only 1.24 acres (table 18). The total forage costs were low at $107.72 per cow-calf pair, even with production costs at $86.87 per acre. The forage contained 14.4% crude protein, yielding a total of 830.06 lbs CP, meeting the cows requirements during each production period at a cost of $0.13 per pound CP. Roughage composed 43% of the total ration at a cost of $75.06. The total feed cost was $182.79 at a low rate of $36.37 per ton of the ration feed and $0.50 per day. The calf accumulated weight was a mean of all harvested forages evaluated at 566.50 pounds at a cost of $0.32 per pound. Net return per cow-calf pair was relatively high at $383.71 and net return per acre was the highest of the harvested forages at $309.44. Late cut field pea forage hay would be an excellent harvested forage that would help modern high-performance cows produce at their genetic potential and that would improve the value captured from the land natural resources.

Early Crested Wheatgrass Hay

The 12-month early crested wheatgrass forage hay strategy required a modest total land are of 4.40 acres (table 19). The total forage costs were $116.60 per cow-calf pair, with moderate production costs at $26.50 per acre because it is a perennial grass hay. The forage contained 14.5% crude protein, yielding a total of 830.42 lbs CP, meeting the cows requirements during each production period at a cost of $0.14 per pound CP. Roughage composed 43% of the total ration at a cost of $75.70. The total feed cost was $192.32 at a low rate of $38.26 per ton of the ration feed and $0.53 per day. The calf accumulated weight was a mean of all harvested forages evaluated at 566.50 pounds at a cost of $0.34 per pound. Net return per cow-calf pair was relatively high at $374.10, but it was the lowest of the harvested forages, and net return per acre was modest at $85.02. Early cut crested wheatgrass hay was the most convenient harvested forage to put up and to deliver and was readily accepted by every cow. Crested wheatgrass hay cut during the boot stage is excellent forage that would help modern high-performance cows produce at their genetic potential and that would improve the value captured from the land natural resources.

The four harvested forage types evaluated for costs and returns during the six cow production periods (tables 10-15) all had moderate to low costs with moderate to high returns, and all harvested forage types would provide a positive profit margin. Late Pea Forage hay had the smallest land area at 1.24 acres, and the highest net return per acre at $309.44. Early Forage Barley Hay had the lowest cost per pound of crude protein at $0.11. Early Forage Barley Hay and Early Oat Forage Hay had the lowest total feed costs at $155.49 and $156.08, the lowest cost per pound of calf weight gain at $0.27 and $0.28, and they had the highest net returns per cow-calf pair at $411.01 and 410.42. Early Crested Wheatgrass Hay had the largest land area at 4.40 acres, the highest cost per pound of crude protein at $0.14, the highest total feed cost at $192.32, the highest cost per pound of calf weight gain at $0.34, the lowest net return per cow-calf pair at $374.10, and the lowest net return per acre at $87.02.

Harvested forages cut at the proper plant growth stage can provide excellent feed that meets the cows requirements, can be grown on relatively small land areas, and can return large profits per acre. Twelve-month harvested forage management strategies are not practical for most mature beef cow-calf operations but these four examples illustrate that despite relatively high production costs per acre, harvested forages can return impressive quantities of revenue. Furthermore, management strategies that feed harvested forages to cow-calf pairs for twelve months can be a viable stratagem for young producers to expedite reduction of large startup depts.

There are numerous other annual and perennial forage types that would also be excellent harvested forages. Under normal conditions of using annual forages, two or more different types would be selected that would work together in a simple cropland rotation scheme that would have different optimum planting and harvest dates but be able to use the same equipment. An example would be an early cut annual cereal forage and a late cut annual legume field pea seeded separately.

Table 16. Costs and Returns for 12 month Early Forage Barley Hay Strategy with 1200 lb cow and calf born mid March.

Days		Dry Gestation 37 d	Third Trimester 90 d	Early Lactation 45d	Spring Lactation 28 d	Summer Lactation 135 d	Fall Lactation 30 d	12-month Season 365 d
Forage Type					Early Forage Barley Hay			
Land Area	ac	0.09	0.27	0.20	0.11	0.55	0.12	1.34
Production Cost	$	6.14	18.42	13.64	7.50	37.52	8.19	91.40
Forage Wt	lb	425.50	1296.00	945.00	540.40	2605.50	579.00	6391.40
Forage Cost	$	6.14	18.42	13.64	7.50	37.52	8.19	91.40
Crude Protein	%	13.0	13.0	13.0	13.0	13.0	13.0	13.0
Crude protein Wt	lb	55.32	168.48	122.85	70.25	338.72	75.72	830.88
Crude Protein/d	lb	1.50	1.87	2.73	2.51	2.51	2.51	2.28
Crude Protein Cost	$	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Roughage Wt	lb	462.50	864.00	270.00	299.60	1444.50	321.00	3661.60
Roughage Cost	$	8.09	15.12	4.73	5.24	25.28	5.62	64.08
Total Feed Cost	$	14.23	33.54	18.37	12.74	62.80	13.81	155.49
Cost/day	$	0.38	0.37	0.41	0.46	0.47	0.46	0.43
Acc. Calf Wt	lb	25.00	70.00	85.50	56.00	270.00	60.00	566.50
Return/c-c pr	$	10.77	36.46	67.13	43.26	207.20	46.19	411.01
Return/acre	$	119.67	135.04	335.65	393.27	376.73	384.92	306.72
Calf Wt Gain Cost	$	0.57	0.48	0.21	0.23	0.23	0.23	0.27

Table 17. Costs and Returns for 12 month Early Oat Forage Hay Strategy with 1200 lb cow and calf born mid March.

Days		Dry Gestation 37 d	Third Trimester 90 d	Early Lactation 45d	Spring Lactation 28 d	Summer Lactation 135 d	Fall Lactation 30 d	12-month Season 365 d
Forage Type					Early Oat Forage Hay			
Land Area	ac	0.10	0.31	0.23	0.13	0.63	0.14	1.54
Production Cost	$	6.92	21.44	15.91	8.99	43.58	9.68	106.52
Forage Wt	lb	481.00	1467.00	1066.50	610.40	2943.00	654.00	7221.90
Forage Cost	$	6.92	21.44	15.91	8.99	43.58	9.68	106.52
Crude Protein	%	11.5	11.5	11.5	11.5	11.5	11.5	11.5
Crude protein Wt	lb	55.32	168.71	122.65	70.20	338.45	75.21	830.52
Crude Protein/d	lb	1.50	1.87	2.73	2.51	2.51	2.51	2.28
Crude Protein Cost	$	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Roughage Wt	lb	407.00	693.00	148.50	229.60	1107.00	246.00	2831.10
Roughage Cost	$	7.12	12.13	2.60	4.02	19.37	4.31	49.55
Total Feed Cost	$	14.04	33.57	18.51	13.01	62.95	14.00	156.08
Cost/day	$	0.38	0.37	0.41	0.46	0.47	0.47	0.43
Acc. Calf Wt	lb	25.00	70.00	85.50	56.00	270.00	60.00	566.50
Return/c-c pr	$	10.96	36.43	66.99	42.99	207.05	46.00	410.42
Return/acre	$	109.60	117.52	291.26	330.69	328.65	328.57	266.51
Calf Wt Gain Cost	$	0.56	0.48	0.22	0.23	0.23	0.23	0.28

Table 18. Costs and Returns for 12 month Late Pea Forage Hay Strategy with 1200 lb cow and calf born mid March.

Days		Dry Gestation 37 d	Third Trimester 90 d	Early Lactation 45d	Spring Lactation 28 d	Summer Lactation 135 d	Fall Lactation 30 d	12-month Season 365 d
Forage Type				Late Pea Forage Hay				
Land Area	ac	0.08	0.25	0.18	0.11	0.51	0.11	1.24
Production Cost	$	6.95	21.72	15.64	9.56	44.30	9.56	107.72
Forage Wt	lb	381.10	1170.00	855.00	487.20	2349.00	522.00	5764.30
Forage Cost	$	6.95	21.72	15.64	9.56	44.30	9.56	107.72
Crude Protein	%	14.4	14.4	14.4	14.4	14.4	14.4	14.4
Crude protein Wt	lb	54.88	168.48	123.12	70.16	338.26	75.17	830.06
Crude Protein/d	lb	1.48	1.87	2.74	2.51	2.51	2.51	2.27
Crude Protein Cost	$	0.13	0.13	0.13	0.14	0.13	0.13	0.13
Roughage Wt	lb	506.90	990.00	360.00	352.80	1701.00	378.00	4288.70
Roughage Cost	$	8.87	17.33	6.30	6.17	29.77	6.62	75.06
Total Feed Cost	$	15.82	39.05	21.94	15.73	74.07	16.18	182.79
Cost/day	$	0.43	0.43	0.49	0.56	0.55	0.54	0.50
Acc. Calf Wt	lb	25.00	70.00	85.50	56.00	270.00	60.00	566.50
Return/c-c pr	$	9.18	30.95	63.56	40.27	195.93	43.82	383.71
Return/acre	$	114.75	123.80	353.11	366.09	384.18	398.36	309.44
Calf Wt Gain Cost	$	0.63	0.56	0.26	0.28	0.27	0.27	0.32

Table 19. Costs and Returns for 12 month Early Crested Wheatgrass Hay Strategy with 1200 lb cow and calf born mid March.

Days		Dry Gestation 37 d	Third Trimester 90 d	Early Lactation 45d	Spring Lactation 28 d	Summer Lactation 135 d	Fall Lactation 30 d	12-month Season 365 d
Forage Type				Early Crested Wheatgrass Hay				
Land Area	ac	0.29	0.89	0.65	0.37	1.80	0.40	4.40
Production Cost	$	7.69	23.59	17.23	9.81	47.70	10.60	116.60
Forage Wt	lb	381.10	1161.00	846.00	484.40	2335.50	519.00	5727.00
Forage Cost	$	7.69	23.59	17.23	9.81	47.70	10.60	116.60
Crude Protein	%	14.5	14.5	14.5	14.5	14.5	14.5	14.5
Crude protein Wt	lb	55.26	168.35	122.67	70.24	338.65	75.26	830.42
Crude Protein/d	lb	1.49	1.87	2.73	2.51	2.51	2.51	2.28
Crude Protein Cost	$	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Roughage Wt	lb	506.90	999.00	369.00	355.60	1714.50	381.00	4326.00
Roughage Cost	$	8.87	17.48	6.46	6.22	30.00	6.67	75.70
Total Feed Cost	$	16.56	41.07	23.69	16.03	77.70	17.27	192.32
Cost/day	$	0.45	0.46	0.53	0.57	0.58	0.58	0.53
Acc. Calf Wt	lb	25.00	70.00	85.50	56.00	270.00	60.00	566.50
Return/c-c pr	$	8.36	28.93	61.81	39.97	192.30	42.73	374.10
Return/acre	$	28.83	35.51	95.09	108.03	106.83	106.83	85.02
Calf Wt Gain Cost	$	0.67	0.59	0.28	0.29	0.29	0.29	0.34

Old Style VS. Modern Forage Management Strategies

The old style traditional concept of forage management consists of an accumulation of carryover practices that had been developed during past conditions when beef production was dominated with old style low-performance cattle. These old style concepts and paradigms have been slightly modified for the larger size of modern cows, however, the modern cows' increase in productivity and greater nutrient requirements have not been fully incorporated into these old style traditional forage management concepts, resulting in performance at levels well below the modern cows genetic potential.

The modern biologically effective concept of forage management coordinates forage defoliation by mechanical operation or partial defoliation by grazing animals with grass plant phenological growth stages in order to activate the internal plant growth mechanisms and the ecosystem biogeochemical processes performed by soil microorganisms and to capture the greatest weight of crude protein available per acre. These beneficial activities meet the biological and physiological requirements of the grass plants and soil microbes and provides all the required major essential nutrients to the modern cow permitting performance at the genetic potential and provides adequate quantities of milk to the calf permitting weight growth at the genetic potential level.

Twelve-month forage management strategies during the six range cow production periods were developed using six forage types managed by the old style traditional concept and six forage types managed by the modern biologically effective concept. Data for pasture forage types used during the spring, summer, and fall production periods were from Manske (2018b). The resulting costs and returns were evaluated to compare the effect on forage types and modern cow-calf pairs managed by two very different concepts of forage management. The effects from the biologically effective concept were further compared to the effects from the traditional concept of forage management were applied to hypothetical beef production operations of 5 sections in size.

Traditional Forage Management Strategy

The 12-month traditional forage management strategy required a large total land area of 18.78 acres per cow-calf pair (table 20). The total forage costs were $214.24 per cow-calf pair, with production costs at $11.41 per acre. The forage contained an average 8.8% crude protein, yielding a total of 872.48 lbs CP, at a cost of $0.25 per pound CP, meeting the cows requirements during each production period except the forage was deficient in crude protein during the 30 day fall lactation period. Roughage composed only 1.5% of the total feed at a cost of $2.60. The total feed cost was $216.84 at a rate of $43.14 per ton of the ration feed, $11.55 per acre, and $0.59 per day. The calf accumulated weight was a mean of all harvested forages evaluated during the 172 days of the nongrowing season plus the mean of traditional pasture gain during the 193 days of the growing season for a mean weight of 625.25 pounds at a cost of $0.35 per pound. Net return per cow-calf pair was relatively high at $408.41 and net return per acre was extremely low at $21.75. The traditional concept places priority on capturing the greatest weight of forage dry matter per acre resulting in low crude protein content requiring a larger land area per cow-calf pair causing the costs of forage and crude protein to be unnecessarily high. The low quality feed does not permit the cow to produce milk at her genetic potential resulting in calf weight gain to be lower than their genetic potential, increasing the cost of calf weight gain per pound and reducing the net return per cow-calf pair and per acre.

Biologically Effective Forage Management Strategy

The 12-month biologically effective forage management strategy required a total land area of 13.38 acres per cow-calf pair (table 21). The total forage costs were $154.72 per cow-calf pair, with production costs at $11.56 per acre. The forage contained an average 11.5% crude protein, yielding a total of 979.08 lbs CP, meeting the cows requirements during each production period at a cost of $0.16 per pound CP. Roughage composed 15% of the total forage feed at a cost of $26.47. The total feed cost was $181.19 at a low rate of $36.05 per ton of the forage feed, $13.54 per acre, and $0.50 per day. The calf accumulated weight was a mean of all harvested forages evaluated during the 172 days of the nongrowing season plus the mean of biologically effective pasture gain during the 193 days of the growing season for a mean weight of 687.76 pounds at a cost of $0.26 per pound. Net return per cow-calf pair was an extremely high gain at $506.57 and net return per acre was at $37.86. The biologically effective concept places priority on capturing the greatest weight of crude protein per acre reducing the amount of land area to feed a cow-calf pair, decreasing the costs per pound of crude protein and the forage feed costs. The high quality feed permits the cow to produce milk at or near her genetic potential resulting in calf weight gain to be at or near the genetic potential, decreasing the cost of calf weight gain per pound.

Value Captured by Forage Management Strategies

The resulting cost and return values determined from analysis of two different forage management concepts (tables 20 and 21) were applied to a modest hypothetical land base of 5 sections (3,200 acres) to discover any difference in the quantities of the values captured from the land resource (table 22).

The land area required to produce adequate quantities of forage for 1200 lb cows with calves was 18.78 acres per animal unit on the traditional concept permitting a cow herd of 170 head. The land area was 13.38 acres per animal unit (28.8% less) on the biologically effective concept permitting a cow herd of 239 head (40.6% larger). The captured crude protein on the traditional concept had a mean of 8.8% that yielded a total weight of 872.48 lbs CP per cow-calf pair at a cost of $0.25 per pound. The captured crude protein on the biologically effective concept had a mean of 11.5% (30.7% greater) that yielded a total weight of 979.08 lbs CP (12.2% more) per cow-calf pair at a cost of $0.16 per pound (36.0% lower). The additional crude protein available to each cow on the biologically effective concept permitted these cows to produce milk at or near the genetic potential for most of the grazing season that added 62.5 pounds to the weaning weight of the calves. The mean weaning weight of the calves on the traditional concept was 625.25 lbs per calf at a cost of $0.35 per pound with a total calf weight for 170 calves at 106,292.50 pounds that had a prorated gross return of $33.29 per acre. The mean weaning weight of calves on the biologically effective concept was 687.76 lbs per calf (10.0% heavier) at a cost of $0.26 per pound (25.7% less) with a total calf weight for 239 calves at 164,374.64 pounds (54.6% greater) that had a prorated gross return of $51.40 per acre (54.4% larger). The annual feed cost per cow-calf pair on the traditional concept was $216.84 with a total herd feed cost at $36,862.80. This feed cost was prorated at $11.55 per acre. The annual feed cost per cow-calf pair on the biologically effective concept was $181.19 (16.4% lower) with a total herd feed cost at $43,304.41 (only 17.5% greater). This feed cost was prorated at $13.54 per acre (17.2% larger). The net return per cow-calf pair on the traditional concept was $408.41 with a total herd net return minus the feed cost was $69,429.70. The prorated net return was $ 21.74 per acre. The net return per cow-calf pair on the biologically effective concept was $506.57 (24.0% greater) with a total herd net return minus the feed cost was $121,070.23 (74.4% greater). The prorated net return was $37.86 per acre (74.2% larger). The same size land base for a beef production operation yielded $51,640.53 per year more profit after paying the feed bill when the forage resource was managed by the biologically effective concept compared to that produced when the forage resource was managed by the traditional concept (table 22).

Biologically effective forage management could be implemented to help beef production operations to expand the size of the cow herd without needing to expand the land base. Biologically effective management of forages can provide a mechanism to produce relatively low cost, high quality forage that could feed about 40% more modern high performance cows producing at or near the genetic potential on a land base that was about 29% smaller per cow and that could greatly increase the net returns by about 74% (table 22).

Table 20. Costs and Returns for 12 month Traditional Forage Management Strategy with 1200 lb cow and calf born mid March.

Days		Dry Gestation 37 d	Third Trimester 90 d	Early Lactation 45d	Spring Lactation 28 d	Summer Lactation 135 d	Fall Lactation 30 d	12-month Season 365 d
Forage Type		Late Crested Wheat Hay`	Late Oat Forage Hay	Early Oat Forage Hay	Crested Wheat One Pasture	Native Range Seasonlong Pasture	Native Range Late Season Pasture	
Land Area	ac	0.56	0.38	0.23	2.14	11.43	4.04	18.78
Production Cost	$	15.74	28.32	15.91	18.75	100.13	35.39	214.24
Forage Wt	lb	888.00	2160.00	1066.50	840.00	4050.00	900.00	9904.50
Forage Cost	$	15.74	28.32	15.91	18.75	100.13	35.39	214.24
Crude Protein	%	6.4	7.8	11.5	16.8	8.4	4.8	8.8
Crude protein Wt	lb	56.83	168.48	122.65	141.12	340.20	43.20	872.48
Crude Protein/d	lb	1.54	1.87	2.73	5.04	2.52	1.44	2.39
Crude Protein Cost	$	0.28	0.17	0.13	0.13	0.29	0.82	0.25
Roughage Wt	lb	0.0	0.0	148.50	0.0	0.0	0.0	148.50
Roughage Cost	$	-	-	2.60	-	-	-	2.60
Total Feed Cost	$	15.74	28.32	18.51	18.75	100.13	35.39	216.84
Cost/day	$	0.43	0.32	0.41	0.67	0.74	1.18	0.59
Acc. Calf Wt	lb	25.00	70.00	85.50	72.65	354.37	17.73	625.25
Return/c-c pr	$	9.26	41.69	66.99	53.92	254.24	-17.66	408.41
Return/acre	$	16.54	109.68	291.26	25.20	22.24	-4.37	21.75
Calf Wt Gain Cost	$	0.63	0.41	0.22	0.26	0.28	2.00	0.35

Table 21. Costs and Returns for 12 month Biologically Effective Forage Management Strategy with 1200 lb cow and calf born mid March.

Days		Dry Gestation 37 d	Third Trimester 90 d	Early Lactation 45d	Spring Lactation 28 d	Summer Lactation 135 d	Fall Lactation 30 d	12-month Season 365 d
Forage Type		Late Forage Barley Hay	Early Forage Barley Hay	Late Pea Forage Hay	Crested Wheat Two Pasture	Native Range Twice-over Pasture	Altai Wildrye Pasture	
Land Area	ac	0.12	0.27	0.18	1.20	10.22	1.39	13.38
Production Cost	$	8.44	18.42	15.64	10.51	89.53	12.18	154.72
Forage Wt	lb	599.40	1296.00	855.00	840.00	4050.00	900.00	8540.40
Forage Cost	$	8.44	18.42	15.64	10.51	89.53	12.18	154.72
Crude Protein	%	9.2	13.0	14.4	17.1	9.8	10.2	11.5
Crude protein Wt	lb	55.14	168.48	123.12	143.64	396.90	91.80	979.08
Crude Protein/d	lb	1.49	1.87	2.74	5.13	2.94	3.06	2.68
Crude Protein Cost	$	0.15	0.11	0.13	0.07	0.23	0.13	0.16
Roughage Wt	lb	288.60	864.00	360.00	0.0	0.0	0.0	1512.60
Roughage Cost	$	5.05	15.12	6.30	-	-	-	26.47
Total Feed Cost	$	13.49	33.54	21.94	10.51	89.53	12.18	181.19
Cost/day	$	0.36	0.37	0.49	0.38	0.66	0.41	0.50
Acc. Calf Wt	lb	25.00	70.00	85.50	76.45	380.47	50.34	687.79
Return/c-c pr	$	11.51	36.46	63.56	65.94	290.94	38.16	506.57
Return/acre	$	95.92	135.04	353.11	54.95	28.47	27.45	37.86
Calf Wt Gain Cost	$	0.54	0.48	0.26	0.14	0.24	0.24	0.26

Table 22. Summary of costs and returns for the Biologically Effective concept compared to the Traditional concept of forage management strategies on a land base of 5 sections.

		Traditional Forage Management Strategy	Biologically Effective Forage Management Strategy	Percent Difference
Land Base	ac	3,200	3,200	Same
Land/Cow/Yr	ac	18.78	13.38	-28.8
No. Cows	hd	170	239	40.6
Crude Protein mean	%	8.8	11.5	30.7
Crude protein Wt/AU	lb	872.48	979.08	12.2
Crude Protein Cost/lb	$	0.25	0.16	-36.0
Acc. Calf Wt/hd	lb	625.25	687.76	10.0
Total Calf Wt/Yr	lb	106,292.50	164,374.64	54.6
Gross Return @ $1.00/lb	lb	106,292.50	164,374.64	54.6
Feed Cost/AU	$	216.84	181.19	-16.4
Total Feed Cost	$	36,862.80	43,304.41	17.5
Net Return/AU	$	408.41	506.57	24.0
Return-Feed Cost	$	69,429.70	121,070.23	74.4
Wt gain Cost/lb	$	0.35	0.26	-25.7
Gross Return/Acre	$	33.29	51.40	54.4
Feed Costs/Acre	$	11.55	13.54	17.2
Return-Feed Costs/Acre	$	21.74	37.86	74.2

Discussion

Beef producers have genetically improved the North American beef herd over the past 75 years, or so, in order to develop high quality feeder calves that are able to grow rapidly on primarily high energy grain based rations and to create flavorful, tender meat products. As a result, the continents cow herd has been selectively transformed into modern high-performance cows. The ration technologies utilized to quickly finish slaughter animals have been continuously improved. Unfortunately, forage management technologies have not simultaneously been developed and improved that match the available nutrients with the increased forage nutrients required by modern cows to routinely perform at their genetic potential. Weight production by modern high performance cows with calves has been severely stifled by the widespread use of slightly modified traditional forage management technologies and paradigms that had been developed for the old style low-performance livestock.

Modern cows produce calf weight at their genetic potential while the available forage contains an increase of nutrient at or slightly above the required quantities. A week of forage deficient in the required quantities of nutrients causes large reductions in productivity. Decreases in milk production caused by deficient quality forage cannot be recovered and this decrease in milk quantity results in calf weaning weights well below their genetic potential. In order to maintain modern cow and calf production at genetic potential, the forage management strategies must provide the nutrients at required quantities each day for 365 days per year and during no period longer than a few days can the forage be even slightly deficient in required nutrients.

Ruminant livestock have the ability to survive on very low quality forage, however, modern high-performance cows require high quality forage as pasture or from rations that meet their increased nutrient requirements in order to produce at their genetic potential. High quality forages do not have to have high costs. High quality forage types that provide low feed costs will have low captured crude protein costs per pound, low forage feed costs per day, and low calf weight gain costs per pound. Forage management practices that capture greater wealth from the land resources will have smaller land area requirements to feed cow-calf pairs and will have greater net returns per acre after feed costs. Crude protein is the valuable nutrient produced by forage plants on the land natural resources. Production of a pound of energy (TDN) requires a minuscule of the ecosystem resources compared to the production of a pound of crude protein. Forage feed costs should not be evaluated by the forage dry matter costs nor by other traditional costs that do not respond proportionally, with changes in the forage quantity of nutrients, mainly crude protein.

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