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Pasture Forage Quality in West Virginia - 1999 to 2001

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Pasture Forage Quality in West Virginia: An On-Farm Research Report for 1999 to 2001[1]

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For optimum productivity and health, livestock need to have adequate nutrient intake. Because of hilly terrain, pasture is the base of much of the rumenant livestock production in West Virginia. To know how to manage pastures and pasture supplementation, producers need improved knowledge of pasture nutritive value.

Nutrients are divided into macronutrients and micronutrients based on the relative amount needed daily. Macronutrients are those needed in relatively large amounts, measured in pounds and ounces or as a percentage of the ration. Examples of macronutrients are water, crude protein (CP), total digestible nutrients (TDN), and such minerals as calcium (Ca) and phosphorus (P). Micronutrients are those needed in relatively small amounts measured in parts per million or milligrams in the ration. Examples of micronutrients are copper (Cu) and zinc (Zn).

The nutrient requirement of an animal is determined by the animal's species, age, size, and production level. Young animals need nutrients for growth. A first-calf heifer needs nutrients for growth and milk production when lactating. Animals with the genetic ability for high growth rates need more nutrients than those producing at lower levels if they are to achieve their genetic potential. The requirement for micronutrients is less well defined than for macronutrients and is usually given as a concentration in the total ration.

After water, energy is the nutrient needed in the greatest amount. Its availability depends on the forage's digestibility. The ruminant animal's need for protein is related to its energy intake and level of production. For animals fed cool-season forages, digestible energy intake will usually limit production. When one feeds an energy supplement on pasture, if the supplement is fed in excess to the available CP in the forage, protein may limit production unless protein is provided in the supplement.

Nutrient intake from pasture depends on the concentration and availability of the nutrient in the forage and the forage intake by the animal. Nutrients in forage are a function of plant species, plant maturity, and soil fertility (Baker and Reid, 1977). For example, on a soil low in a mineral required for plant growth, a forage species adapted to using that mineral in low amounts will be most competitive and will be the dominant species in the stand. Usually such adapted plants have lower concentrations of the mineral in their tissue than plants that have higher requirements for the mineral. A classic

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example is sweet vernal grass that is adapted to low soil phosphorus and soil pH. This grass is common in West Virginia and is often the dominant species on soils low in pH and phosphorus. This species is also one of the earliest maturing grasses so digestible energy and CP will also likely be lower than for grasses that mature later in the spring. When such a site is treated with phosphorus and lime, orchardgrass is able to grow better and can then outcompete the sweet vernal grass and become dominant in the field.

The availability of minerals to animals varies with forage species, animal species and breed, and the presence of other interacting minerals in the forage, water, and mineral supplements consumed. In some locations, minerals in spring and well water can make major contributions of minerals to the diet. Also, water high in salt will affect animal consumption of supplemental minerals that use salt as a carrier.

Forage dry matter intake (DMI) is a function of animal size, production status, and forage quality. Large animals eat more than small animals. High-producing animals generally consume more forage than less-productive animals. Intake is highest for young forages low in neutral detergent fiber (NDF). Forage intake generally decreases as NDF increases with plant maturity. Legumes are lower in NDF than grasses and as the amount of legumes increases in a forage stand, livestock can consume more forage. As a plant matures, NDF increases, but TDN (a measure of digestible energy) and CP content decrease.

Animal intake of pasture is also determined by plant height, stand density, and rate of supplemental feeding. Pastures that are too short reduce intake since the animal cannot get much feed in each bite. Pastures that are too tall are usually overmature, with high NDF content and lower digestibility. Feeding supplements on pasture tends to reduce forage intake.

Lack of adequate minerals in the diet shows up as poor animal performance and health problems rather than classic mineral deficiency symptoms. Because of this, supplemental salt and minerals are usually fed to livestock. However, when supplemental minerals are fed free-choice year-round, the expense can be high. The strategic feeding of appropriate minerals at selected times in the animal production cycle can reduce production costs and maintain healthy livestock. To do this, livestock producers need to know the risk of a mineral being deficient relative to the needs of their livestock.

Methods

To determine the nutritive value of pastures Extension agents and farmers sampled pastures across West Virginia. Additional samples were provided by grassland technicians employed by West Virginia Conservation Agency and by staff of USDA/NRC.

Pastures were sampled monthly. Rotationally grazed pastures were sampled shortly before cattle were turned into the pasture. Pastures were walked at random, and 30 to 50 small "grab" samples were taken to represent what the cattle were eating from the pasture. Samples were plucked to the same height that the cattle were grazing the pasture. Weeds such as thistle or buttercup that livestock refuse were avoided. The three most abundant forage species in the pasture were identified. Pasture ruler height was measured and the sampling date and the number of days since the pasture was last grazed (for rotationally grazed pastures) were recorded. Pasture samples were placed in plastic bags and the excess air removed. They were frozen as soon as possible. Samples were oven dried and air equilibrated before shipment to a forage testing laboratory participating in the National Forage Testing Association program (www.foragetesting.org/). Samples were analyzed for fiber, carbohydrate, and protein fractions by near infrared analysis and for minerals by wet chemistry analysis. Because of funding constraints, not all samples were analyzed for trace minerals. Statistical analysis were performed using analysis of variance (NCSS200).

Results and Discussion

A total of 607 pasture samples were collected across West Virginia (Figure 1) representing 62 site years of data (Table 1). Growing season temperatures at Morgantown W.Va. during this study were near the 30-year average (Figure 2). Rainfall at Morgantown was a little less than the 30-year average with the 1999 growing season experiencing one of the worse droughts in 50 years (Figure 3). In general, temperature patterns across the state are reflected in those at Morgantown. Rainfall patterns were more variable across the state, with some areas experiencing dry weather periods different than those in Morgantown, except for the drought of 1999 which was generally statewide.

The primary forage species in the sampled pastures were cool-season grasses and clovers typical to the Appalachian region (Table 2). Fescue, unidentified grasses, bluegrass, orchardgrass, and clovers were the number one species in 95% of the pastures. Clover, orchardgrass, tall fescue, and bluegrass were the number two species on 94% of pastures. Clover, bluegrass, orchardgrass, tall fescue, and crabgrass were the number three species on 91% of pastures. (Common and scientific names of plant species present in the sampled pastures are presented in Appendix Table 1.)

Approximately two-thirds (64%) of the pastures were continuously stocked, resulting in a large range in pasture height, fiber content, and estimated TDN content of the pastures (Table 3). Some of the nutrients studied in these pastures did not have normal distributions about the means, so the mean and standard deviation do not accurately estimate the probability of a pasture being within the nutritional needs of a given class of livestock.

Figure 1. Distribution of pasture samples taken in 1997 to 2001.

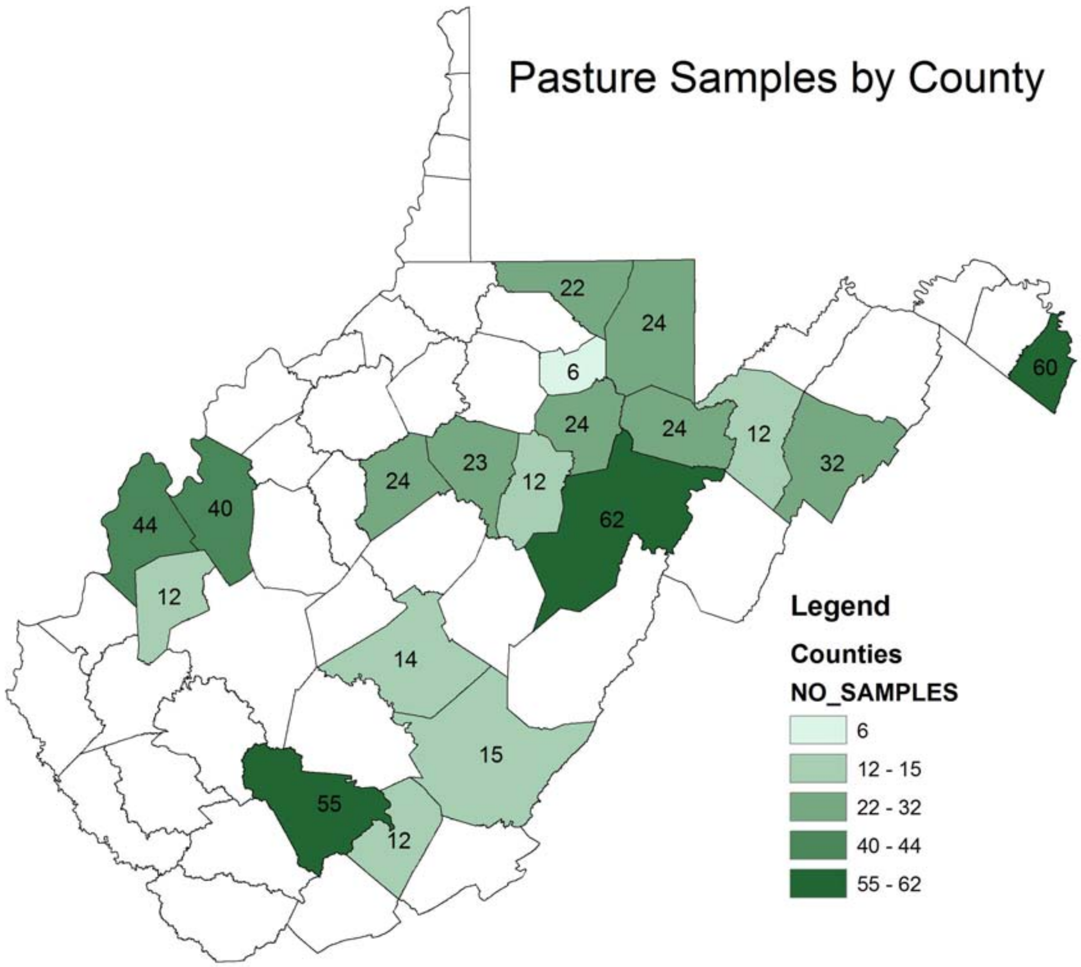

Table 1. Number of samples collected each year and number of sites from which the samples were collected.

Year	Number of Samples	Number of Sites
1997	102	14
1998	58	13
1999	147	7
2000	165	15
2001	135	13
Total	607	62

Performance of lactating and growing animals on the sampled pastures was most often limited by lack of adequate forage during midsummer. When pasture height drops below 4-inches, intake will likely decrease (Ingram, 1984). Of the pastures studied, 40% had heights less than or equal to 4 inches (Table 4). Even though individual animal performance may drop at these higher grazing pressures, animal production per acre may increase as better utilization of the forage occurs. However, too close grazing is detrimental to animal production and pasture health.

Grazing management (continuous stocking vs. rotational stocking of paddocks) had an effect on pasture quality by affecting plant height and maturity. Continuously grazed pastures were shorter than rotationally grazed pastures (5.7 vs. 9.8 inches, respectively) and had lower ADF (31.5 vs. 32.8) and Ca (0.65 vs. 0.74). They were higher in ash (10.2 vs. 8.6), resulting in higher micromineral content for Fe (480 vs. 253), Zn (37.8 vs. 28.6), Cu (11.7 vs. 9.4), and Mn (122.8 vs. 86.7).

In a study evaluating the quality of rotationally grazed pastures in the Northeast (Rayburn, 1994), average pasture quality was higher than found in these predominantly continuously grazed pastures. For the Northeast, pastures average values for ADF, NDF, NSC, and CP were 27, 47, 17, and 22% respectively. Similar average values were obtained in Jefferson County, W.Va. (27, 46, 19, and 22%), where all pastures were managed under rotational grazing.

To identify the risk of pastures not meeting the needs of a given class of livestock, the percentile ranking (cumulative distribution) of nutrients in the sampled pastures are provided in Tables 4 through 8. These tables identify the percent of samples that fall below a given nutritional concentration. The mineral nutrient requirement of beef cattle (NRC 2000), dairy cattle (NRC 1989), and sheep (NRC 1985) are provided in Tables 9, 10, and 11.

Figure 2. Mean monthly temperature for 1997 to 2001 and the 30-year average for Morgantown W.Va.

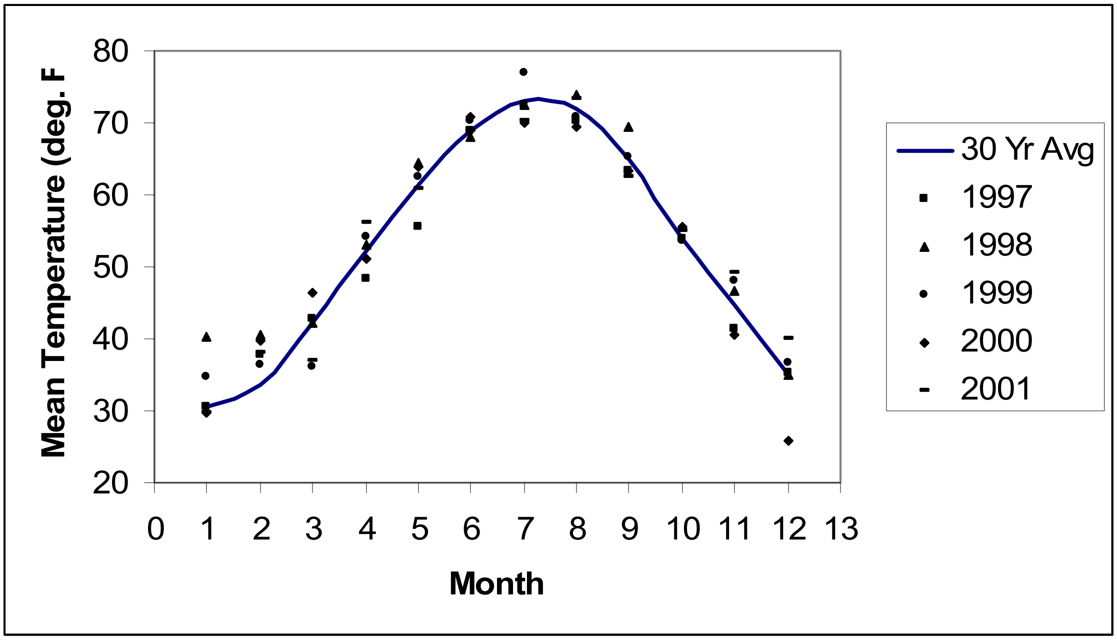

Figure 3. Monthly rainfall for 1997 to 2001 and the 30-year average monthly rainfall for Morgantown, W.Va.

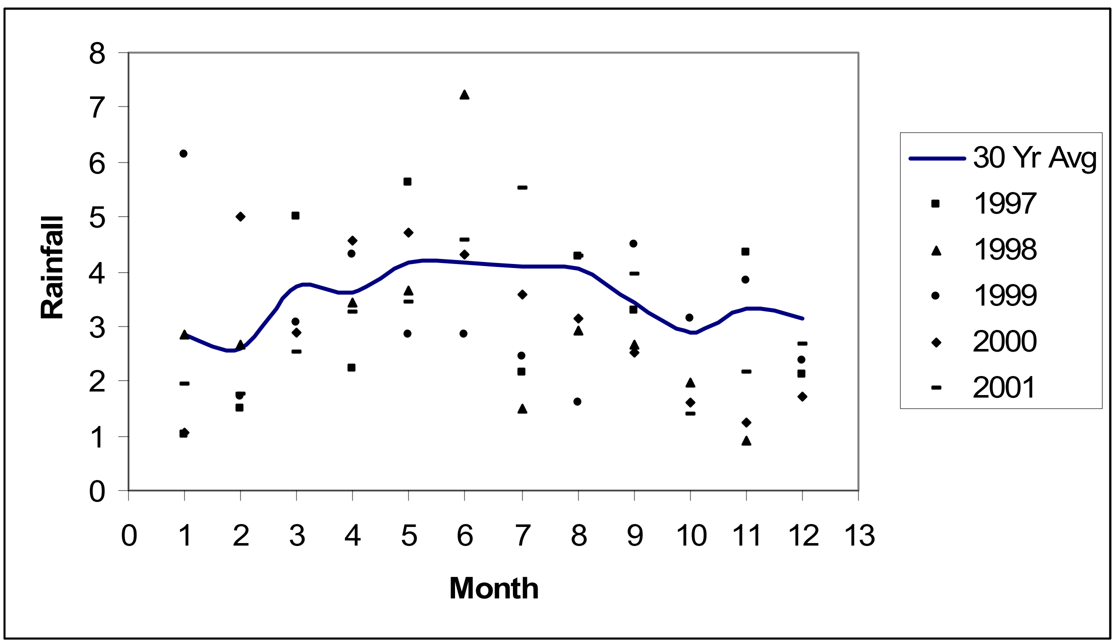

Table 2. Frequency of pasture species being reported as ranking number one, two, or three in the pasture sampled.

Species 1	Count	Percent	Species 2	Count	Percent	Species 3	Count	Percent
Fescue	171	42	Clover	115	37	Clover	106	42
Grass	106	26	Orchardgrass	111	36	Bluegrass	45	18
Bluegrass	46	11	Fescue	39	13	Orchardgrass	42	17
Orchardgrass	34	8	Bluegrass	25	8	Fescue	27	11
Clover	32	8	Timothy	7	2	Crabgrass	8	3
Timothy	6	1	Crabgrass	6	2	Grass	6	2
Crabgrass	5	1	Weeds	4	1	Velvet grass	6	2
Quackgrass	2	<1	Grass	3	1	Sweet Vernal	5	2
Sweet Vernal	2	<1	Broomsedge	2	1	Timothy	5	2
Weeds	2	<1				Weeds	2	1
Broomsedge	1	<1				Broomsedge	1	<1
Dandelions	1	<1				Ragweed	1	<1
Ryegrass	1	<1						
Switchgrass	1	<1						
Total reported	410	100		312	100		254	100

Table 3. Mean, standard deviation (SD), minimum (Min), and maximum (Max) values of pasture measurements and sample analysis.

Item	Count	Mean	SD	Min	Max
Description					
Height	249	6.2	4.9	0.5	28.0
Fiber, Carbohydrates, Fats and Ash					
ADF	401	32.07	5.45	18.6	49.6
NDF	401	54.42	8.38	28.0	77.9
NSC	398	15.86	5.42	0.23	31.7
LIG	280	5.14	1.34		9.22
Fat	135	4.06	0.83	2.28	6.44
Ash	280	9.30	1.73		14.44
Protein (%)					
CP	566	18.4	4.8	4.8	34.6
SP (% of CP)	281	36.3	7.7	20.0	57.1
DP (% of CP)	280	66.6	6.0	39.2	78.0
Calculated Energy and Feed Values					
TDN %	401	63.2	5.6	31.0	75.9
NEM meg. cal.	384	0.64	0.10	0.00	0.83
NEG meg. cal.	399	0.37	0.08	0.11	0.54
Horse TDN %	195	57.8	7.6	43.4	82.0
RFV	399	113	26	65	243
Macro Minerals (%)					
Ca	606	0.68	0.22	0.21	1.94
P	607	0.34	0.09	0.10	0.59
Mg	607	0.25	0.06	0.11	0.58
K	607	2.46	0.58	0.33	4.50
S	440	0.24	0.06	0.05	0.48
Micro Minerals (ppm)					
Al	167	254	395	10	4172
Cu	589	10.9	4.4	2.0	55.0
Fe	589	403	465	45	4042
Mn	589	110	67		562
Mo	240	1.08	0.73	0.13	3.96
Na	585	0.24	5.00		121.00
Zn	588	34.7	30.8	11.0	384.8

Table 4. Percentile ranking of pastures based on pasture ruler height, crude protein (CP), solubility of crude protein (SP), and degradability of crude protein (DP).

Percentile	Height	CP	SP	DP
99	24.0	31.3	55.6	75.0
95	18.0	27.2	49.2	73.0
90	12.0	25.0	44.9	71.7
85	10.0	23.9	42.4	70.6
80	8.6	22.6	40.6	69.3
75	7.5	21.9	39.2	68.9
70	6.5	21.2	37.9	68.0
65	6.0	20.5	36.9	67.3
60	6.0	20.0	36.0	66.9
55	6.0	19.2	34.6	65.9
50	5.0	18.6	34.0	65.1
45	4.0	17.8	33.0	64.9
40	4.0	17.4	32.2	64.5
35	3.5	16.7	31.1	64.0
30	3.0	15.7	30.2	62.7
25	3.0	15.3	29.2	61.9
20	2.4	14.5	28.0	61.0
15	2.0	13.5	27.2	59.4
10	2.0	12.7	26.1	56.8
5	1.5	11.6	23.8	54.5
1	0.5	8.8	20.0	51.2

Table 5. Percentile ranking of pastures based on acid detergent fiber (ADF), neutral detergent fiber (NDF), lignin (LIG), non-structural carbohydrate (NSC), fat, and ash content of pastures.

Percentile	ADF	NDF	LIG	NSC	Fat	Ash
99	43.4	71.0	9.2	28.4	6.4	14.4
95	38.9	64.3	8.1	25.0	5.6	12.9
90	36.3	61.5	7.3	23.6	5.3	12.1
85	35.4	59.4	6.9	22.1	5.0	11.5
80	34.5	58.1	6.5	21.2	4.8	11.2
75	33.8	56.9	6.2	20.6	4.6	10.9
70	33.2	56.3	5.9	19.8	4.4	10.5
65	32.7	55.4	5.6	19.1	4.3	10.4
60	32.2	54.4	5.5	18.4	4.2	10.2
55	31.6	53.3	5.3	17.8	4.0	10.0
50	30.9	52.1	5.1	17.1	4.0	9.8
45	30.4	51.3	4.9	16.5	3.9	9.6
40	29.8	50.5	4.8	15.8	3.8	9.4
35	29.0	49.8	4.6	14.9	3.6	9.3
30	28.0	48.6	4.5	14.2	3.5	9.0
25	27.3	47.5	4.4	13.3	3.4	8.8
20	26.7	46.5	4.2	12.7	3.4	8.6
15	26.0	45.1	3.9	11.5	3.2	8.3
10	24.8	43.6	3.6	10.8	3.1	8.0
5	23.3	39.7	3.3	9.4	2.8	7.5
1	19.7	33.3	2.5	4.3	2.4	5.8

Table 6. Percentile ranking of pastures based on estimated total digestible nutrients (TDN), net energy lactation (NEL), net energy maintenance (NEM), net energy gain (NEG), and relative feed value (RFV) of pastures sampled.

Percentile	TDN	NEL	NEM	NEG	RFV
99	74.0	0.76	0.80	0.52	207
95	72.3	0.71	0.77	0.50	165
90	71.0	0.70	0.76	0.48	149
85	69.4	0.69	0.74	0.46	139
80	68.0	0.68	0.72	0.44	135
75	67.0	0.68	0.71	0.43	132
70	66.5	0.67	0.69	0.42	127
65	66.0	0.66	0.69	0.42	123
60	65.2	0.64	0.68	0.41	121
55	64.9	0.63	0.66	0.40	118
50	64.1	0.62	0.65	0.38	115
45	63.0	0.61	0.64	0.37	112
40	62.2	0.60	0.61	0.35	111
35	61.9	0.59	0.60	0.34	107
30	61.0	0.59	0.59	0.33	104
25	60.5	0.58	0.58	0.32	102
20	59.4	0.57	0.57	0.31	99
15	57.9	0.55	0.54	0.28	96
10	56.7	0.53	0.52	0.26	93
5	54.6	0.49	0.48	0.23	87
1	52.0	0.43	0.44	0.19	72

Table 7. Percentile ranking of pastures based on major mineral content for calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), sodium (Na), and sulfur (S).

Percentile	Ca	P	Mg	K	Na	S
99	1.47	0.57	0.38	3.91	0.132	0.400
95	1.08	0.51	0.34	3.54	0.050	0.350
90	0.96	0.47	0.32	3.28	0.040	0.340
85	0.88	0.45	0.30	3.16	0.030	0.320
80	0.83	0.43	0.29	3.06	0.030	0.304
75	0.78	0.41	0.28	2.94	0.024	0.290
70	0.76	0.39	0.27	2.84	0.020	0.290
65	0.71	0.37	0.27	2.74	0.020	0.280
60	0.68	0.36	0.26	2.68	0.020	0.270
55	0.66	0.35	0.25	2.60	0.017	0.260
50	0.64	0.33	0.24	2.53	0.013	0.260
45	0.61	0.33	0.23	2.47	0.011	0.250
40	0.59	0.31	0.22	2.40	0.010	0.250
35	0.57	0.30	0.22	2.33	0.010	0.240
30	0.55	0.29	0.21	2.27	0.010	0.230
25	0.53	0.27	0.20	2.14	0.010	0.220
20	0.50	0.26	0.19	2.04	0.010	0.210
15	0.48	0.24	0.18	1.93	0.010	0.200
10	0.44	0.23	0.17	1.76	0.009	0.180
5	0.37	0.20	0.16	1.47	0.006	0.150
1	0.28	0.15	0.12	1.01	0.003	0.101

Table 8. Percentile ranking of pastures based on micro mineral content iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), molybdenum (Mo), and copper absorption.

Percentile	Fe	Zn	Cu	Mn	Mo	Cu Absorption
99	3030	223	24.9	377	3.58	0.054
95	1386	62	19.0	271	2.58	0.051
90	873	51	15.9	204	2.14	0.050
85	686	45	14.9	181	2.00	0.048
80	582	41	14.0	164	1.82	0.047
75	506	38	13.2	147	1.60	0.046
70	442	36	13.0	135	1.56	0.046
65	393	35	12.0	121	1.42	0.045
60	354	33	11.7	112	1.30	0.044
55	315	32	11.0	105	1.24	0.043
50	281	31	10.9	98	1.11	0.043
45	246	29	10.2	92	1.00	0.042
40	225	28	10.0	88	0.89	0.041
35	209	26	9.8	82	0.84	0.040
30	189	25	9.0	77	0.73	0.039
25	174	24	8.9	69	0.64	0.039
20	151	23	8.1	63	0.57	0.037
15	137	21	8.0	58	0.50	0.036
10	123	20	7.0	52	0.47	0.035
5	103	18	6.3	46	0.34	0.033
1	64	13	5.0	35	0.18	0.030

To use the percentile ranking, identify the requirement for the livestock grazing on the pasture based on age and production status of the animal (See Appendix Tables 3 to 10). Select the table containing the nutrient in question. Find the column that contains the nutrient; go down the column to the value of the nutrient needed by the animal. Project across to the lefthand column for the percentile rank. This is the percentage of pastures that do not meet this nutritional requirement. If the exact value of interest is not listed, interpolate between listed values that are above and below the value. For practical purposes, rounding to the nearest 5% is reasonable.

Risk of Pasture Not Meeting the Animals' Nutritional Needs

Different classes of livestock have different nutrient requirements. In many cases, improving the pasture management can improve pasture nutritive quality so that purchased supplements are not needed.

Lactating Cows

The lactating cow has the highest nutrient requirement, especially at peak milk (Table 12). Energy is the first limiting factor for the lactating cow on pasture. A cow producing 30 pounds milk at peak requires 62-65% TDN in the pasture. At the 62% TDN level, 40% of pastures sampled (Table 6) would not meet this requirement. At a 65% TDN requirement, about 60% of pastures would not have adequate TDN. However, spring pastures averaged 3 to 4 units higher in TDN in April and May, which provides additional energy for spring-calving cows in early lactation. Given the lactating cow's requirement for CP (11.8-12.9%), P (0.23-0.24%), and Ca (0.35-0.38%), only 5-10% of pastures are deficient in CP (Table 4), 10-15% deficient in P, and 5% deficient in Ca (Table 7).

More pastures are deficient in energy for the lactating beef cow than there are pastures deficient in protein, Ca, or P. Cows with potential for high milk production that graze energy-deficient pastures may lose body condition and not breed back in a timely manner. Cows producing 20 pounds of milk at peak would find 20%-30% of pasture deficient in TDN. At 10 pounds of peak milk, cows would find only 10% of pasture deficient in TDN. Cows with good genetics for milk production need high-quality pasture to achieve their potential. Pasture management that provides young, rapidly growing forage that's high in TDN achieves this goal. If management cannot economically provide the pasture quality needed, then selecting cattle with lower milk production genetics is an option.

Bred Replacement Heifers

Pastures meet the nutritional needs of the early- and mid-gestation heifer (Appendix Table 7) for TDN, CP, Ca, and P 99% of the time (Tables 6, 4, and 7, respectively). Spring-calving heifers will usually be on winter feed during the last trimester of gestation. Fall-calving heifers on pasture in the last trimester of gestation will find pasture TDN below their needs about 30% of the time, followed by P, 10% and CP, and Ca 5% of the time.

Growing Cattle

The nutritional need of growing cattle varies with the animal's frame size, weight, desired average daily gain, and gender (Appendix Tables 8 to 10). If a growing animal has the genetic potential to finish at 1200 pounds and weighs 780 pounds, and the manager wants the animal to gain at 2.0 pounds per day the animal needs a pasture containing 60% TDN, 9.2% CP, 0.32% Ca, and 0.17% P (Table 15). The first limiting factor for this animal is pasture height affecting intake and then TDN. As previously stated, about 40% of pastures did not have adequate height for maximum DMI by grazing animals. After pasture height, pasture TDN was the next limiting factor with about 25% of pastures having TDN value below the 60% TDN requirement (Table 6). Only 5% of pastures had values below the required CP (Table 4), Ca, or P (Table 7) levels.

Other Macronutrients

Magnesium (Mg) - The forage Mg content was at or below the recommended 0.20% of dry matter in 25% of the pastures sampled. Pasture Mg was 0.04% lower than average in May and June pasture samples. The Mg content of pasture was above average when pastures had legumes as species one or species two, increasing Mg content by 0.05 and 0.02 %, respectively. For lactating cows on lush spring pasture, it is recommended that the Mg in the diet be raised to 0.25 to 0.30% to prevent the occurrence of grass tetany (NRC 1989, p. 28). Forage Mg content was lowest in the spring and increased into the summer and fall. Therefore, it is recommended that Mg supplements be provided during the spring grazing season since 80% of pastures were below the 0.30% Mg content recommended for safety.

Potassium (K) - Forage K content needed by livestock was adequate in more than 99% of the pastures tested (Table 7). Pastures in April and May are often high in K causing an increased risk that Mg will not be absorbed and that grass tetany will occur. The risk of grass tetany can be decreased by not fertilizing pastures with nitrogen and K fertilizers in the spring and by using high Mg lime and P fertilizer as needed to ensure adequate plant Mg content and availability. Feeding Mg supplements in the spring is a standard recommended practice for decreasing the risk of grass tetany.

Sulfur (S) - The S content in pasture and the need by the animal is closely related to the sulfur-containing amino acids in forage and those made by the rumen bacteria. The recommended S content for beef cattle (0.15%) was adequate in 95% of pastures (Table 7). The content of S was higher in plants having high CP content. The upper limit of S in the diet should not exceed 0.40%. Pasture containing high levels of S in conjunction with water high in S can cause reduced feed intake if the total S intake exceeds 0.40% of diet dry matter. Excess levels of S also reduce the absorption of Cu from the animal's diet. It is recommended that S supplementation on pasture be limited to areas where forage sampling shows a need for this mineral.

Sodium (Na) - The Na content is deficient in 95% of pastures sampled (Table 7). It can be supplemented readily by providing free choice salt on pasture. However, if the livestock watering source has a high Na content, this may limit intake of salt-containing minerals so that the livestock do not consume as much mineral as anticipated. It is a good management practice to weigh salt and mineral and record how much is being consumed per head per day to ensure that they are consuming an adequate amount.

Micronutrients

Iodine (I) - Pasture samples were not tested for I. Deficiency of I may occur when feeding recommended level of I if as much as 25% of the ration is the brassicas kale, rape, or turnips. When feeding these crops the recommended dietary iodine is 0.5 ppm for growing and nonlactating cows and 1.0 ppm for late gestation and lactation cows (NRC 1988).

Selenium (Se) - Pasture samples were not tested for Se. Supplementation of Se is recommended in West Virginia. Deficiency in Se is most likely to occur when forage is grown on acidic soils. It is legal to supplement Se to beef cattle at 0.30 mg/kg of total diet up to 3 mg/head/day (NRC Beef Update 2000, p.68).

Cobalt (Co) - Pasture samples were not tested for Co. Supplementation for Co is recommended at 0.10 ppm of ration dry matter.

Manganese (Mn) - Pasture content of Mn was sufficient in more than 95% of pastures tested (Table 8).

Iron (Fe) - In 99% of pastures, FE content was sufficient to meet cattle's nutrient requirement (Table 8). Almost 10% of pastures exceed the recommended 1000-ppm of Fe in the DM, which is considered the maximum tolerable allowance of Fe. Forage had Fe exceeding 400 ppm in 30% of the pastures sampled. At this level, Fe can reduce the availability of Cu in the diet. It is recommended that Fe not be supplemented to cattle on pasture.

Molybdenum (Mo) - There is no stated requirement for Mo for grazing ruminants.

Copper (Cu) - The Cu content of pasture forage was below the 10 ppm recommended for beef cattle in about 40% of pastures (Table 8). Supplementation with Cu was shown to reduce the risk of Cu deficiency in beef cattle (APHIS, 2000a). Cattle breeds differ in their need for Cu. Simmental and Charolais cattle require higher levels of Cu than Angus (NRC 2000). Among dairy breeds, Jerseys are more efficient at Cu retention than Holsteins (NRC 2001)

Dietary S and Mo inhibit the absorption of Cu (Table 8). In the Northeast, high levels of S in the forage is a primary contributing factor to lower levels of Cu absorption since Mo levels are not excessively high. The forage content of S and Mo are also positively correlated, meaning that forages high in S tend to be high in Mo (Appendix Table 11). Across the United States, 21% of tested water exceeded the sulfate content considered safe for cattle (APHIS, 2000 b).

Zinc (Zn) – Pastures were deficient in Zn in 50% of pasture samples analyzed (Table 8). Pastures sampled in August and September were higher in Zn than average. Supplementation with Zn was shown to reduce the risk of Zn deficiency in beef cattle (APHIS, 2000c).

Mineral Supplement calculator

As a part of this project, a mineral supplement calculator spreadsheet was developed (Tables 9 and 10). This spreadsheet allows the user to enter the animal's size, expected pasture DMI, and daily mineral intake; the mineral requirement of the animal; and the expected mineral concentration in pasture. The examples used the pasture mineral values at the 10th percentile level. This is the level that will ensure that cattle on 90% of the sampled pastures would receive adequate minerals in their diet from the combined pasture and supplement. Based on a manager's risk aversion, a different percentile level can be used.

The spreadsheet then calculates the concentration of minerals needed in the mineral supplement to provide adequate supplementation to the pasture. When having supplements mixed, it is important to ensure that each mineral source used in the mix is adequately available to the animal. These calculations do not account for the interactions of minerals contained in drinking water, the pasture, or other supplemental feeds.

When the goal is to minimize the cost of mineral supplementation, using a trace mineral salt program year-round would provide adequate levels of Co (13-16 ppm), Cu (396-480), I (66-80 ppm), Se (26-32 ppm), and Zn (1320-1600). The first number represents the needs of a 660-pound calf consuming pasture DM at 2.5% body weight and 2 ounces of supplement. The second number represents a 1200-pound cow consuming pasture DM at 2.5% body weight and 3 ounces of supplement. These values would provide adequate levels of the micronutrients on 90% of pastures in this study. The Se levels are for supplying 0.2 ppm of the total ration, which is less than the legal allowance of 0.3 ppm total ration, to provide a safety factor if the animals eat more supplement than expected. Levels for Co and I are for the basic NRC requirements, all of which are provided by the supplement. Given the high S and Fe content in West Virginia's pastures, Fe should not be added to the trace mineral supplement to ensure adequate Cu absorption in cattle.

For seasonal needs, this trace mineral salt package can, where necessary, be supplemented using dicalcium or monocalcium phosphate to provide Ca and P. For grass tetany protection in the spring, this trace mineral salt package could be supplemented with magnesium oxide and a palatability enhancer such as wheat-mids, soybean meal, corn meal, or dry molasses to ensure adequate intake.

Table 17. Example of mineral concentrations needed in a pasture mineral supplement intended to cover 90 percent of pastures for a 1200-pound cow, producing 30 pounds of milk and consuming 3 ounces of supplement per day.

Minerals Supplement Calculator.

Enter data in market cells.

Animal description:		
	Lactating cow, 30 lbs milk	
Body weight	1200	Lbs
Dry matter intake	2.50	% body wt.
Mineral intake	3	oz/day
	85.23	gm/day
Feed intake	30	lbs/day
	13.64	kg/day

Mineral	Recommended in ration	Expected in pasture	Needed	Supplied	Amount needed from Supplement	Concentration needed in supplement
Ca%	0.38	0.44	51.82 gm	60.00 gm	-8.18 gm	
P%	0.24	0.23	32.73 gm	31.36 gm	1.36 gm	1.6%
K%	0.7	1.76	95.45 gm	240.00 gm	-144.55 gm	
Mg%	0.2	0.17	27.27 gm	23.18 gm	4.09 gm	4.8%
Na%	0.1	0.009	13.64 gm	1.23 gm	12.41 gm	14.6%
S%	0.15	0.18	2.05 gm	2.45 gm	-0.41 gm	
Zn ppm	30	20	409.1 mg	272.7 mg	136.4 mg	1600 ppm
Mn ppm	40	52	545.5 mg	709.1 mg	-163.6 mg	
Cu ppm	10	7	136.4 mg	95.5 mg	40.9 mg	480 ppm
Fe ppm	50	123	681.8 mg	1677.3 mg	-995.5 mg	
Co ppm	0.1		1.36 mg	0.00 mg	1.36 mg	16 ppm
I ppm	0.5		6.82 mg	0.00 mg	6.82 mg	80 ppm
Se ppm	0.1		1.36 mg	0.00 mg	1.36 mg	16 ppm

Se can be supplemented at up to 0.30 ppm of diet.

Table 18. Example of mineral concentrations needed in a pasture mineral supplement intended to cover 90% of pastures for 660-pound steers, consuming 2 ounces of supplement.

Minerals Supplement Calculator.

Enter data in market cells.

Animal description:

	Growing Steer	
Body weight	660	lbs
Dry matter intake	2.50	% body wt.
Mineral intake	2	oz/day
	56.82	gm/day
Feed intake	16.5	lbs/day
	7.50	kg/day

Mineral	Recommended in ration	Expected in pasture	Needed	Supplied	Amount needed from Supplement	Concentration needed in supplement
Ca%	0.36	0.44	27.00 gm	33.00 gm	-6.00 gm	
P%	0.19	0.23	14.25 gm	17.25 gm	-3.00 gm	
K%	0.7	1.76	52.50 gm	132.00 gm	-79.50 gm	
Mg%	0.2	0.17	15.00 gm	12.75 gm	2.25 gm	4.0%
Na%	0.1	0.009	7.50 gm	0.68 gm	6.83 gm	12.0%
S%	0.15	0.18	1.13 gm	1.35 gm	-0.23 gm	
Zn ppm	30	20	225.0 mg	150.0 mg	75.0 mg	1320 ppm
Mn ppm	40	52	300.0 mg	390.0 mg	-90.0 mg	
Cu ppm	10	7	75.0 mg	52.5 mg	22.5 mg	396 ppm
Fe ppm	50	123	375.0 mg	922.5 mg	-547.5 mg	
Co ppm	0.1		0.75 mg	0.00 mg	0.75 mg	13 ppm
I ppm	0.5		3.75 mg	0.00 mg	3.75 mg	66 ppm
Se ppm	0.1		0.75 mg	0.00 mg	0.75 mg	13 ppm

Se can be supplemented at up to 0.30 ppm of diet.

Conclusions

Most pastures in West Virginia are adequate for average-producing beef cattle used in a cow/calf production system. Where animals of above average production ability are desired, above-average management is needed to provide adequate forage quantity and quality over the grazing season. This management needs to include proper stocking rate, the use of a buffer in the grazing system (aftermath grazing or warm-season grasses), and the use of rotational grazing with proper control of pre- and post-grazing pasture height.

Liming, fertilization, seeding, and grazing management determine forage species present in a pasture and the forage nutrient content. Compared with other pastures, pastures having legumes as species number one or two were often higher in TDN, CP, Ca, P, Cu, Mg, Mn, and Mo; and lower in NDF than those having grass or weeds as species number one. Legume management in pasture will increase forage quality and can provide as much animal gain per acre of yearling cattle as the same grass fertilized with 200 pounds of nitrogen fertilizer (Blazer et al, 1969).

Forage height was the primary limiting factor for dry matter intake and therefore nutrient intake by grazing cattle on continuously grazed pastures in this study. Digestible energy content was the first limiting nutrient in pasture forage for grazing animals. This study found that forage availability was increased in these West Virginia pastures during the summer and fall and digestible energy concentration in pasture forage was increased (ADF and NDF were decreased) through the use of rotational grazing.

Pasture content of Ca and P may be inadequate for high-producing beef cows at peak lactation and fast-growing calves in 5-15% of pastures. Pasture mineral content of Mg continues to justify the use of Mg supplements to reduce the risk of animal death caused by grass tetany in the spring.

The microminerals Co, Cu, I, Se, and Zn are needed in trace mineral supplements. With the high content of Fe in pasture forage samples, it is recommended that Fe not be used in trace mineral supplements. A good trace mineral salt can then be supplemented strategically with Ca, P, and Mg to meet the seasonal needs of all classes of grazing animals.

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Appendix Table 1. Common and scientific names of forages represented in the pasture samples.

Cool-Season Grasses
orchardgrass (*Dactylis glomerata*, L.)
Kentucky bluegrass (*Poa pratensis* L.)
smooth bromegrass (*Bromus inermis* Leyss.)
tall fescue (*Festuca arundinacea* Schreb.)
timothy (*Phleum pratense* L.)
quackgrass (*Agropyron repens* L.)
velvet grass (*Holcus lanatus* L.)
sweet vernal grass (*Anthoxanthum odoratum* L.)
perennial ryegrass (*Lolium perenne* L.)

Legumes
white clover (*Trifolium repens* L.)
red clover (*Trifolium pratense* L.)
alfalfa (*Medicago sativa* L.)

Herbs/Forbes
common plantain (*Plantago rugelii* Dcne.)
buckhorn plantain (*Plantago lanceolata* L.) English plantain
common dandelion (*Taraxacum officinale* Weber.)
curly dock (*Rumex crispus* L.) yellow dock
lamb's quarter (*Chenopodium album* L.)
common ragweed (*Ambrosia artemisifolia* L.)

Warm-Season Grasses
switchgrass (*Panicum virgatum* L.)
broomsedge (*Andropogon virginicus* L.)
crabgrass (*Digitaria sanguinalis* L.)

Appendix Table 2. Abbreviations used in tables and figures.

DM	dry matter
Count	number of samples in the mean
CP	crude protein
ADF	acid detergent fiber
Mean	average
NDF	neutral detergent fiber
NSC-CHO	nonstructural carbohydrates
NEL	net energy lactation
NEG	net energy gain
NEM	net energy maintenance
TDN	total digestible nutrients
RFV	relative feed value
Ca	calcium
P	phosphorus
K	potassium
Mg	magnesium
Mo	molybdenum
Na	sodium
Zn	zinc
Mn	manganese
Cu	copper
Fe	iron
Al	aluminum
S	sulfur
Std Error	standard error
95% LCL	lower confidence limit on mean at the 95% probability level
95% UCL	upper confidence limit on mean at the 95% probability level

Appendix Table 1. Suggested mineral requirements of beef cattle with value for Ca and P in parenthesis calculated for 1000-pound cow making 20 pounds milk. (Adapted from Nutrient Requirements of Beef Cattle, National Research Council, 2000.)

Mineral	Suggested Value	Range	Maximum Tolerable Level
Ca, % †	0.16-0.58 (0.32)		2
Co, ppm	0.10	0.07-0.11	5
Cu, ppm	10	4-10	115
I, ppm	0.5	0.20-2.0	50
Fe, ppm	50	50-100	1000
Mg, %	0.20	0.05-0.25	0.40
Mn, ppm	40	20-50	1000
Mo, ppm			6
P, % †	0.17-0.39 (0.21)		1
K, %	0.70	0.5-0.7	3
Se, ppm††	0.10	0.05-0.30	2
Na, %	0.10	0.06-0.10	10
Cl, %			
S, %	0.15	0.08-0.15	0.40
Zn, ppm	30	20-40	500

† Depending on age and production status.
†† It is legal to supplement Se to beef cattle at the level of 0.30 mg/kg of the total diet up to 3 mg/head/day (NRC Beef Update 2000, p.68).

Appendix Table 2. Suggested mineral requirements of dairy cattle with values in parenthesis for a 1200-pound cow producing 80 pounds of milk. (Adapted from the Nutrient Requirements of Dairy Cattle, National Research Council, 2001.)

Mineral	Suggested Value	Range	Maximum Tolerable Level
Ca, % †	0.29-0.77 (0.64)		2
Co, ppm	0.10	0.07-0.11	5
Cu, ppm	10	4-10	115
I, ppm	0.25-0.60	0.20-2.0	50
Fe, ppm	50	50-100	1000
Mg, %	0.16-0.25	0.05-0.25	0.40
Mn, ppm	40	20-50	1000
Mo, ppm			6
P, % †	0.19-0.48 (0.41)		1
K, %	0.65-1.00	0.5-0.7	3
Se, ppm	0.30	0.05-0.30	2
Na, %	0.10-0.18	0.06-0.10	10
Cl, %	0.20-0.25		
S, %	0.16-0.25	0.08-0.15	0.40
Zn, ppm	40	20-40	500

† Depending on age and production status.

Appendix Table 3. Suggested mineral requirements of sheep. (Adapted from the Nutrient Requirements of Sheep, National Research Council, 1985.)

Mineral	Suggested Value	Maximum Tolerable Level
Ca, % †	0.20-0.82	2
Co, ppm	0.10-0.20	10
Cu, ppm	7-11	25
I, ppm	0.10-0.80	50
Fe, ppm	30-50	500
Fl, ppm		60-150
Mg, %	0.12-0.18	0.40
Mn, ppm	20-40	1000
Mo, ppm	0.5	10
P, % †	0.16-0.38	1
K, %	0.50-80	3
Se, ppm	0.10-0.20	2
Na, %	0.09-0.18	10
Cl, %		
S, %	0.14-0.26	0.40
Zn, ppm	20-33	750

† depending on age and production status

Appendix Table 4. Dry matter intake, total digestible nutrient, crude protein, calcium and phosphorus requirements of beef cows at three weights and three levels of peak milk production prior to rebreeding (adapted from NRC 2000).

	Peak Milk lbs		
	10	20	30
1000 lbs Cow			
Dry Matter Intake lbs	22	25	28
Dry Matter Intake %BW	2.20	2.50	2.80
Total Digestible Nutrients %	57	61	65
Crude Protein %	9.1	11.1	12.9
Calcium %	0.25	0.32	0.38
Phosphorus %	0.17	0.21	0.24
1200 lbs Cow			
Dry Matter Intake lbs	25	28	31
Dry Matter Intake %BW	2.08	2.33	2.58
Total Digestible Nutrients %	56	60	63
Crude Protein %	8.8	10.7	12.2
Calcium %	0.25	0.31	0.36
Phosphorus %	0.17	0.21	0.23
1400 lbs Cow			
Dry Matter Intake lbs	28	31	33
Dry Matter Intake %BW	2.00	2.21	2.36
Total Digestible Nutrients %	56	59	62
Crude Protein %	8.6	10.3	11.8
Calcium %	0.25	0.30	0.35
Phosphorus %	0.17	0.20	0.23

Appendix Table 5. Dry matter intake and ration content of total digestible nutrient, crude protein, calcium and phosphorus requirements of bred heifers in mid and last trimester of gestation (adapted from NRC 2000).

Ration Component	Mid Gestation	Last Trimester
Dry Matter Intake %BW	1.7	2.1
Total Digestible Nutrient %	50	61
Crude Protein %	7.2	10.0
Calcium %	0.21	0.32
Phosphorus %	0.16	0.23

Appendix Table 6. Total digestible nutrient (TDN), dry matter intake (DMI), average daily gain (ADG), crude protein (CP), calcium (Ca), and phosphorus (P) requirements of a steer that will finish at 1000 pounds or heifer maturing at 1000 pounds (adapted from NRC 2000).

Body Wt. Lbs.	TDN %	DMI Lbs.	DMI % B.Wt.	ADG %	CP %	Ca %	P %
1000 Lbs. Finished Steer or Mature Heifer Weight							
550	50	15.2	2.76	0.64	7.1	0.21	0.13
550	60	16.1	2.93	1.77	9.8	0.36	0.19
550	70	15.7	2.85	2.68	12.4	0.49	0.24
550	80	14.8	2.69	3.34	14.9	0.61	0.29
600	50	16.2	2.70	0.64	7.0	0.21	0.13
600	60	17.2	2.87	1.77	9.5	0.34	0.18
600	70	16.8	2.80	2.68	11.9	0.45	0.23
600	80	15.8	2.63	3.34	14.3	0.56	0.27
650	50	17.3	2.66	0.64	6.9	0.20	0.12
650	60	18.2	2.80	1.77	9.2	0.32	0.17
650	70	17.8	2.74	2.68	11.5	0.42	0.21
650	80	16.8	2.58	3.34	13.7	0.52	0.26
700	50	18.2	2.60	0.64	6.8	0.19	0.12
700	60	19.3	2.76	1.77	8.8	0.30	0.16
700	70	18.8	2.69	2.68	10.9	0.39	0.20
700	80	17.8	2.54	3.34	13.0	0.48	0.24
750	50	19.2	2.56	0.64	6.7	0.19	0.12
750	60	20.3	2.71	1.77	8.5	0.28	0.16
750	70	19.8	2.64	2.68	10.3	0.37	0.19
750	80	18.7	2.49	3.34	12.2	0.45	0.23
800	50	20.2	2.53	0.64	6.5	0.19	0.12
800	60	21.3	2.66	1.77	8.1	0.27	0.15
800	70	20.8	2.60	2.68	9.8	0.34	0.18
800	80	19.6	2.45	3.34	11.5	0.42	0.22

Appendix Table 7. Total digestible nutrient (TDN), dry matter intake (DMI), average daily gain (ADG), crude protein (CP), calcium (Ca), and phosphorus (P) requirements of a steer that will finish at 1200 pounds or heifer maturing at 1200 pounds (adapted from NRC 2000).

Body Wt. Lbs.	TDN %	DMI Lbs.	DMI % B.Wt.	ADG %	CP %	Ca %	P %
1200 Lbs. Finished Steer or Mature Heifer Weight							
660	50	17.5	2.65	0.72	7.3	0.22	0.13
660	60	18.4	2.79	2.00	10.2	0.36	0.19
660	70	18.0	2.73	3.04	13.0	0.49	0.24
660	80	17.0	2.58	3.78	15.8	0.61	0.29
720	50	18.6	2.58	0.72	7.1	0.21	0.13
720	60	19.7	2.74	2.00	9.7	0.34	0.18
720	70	19.2	2.67	3.04	12.2	0.45	0.23
720	80	18.2	2.53	3.78	14.6	0.56	0.27
780	50	19.8	2.54	0.72	6.9	0.20	0.13
780	60	20.9	2.68	2.00	9.2	0.32	0.17
780	70	20.4	2.62	3.04	11.4	0.42	0.21
780	80	19.3	2.47	3.78	13.6	0.52	0.26
840	50	20.9	2.49	0.72	6.8	0.20	0.13
840	60	22.1	2.63	2.00	8.8	0.30	0.16
840	70	21.6	2.57	3.04	10.8	0.39	0.20
840	80	20.4	2.43	3.78	12.8	0.48	0.24
900	50	22.0	2.44	0.72	6.6	0.19	0.12
900	60	23.3	2.59	2.00	8.4	0.28	0.16
900	70	22.7	2.52	3.04	10.2	0.37	0.19
900	80	21.5	2.39	3.78	12.0	0.44	0.23
960	50	23.1	2.41	0.72	6.5	0.19	0.12
960	60	24.4	2.54	2.00	8.1	0.27	0.15
960	70	23.9	2.49	3.04	9.7	0.34	0.19
960	80	22.5	2.34	3.78	11.3	0.41	0.22

Appendix Table 8. Total digestible nutrient (TDN), dry matter intake (DMI), average daily gain (ADG), crude protein (CP), calcium (Ca), and phosphorus (P) requirements of a steer that will finish at 1400 pounds or heifer maturing at 1400 pounds (adapted from NRC 2000).

Body Wt. Lbs.	TDN %	DMI Lbs.	DMI %B.Wt.	ADG %	CP %	Ca %	P %
1400 Lbs. Finished Steer or Mature Heifer Weight							
770	50	19.6	2.55	0.80	7.3	0.22	0.13
770	60	20.7	2.69	2.20	10.1	0.36	0.19
770	70	20.2	2.62	3.38	12.9	0.49	0.24
770	80	19.1	2.48	4.20	15.6	0.61	0.29
840	50	20.9	2.49	0.80	7.1	0.21	0.13
840	60	22.1	2.63	2.20	9.6	0.34	0.18
840	70	21.6	2.57	3.38	12.1	0.45	0.23
840	80	20.4	2.43	4.20	14.5	0.56	0.27
910	50	22.2	2.44	0.80	6.9	0.21	0.13
910	60	23.5	2.58	2.20	9.1	0.32	0.17
910	70	22.9	2.52	3.38	11.3	0.42	0.22
910	80	21.6	2.37	4.20	13.5	0.51	0.26
980	50	23.5	2.40	0.80	6.7	0.20	0.13
980	60	24.8	2.53	2.20	8.7	0.30	0.17
980	70	24.2	2.47	3.38	10.7	0.39	0.20
980	80	22.9	2.34	4.20	12.6	0.47	0.24
1050	50	24.7	2.35	0.80	6.6	0.20	0.13
1050	60	26.1	2.49	2.20	8.3	0.28	0.16
1050	70	25.5	2.43	3.38	10.1	0.37	0.20
1050	80	24.1	2.30	4.20	11.9	0.44	0.23
1120	50	25.9	2.31	0.80	6.5	0.19	0.13
1120	60	27.4	2.45	2.20	8.0	0.27	0.16
1120	70	26.8	2.39	3.38	9.6	0.32	0.19
1120	80	25.3	2.26	4.20	11.2	0.41	0.22

Appendix Table 9. Correlation coefficients between various measured pasture characteristics.

	CP	SP	DP	ADF	NDF	LIG	NSC	Fat	Ash	TDN	RFV
CP	1.00	0.18	0.34	-0.75	-0.75	-0.25	0.04	0.72	0.50	0.46	0.77
SP	0.18	1.00	0.47	-0.04	0.00	-0.20	-0.12	0.00	-0.01	0.20	0.01
DP	0.34	0.47	1.00	-0.33	-0.18	-0.57	0.03	0.30	-0.16	0.54	0.25
ADF	-0.75	-0.04	-0.33	1.00	0.86	0.40	-0.50	-0.63	-0.34	-0.77	-0.89
NDF	-0.75	0.00	-0.18	0.86	1.00	0.21	-0.63	-0.55	-0.45	-0.50	-0.96
LIG	-0.25	-0.20	-0.57	0.40	0.21	1.00	-0.13	-0.41	0.23	-0.62	-0.27
NSC	0.04	-0.12	0.03	-0.50	-0.63	-0.13	1.00	-0.18	-0.03	0.36	0.59
Fat	0.72	0.00	0.30	-0.63	-0.55	-0.41	-0.18	1.00	0.32	0.62	0.57
Ash	0.50	-0.01	-0.16	-0.34	-0.45	0.23	-0.03	0.32	1.00	-0.02	0.36
TDN	0.46	0.20	0.54	-0.77	-0.50	-0.62	0.36	0.62	-0.02	1.00	0.55
RFV	0.77	0.01	0.25	-0.89	-0.96	-0.27	0.59	0.57	0.36	0.55	1.00
Ca	0.32	0.04	0.07	-0.20	-0.39	0.15	0.19	-0.11	0.19	-0.07	0.37
P	0.57	0.28	0.22	-0.31	-0.42	-0.11	-0.09	0.40	0.40	0.08	0.39
Mg	0.35	0.06	0.07	-0.13	-0.19	0.01	-0.09	0.26	0.28	0.03	0.15
K	0.70	0.11	0.16	-0.53	-0.59	-0.21	0.01	0.60	0.47	0.27	0.58
Na	0.01	0.16	0.28	0.06	0.10	-0.12	-0.08	0.05	-0.16	0.07	-0.05
Fe	-0.02	-0.09	-0.14	0.06	0.04	0.19	-0.13	-0.16	0.45	-0.12	-0.07
Zn	0.19	-0.07	0.01	-0.22	-0.15	0.08	-0.02	0.17	0.22	0.23	0.15
Cu	0.20	-0.14	-0.07	-0.20	-0.19	0.10	0.04	0.27	0.47	0.15	0.16
Mn	-0.20	-0.05	-0.24	0.09	0.09	0.21	-0.02	-0.07	0.17	-0.13	-0.10
Mo	0.30	-0.21	-0.11	-0.30	-0.35	0.02	0.10	0.16	0.29	0.09	0.34
S	0.68	-0.04	-0.02	-0.56	-0.53	-0.10	0.01	0.65	0.54	0.35	0.52
Height	-0.21	-0.12	-0.12	0.23	0.30	0.11	-0.11	-0.10	-0.25	-0.12	-0.27
Days Rot	-0.07	-0.02	-0.08	-0.02	-0.27	0.31	0.04	0.17	0.19	-0.10	0.21
Al	-0.03	0.04	-0.14	-0.06	-0.03	0.18	-0.05	0.00	0.06	0.10	0.03
DOY	0.03	-0.31	-0.35	0.15	0.15	0.21	-0.17	0.06	0.19	-0.21	-0.18
CF	-0.82	0.00	0.00	1.00	0.89	0.00	-0.34	0.00	0.00	-0.98	-0.93
ADF/NDF	-0.09	-0.04	-0.31	0.39	-0.13	0.43	0.14	-0.15	0.23	-0.59	0.01
Grass Fraction	0.07	0.02	0.28	-0.39	0.11	-0.43	-0.10	0.15	-0.24	0.59	0.00

Appendix Table 9 (continued). Correlation coefficients between various measured pasture characteristics.

	Ca	P	Mg	K	Na	Fe	Zn	Cu	Mn	Mo	S	Al
CP	0.32	0.57	0.35	0.70	0.01	-0.02	0.19	0.20	-0.20	0.30	0.68	-0.03
SP	0.04	0.28	0.06	0.11	0.16	-0.09	-0.07	-0.14	-0.05	-0.21	-0.04	0.04
DP	0.07	0.22	0.07	0.16	0.28	-0.14	0.01	-0.07	-0.24	-0.11	-0.02	-0.14
ADF	-0.20	-0.31	-0.13	-0.53	0.06	0.06	-0.22	-0.20	0.09	-0.30	-0.56	-0.06
NDF	-0.39	-0.42	-0.19	-0.59	0.10	0.04	-0.15	-0.19	0.09	-0.35	-0.53	-0.03
LIG	0.15	-0.11	0.01	-0.21	-0.12	0.19	0.08	0.10	0.21	0.02	-0.10	0.18
NSC	0.19	-0.09	-0.09	0.01	-0.08	-0.13	-0.02	0.04	-0.02	0.10	0.01	-0.05
Fat	-0.11	0.40	0.26	0.60	0.05	-0.16	0.17	0.27	-0.07	0.16	0.65	0.00
Ash	0.19	0.40	0.28	0.47	-0.16	0.45	0.22	0.47	0.17	0.29	0.54	0.06
TDN	-0.07	0.08	0.03	0.27	0.07	-0.12	0.23	0.15	-0.13	0.09	0.35	0.10
RFV	0.37	0.39	0.15	0.58	-0.05	-0.07	0.15	0.16	-0.10	0.34	0.52	0.03
Ca	1.00	0.19	0.38	0.09	0.03	0.08	0.07	0.05	-0.14	0.21	0.17	-0.06
P	0.19	1.00	0.35	0.59	-0.04	0.10	0.00	0.10	-0.15	0.19	0.34	-0.11
Mg	0.38	0.35	1.00	0.20	0.02	0.09	0.09	0.07	-0.17	0.05	0.36	-0.05
K	0.09	0.59	0.20	1.00	-0.05	-0.02	0.14	0.08	-0.10	0.24	0.61	-0.10
Na	0.03	-0.04	0.02	-0.05	1.00	-0.03	-0.01	0.15	-0.06	-0.12	-0.01	-0.11
Fe	0.08	0.10	0.09	-0.02	-0.03	1.00	0.11	0.36	0.40	0.04	0.10	0.89
Zn	0.07	0.00	0.09	0.14	-0.01	0.11	1.00	0.27	0.11	0.10	0.30	0.03
Cu	0.05	0.10	0.07	0.08	0.15	0.36	0.27	1.00	0.21	0.16	0.17	0.39
Mn	-0.14	-0.15	-0.17	-0.10	-0.06	0.40	0.11	0.21	1.00	-0.25	0.03	0.45
Mo	0.21	0.19	0.05	0.24	-0.12	0.04	0.10	0.16	-0.25	1.00	0.32	0.11
S	0.17	0.34	0.36	0.61	-0.01	0.10	0.30	0.17	0.03	0.32	1.00	0.08
Height	-0.11	-0.04	-0.25	-0.02	0.08	-0.29	-0.16	-0.26	-0.13	0.01	-0.22	0.00
Days Rot	0.21	0.06	0.09	0.06	0.00	-0.15	0.22	0.02	-0.09	0.20	0.13	0.00
Al	-0.06	-0.11	-0.05	-0.10	-0.11	0.89	0.03	0.39	0.45	0.11	0.08	1.00
DOY	0.08	-0.06	0.40	0.02	-0.05	0.23	0.22	0.08	0.07	0.01	0.24	0.10
CF	-0.23	-0.62	-0.15	-0.66	0.03	0.09	-0.24	-0.10	0.25	0.00	-0.63	0.15
ADF/NDF	0.35	0.16	0.11	0.01	-0.06	0.05	-0.16	-0.04	0.03	0.09	-0.14	-0.07
Grass Fraction	-0.37	-0.15	-0.14	-0.02	0.06	-0.05	0.13	0.04	-0.01	-0.09	0.14	0.10

Appendix Table 9 (continued). Correlation coefficients between various measured pasture characteristics.

	DOY	CF	ADF/NDF	Grass Fraction	Height	Days Rot
CP	0.03	-0.82	-0.09	0.07	-0.21	-0.07
SP	-0.31	0.00	-0.04	0.02	-0.12	-0.02
DP	-0.35	0.00	-0.31	0.28	-0.12	-0.08
ADF	0.15	1.00	0.39	-0.39	0.23	-0.02
NDF	0.15	0.89	-0.13	0.11	0.30	-0.27
LIG	0.21	0.00	0.43	-0.43	0.11	0.31
NSC	-0.17	-0.34	0.14	-0.10	-0.11	0.04
Fat	0.06	0.00	-0.15	0.15	-0.10	0.17
Ash	0.19	0.00	0.23	-0.24	-0.25	0.19
TDN	-0.21	-0.98	-0.59	0.59	-0.12	-0.10
RFV	-0.18	-0.93	0.01	0.00	-0.27	0.21
Ca	0.08	-0.23	0.35	-0.37	-0.11	0.21
P	-0.06	-0.62	0.16	-0.15	-0.04	0.06
Mg	0.40	-0.15	0.11	-0.14	-0.25	0.09
K	0.02	-0.66	0.01	-0.02	-0.02	0.06
Na	-0.05	0.03	-0.06	0.06	0.08	0.00
Fe	0.23	0.09	0.05	-0.05	-0.29	-0.15
Zn	0.22	-0.24	-0.16	0.13	-0.16	0.22
Cu	0.08	-0.10	-0.04	0.04	-0.26	0.02
Mn	0.07	0.25	0.03	-0.01	-0.13	-0.09
Mo	0.01	0.00	0.09	-0.09	0.01	0.20
S	0.24	-0.63	-0.14	0.14	-0.22	0.13
Height	-0.19	0.00	-0.12	0.14	1.00	0.42
Days Rot	-0.01	0.00	0.31	-0.27	0.42	1.00
Al	0.10	0.15	-0.07	0.10	0.00	0.00
DOY	1.00	0.08	0.02	-0.04	-0.19	-0.01
CF	0.08	1.00	0.53	-0.55	0.00	0.00
ADF/NDF	0.02	0.53	1.00	-0.97	-0.12	0.31
Grass Fraction	-0.04	-0.55	-0.97	1.00	0.14	-0.27