FORAGE AND BEEF PRODUCTION AND WATER USE FROM SEASON-LONG RECLAIMED AND NATIVE PASTURES[1]

by

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Abstract. Northern Great Plains range and pastures provide a valuable source of hay and forage for livestock. This study was conducted to provide a better understanding of the interrelationship of forage and beef production with site and environmental conditions. Cool-season pastures on reclaimed mined land and native range were continuously grazed for 126 days in each of three years. Season-long grass, forb, total forage, and beef production and their production per unit of water used were modeled using multiple stepwise regression. Independent variables of litter at the end of grazing, percent grass in the current year's forage production, April through July precipitation (all positively related), and mean-maximum daily air temperature during the same period (negatively related) explained 67% ($P>F=.0039$) of the variation in grass production. Season-long beef production was positively related to the amount of grass produced ($R^2=.32$, $P>F=.0148$). Season-long grass and beef produced per unit of water used (kg/ha/mm) were positively related to grass or beef production in kg/ha and negatively related to April through July free-water pan evaporation ($R^2=.98$, $P>F=.0001$ and $R^2=.93$, $P>F=.0001$, respectively). These relationships emphasize that producers can best increase beef production by concentrating on increasing grass production. Those factors significantly related to grass and beef production or production per unit of water used are prime candidates for management or modification.

Additional Key Words: continuous grazing, grass, forb, environment, rangeland, cool-season pasture, production/water used, northern Great Plains, mined-land reclamation

Introduction

In the early 1970s, surface mining for lignite coal increased in the northern Great Plains. A consensus developed that land disturbed by mining must be returned to levels of production that existed before disturbance. Research was conducted on methodology to restore vegetation

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and production, and the best methods were incorporated into the mining and reclamation process. The first North Dakota grassland released from bond was studied to evaluate the success of reclamation methods and the usability of the reestablished vegetation for livestock grazing and occasional hay production (Hofmann et al. 1981, Hofmann et al. 1983, Ries and Hofmann 1984, and Hofmann and Ries 1988). This 1976 through 1981 research established that reclaimed grassland provided livestock grazing equal to or better than that on similar land not disturbed by mining (Ries and Hofmann 1983). Under proper stocking and use rates, the reclaimed pasture continued this level of forage production, reflecting expected beef gains and soil stability. More recent research found beef gains from these cool-season reclaimed pastures grazed season-long were similar to gains from native pastures grazed season-long when stocked at the same rate (Hofmann and Ries 1989).

Northern Great Plains range and pasture land provide a valuable source of forage and hay for livestock. Forage and hay production can vary greatly from year to year in response to environmental factors (Rogler and Haas 1947, Ries and Fisser 1979) and these responses are important to better understand forage and beef production in the northern Great Plains.

A second interest in pasture and rangeland management in the northern Great Plains concerns the dry matter yield of forage produced per unit of water used. Any practice that can increase forage production per unit of water used can result in more forage or hay from the limited precipitation that is typical of this region. In a preliminary study conducted during 1977-1981, Ries and Hofmann (1985) found that forage produced per unit of water used from cool-season pastures on reclaimed land was equal to that measured from similar composition hayland on unmined land. We also found a significant year*treatment interaction. The desire to investigate both forage and beef production per unit of water used stimulated the study being reported in this paper.

The production of forage or grain production per unit of water used is by convention known as water-use-efficiency (WUE). WUE (kg/ha/mm) is calculated by dividing total measured production (kg/ha) by the total amount of water used to result in that production. Various legumes and pasture and range grasses are known to vary in their WUE (Fairbourn 1982). Holmen et al. (1961) found that bromegrass (<u>Bromus inermis</u> Leyss.) and a bromegrass-alfalfa (<u>Medicago sativa</u> L.) mixture irrigated to medium soil water levels improved WUE over non-irrigated, dryland plots. Their data further suggest that water used by irrigated grasses is even more efficient when fertilizers are applied to correct nutrient deficiencies. Fertilization of native range communities also improved WUE (Wight and Black 1978 and 1979). The WUE of wheat grain, corn silage, and grass-legume forage grown on fertilized leveled spoils in North Dakota has been reported (Bauer et al. 1978). Topsoil thickness and fertility on reclaimed land have also been found to affect the WUE of corn silage and wheat (Schroeder et al. 1980). Little is known about beef WUE.

Our first objective of this study was to evaluate grass, forb, total forage (grass + forb), and beef production and production per unit of water used for reclaimed and native pastures grazed season-long. The second objective was to use multiple stepwise regression to model the relationship of environmental and site conditions to this production and production per unit of water used during the three years of this study.

Material and Methods

The study area was located near Center, North Dakota, on reclaimed surface mined land and an adjacent unmined native rangeland (Hofmann and Ries 1988, 1989). Native soils of the area are Cabba (loam mixed, calcareous, frigid, shallow, Typic Ustorthents) and Sen (fine-silty, mixed Typic Haploborolls). Minespoils are silt loam texture, with a SAR level of about 2. Spoils were reshaped to near original contour and covered with approximately 10 cm of clay loam topsoil material. In the spring of 1973, the area was fertilized with 112 kg/ha of 11-11-0 fertilizer and seeded with a mixture of smooth bromegrass, crested wheatgrass (*Agropyron desertorum* [Fisch.] Schult.), intermediate wheatgrass (*Agropyron intermedium* [Host] Beauv.), and alfalfa and biennial yellow sweetclover (*Melilotus officinalis* Lam.).

Two sets of reclaimed pastures from an earlier grazing intensity study were used in this season-long grazing study (Hofmann and Ries 1988). One set had been heavily and moderately grazed (R1), the other had been lightly grazed (R2). Vegetation on these pastures included smooth bromegrass, crested wheatgrass, and a few other minor grasses. Alfalfa was the primary forb that contributed 370 kg/ha or about 27% of the total forage on the reclaimed pastures.

One set of unmined, native rangeland pastures (Native) was also studied. Vegetation on these pastures was sedges (*Carex* spp.), Kentucky bluegrass (*Poa pratensis* L.), needle-and-thread grass (*Stipa comata* Trin. and Rupr.), green needlegrass (*Stipa viridula* Trin.), western wheatgrass (*Agropyron smithii* Rydb.), blue grama (*Bouteloua gracilis* [H.B.K.] Lag.), and other minor grasses. Various forbs that included sunflower (*Helianthus annuus* L.), white prairie-clover (*Petalostermum candidum* Michx.), green sage (*Artemisia glauca* Pall.), fringed sage (*Artemisia frigida* Willd.), prairie thistle (*Cirsium undulatum* [Nutt.] Spreng.) and others contributed 240 kg/ha or about 40% of the total forage on the native pastures.

Replicated pastures, 1.86 ha in size, were grazed by 2 yearling Hereford x Simmental steers (2.9 AUM/ha) from 25, 30, and 29 May to 28 September, and 3 and 2 October during 1983, 1984, and 1985, respectively, for a 126 day grazing period each year.

Weather data including precipitation and mean-maximum, -minimum, and -average daily air temperatures were collected by the U.S. Weather Bureau Station at Center, ND, about 2 km west-northwest of the study area. Free-water evaporation was recorded with a standard evaporation pan at the Northern Great Plains Research Laboratory Weather Station about 64 km southeast of the study area (Table 1).

Soil water was measured to a depth of 1.8 m with a neutron moisture meter at six access tubes randomly located in each pasture. Soil water readings were taken in April and mid-October each year. Previous research (Hofmann et al. 1983) found very limited runoff or deep percolation of water from normal precipitation events. Therefore, the difference in soil water content from April to mid-October each year provided a measure of water used for evapotranspiration from the soil. Soil water recharge was the increase in soil water content observed from mid-October the previous fall to April of the next growing season. Total water used to produce season-long forage and beef was calculated as the sum of precipitation received and the soil water used from April to mid-October each year.

Forage production was measured at the end of grazing each year by clipping a 0.3 x 3.0 m area at a height of 5 cm under six caged areas per pasture near each randomly located soil moisture access tube. All standing live and dead vegetation plus ground litter were harvested. Samples were hand separated into current year's grasses, current year's forbs, and litter. Total forage production is the sum of current year's grass plus forb production. All forage dry matter and litter weights were recorded on an oven dry basis in kg/ha.

Beef production in kg/ha at the end of grazing was determined by summing the live weight gains for the two steers per pasture from 14-day interval weighings throughout the grazing period.

Both forage and beef data in our study included production per unit of water used during the complete grazing season. The amount of forage or beef produced per unit of water used (kg/ha/mm) was determined by dividing the season-long production in kg/ha by season-long total water used in mm. This provided a similar water use base for forage and beef production per unit of water used. Most studies of forage WUE in the literature reflect water usage and forage yield measured only during the time period when forage production is near the maximum rate. Thus WUE values for the entire grazing season that are reported in our study would be expected to be lower than those commonly reported in the literature.

Analysis of variance for forage and beef production and

Table 1. Environmental data for each season of study.

Season	Pptn. (mm)	Soil Water Used (mm)	Mean Max. Temp. (C)	Mean Min. Temp. (C)	Mean Avg. Temp. (C)	Free Water Evap. (mm)
4/4-10/19/83	246	162	21.0	6.7	13.8	1032
4/25-10/25/84	203	84	20.1	6.4	13.2	955
4/25-10/10/85	306	48	20.0	6.3	13.2	906

production per unit of water used for each season was a completely random design analyzed as a split plot in time, with reclaimed and native pastures as whole plots and years as subplots. Year and pasture treatment means with significant F tests were further separated by using a Waller/Duncan test to rank means.

Multiple stepwise regression (STEPWISE, Forward Selection) with an entry and stay level P=.25 (SAS Institute 1985) was used to model season-long forage and beef production and production per unit of water used for all pastures over the 3 years of the study. The simple correlation matrix of dependent and independent variables (Tables 2 and 3) was used to determine relationships between dependent and independent variables and within independent variables. Highly related independent variables were controlled so only one of the variables would be in the series of independent variables at the same time. Decisions on which of the related independent variables were most important was determined by an evaluation of their expected biological importance.

Dependent variables Y1 through Y3 (Table 2) were evaluated considering independent variables X1 through X22 (Table 3). Dependent variable Y4 was modeled considering independent variables X1 through X25. Since production per unit of water used (kg/ha/mm) is calculated by dividing production (kg/ha) by a common factor, total water used (mm), a relationship due to calculation exists between these factors. The mathematical formula for water-use-efficiency was changed to a linear multiple regression equation where the R^2 should be 1.00. Grass, forb, total forage, and beef production (kg/ha) were more related to production per unit of water used (kg/ha/mm) than total water used (Table 4--simple correlation coefficients of 0.93, 0.91, 0.92, and 0.70, respectively). All are highly significant with a P>F < 0.01. The independent variables of total water used (mm) and free-water pan evaporation during April through July (mm) were very highly correlated (r=0.94, P>F=.0001, r^2=0.89).

Table 2. Production parameters modeled by stepwise multiple regression.

Production (kg/ha)	Production/Unit of Water Used (kg/ha/mm)
Y1 = grass production	Y5 = grass
Y2 = forb production	Y6 = forb
Y3 = total forage (grass+forb)	Y7 = total forage
Y4 = beef production	Y8 = beef

Table 3. Environmental and site factors considered in modeling season-long grass, forb, total forage, and beef production and production per unit of water used.

X1 =	total soil water used during season to 1.8 m - range 26 to 182 mm
X2 =	precipitation received during season - range 203 to 306 mm
X3 =	total water used during season = X1 + X2 - range 255 to 428 mm
X4 =	free-water evaporation the Sep and Oct before season - range 167 to 187 mm
X5 =	mean-maximum daily air temperature Sep and Oct before season - range 15.9 to 17.3 C
X6 =	mean-minimum daily air temperature Sep and Oct before season - range 3.5 to 4.4 C
X7 =	mean-average daily air temperature Sep and Oct before season - range 9.7 to 10.8 C
X8 =	precipitation received during Sep and Oct before season - range 50 to 230 mm
X9 =	recharge in soil water to 1.8 m over the winter before season - range -7 to 142 mm
X10 =	litter remaining in pasture at the end of the season - range 887 to 1767 kg/ha
X11 =	grass in total forage for season - range 61 to 89%
X12 =	forbs in total forage for season - range 11 to 39%
X13 =	free-water evaporation during Apr+May+Jun+Jul of season - range 566 to 648 mm
X14 =	free-water evaporation during Aug+Sep+Oct of season - range 284 to 389 mm
X15 =	mean-maximum daily air temperature during Apr, May, Jun, and Jul of season - range 19.6 to 22.9 C
X16 =	mean-minimum daily air temperature during Apr, May, Jun, and Jul of season - range 5.8 to 7.5 C
X17 =	mean-average daily air temperature during Apr, May, Jun, and Jul of season - range 12.7 to 15.2 C
X18 =	mean-maximum daily air temperature during Aug, Sep, and Oct of season - range 16.2 to 21.4 C
X19 =	mean-minimum daily air temperature during Aug, Sep, and Oct of season - range 4.8 to 7.9 C
X20 =	mean-average daily air temperature during Aug, Sep, and Oct of season - range 10.5 to 14.7 C
X21 =	precipitation received during Apr+May+Jun+Jul of season - range 127 to 172 mm
X22 =	precipitation received during Aug+Sep+Oct of season - range 76 to 134 mm
X23 =	grass production - range 232 to 2013 kg/ha
X24 =	forb production - range 55 to 587 kg/ha
X25 =	total forage production (grass+forb) - range 287 to 2401 kg/ha
X26 =	beef production - range 41.4 to 90.1 kg/ha

Table 4. Simple relationship (r) between grass, forb, total forage, and beef production per unit of water used (kg/ha/mm) and grass, forb, total forage, beef production (kg/ha) and total water used (mm).

Production/ water used (kg/ha/mm)	Production Grass	Forb	Total Forage	Beef	Total Water Used (mm)
	------------kg/ha	-------	-------	-------	
Grass	.93**	.47*	.92**	.41	-.54*
Forb	.54*	.91**	.70**	.18	-.45
Total Forage (grass+forb)	.90**	.61**	.92**	.38	-.55*
Beef	.63**	.32	.62**	.70**	-.59*

* P<.05 (n=18)
** P<.01 (n=18)

Therefore, dependent variables Y5 through Y8 were evaluated with the multiple regression equation developed from the mathematical equation for water-use-efficiency with April through July free-water pan evaporation (mm) substituted for season-long total water used (mm).

Results

Season-long grass and forb production were the same for the reclaimed or native pastures (Table 5). Both reclaimed pastures produced significantly more total forage than the native pastures. Season-long forb production was statistically the same during each year of this study, while grass and total forage production were significantly less in 1985 than in the other years. No significant difference in beef production was found among pastures or years. Season-long grass and forb production per unit of water used were the same for all pastures (Table 5). Total forage production per unit of water used was significantly less for the native pastures. Grass, forb, and total forage production per unit of water used varied significantly among years. Grass, forb, and total forage production per unit of water used were significantly higher in 1984 than in the other 2 years. No significant differences in beef production per unit of water used were found among pastures or years. A

Table 5. Season-long grass, forb, total forage, and beef production and production per unit of water used during study.

	Grass Production (kg/ha)	Grass Production/Water Used (kg/ha/mm)		Forb Production (kg/ha)	Forb Production/Water Used (kg/ha/mm)
Treatment			Treatment		
R2	1532 a[1/]	4.5 a	R2	402 a	1.2 a
R1	1191 a	3.7 a	R1	333 a	1.0 a
Native	617 a	1.7 a	Native	244 a	0.7 a
year			year		
1984	1277 a	4.5 a	1984	384 a	1.4 a
1983	1140 a	2.8 b	1983	369 a	0.9 b
1985	922 b	2.6 b	1985	226 a	0.6 b
trt*yr	NS	*[2/]		NS	NS

	Total Forage (grass+forb) Production (kg/ha)	Total Forage (grass+forb) Production/Water Used (kg/ha/mm)		Beef Production (kg/ha)	Beef Production/Water Used (kg/ha/mm)
Treatment			Treatment		
R2	1934 a	5.7 a	R2	80.1 a	0.23 a
R1	1523 a	4.7 a	R1	72.6 a	0.22 a
Native	861 b	2.4 b	Native	62.5 a	0.18 a
year			year		
1984	1662 a	5.9 a	1984	69.0 a	0.24 a
1983	1508 a	3.7 b	1983	76.3 a	0.19 a
1985	1148 b	3.2 b	1985	70.0 a	0.20 a
trt*yr	NS	*		NS	NS

1/ Within columns, means followed by the same letter are not different at $P \leq 0.05$ (Protected Waller-Duncan test, K=100).

2/ Treatment*year interaction significant at $P \leq 0.05$.

significant treatment*year interaction for grass and total forage production per unit of water used was found.

Season-long grass production during the three years of this study was positively related to the litter remaining at the end of grazing, the percent grass present in the current year's production, and the amount of precipitation received during the growing season of April through July each year (Table 6). Grass production was negatively related to the mean-maximum air temperatures during April through July of each year. These four factors explained 67% (P>F=.0039) of the grass production observed.

Season-long forb production was positively related to soil water recharge over the winter prior to each season, percent forbs present in the current year's production, and the amount of litter remaining after each grazing period. It was negatively related to the previous September plus October free-water pan evaporation (Table 6). These factors accounted for 69% (P>F=.0023) of the variation observed in forb production.

Season-long total forage production (grasses + forbs) was positively related to litter remaining at the end of each grazing period and precipitation received during each April through July growing season. Mean-maximum air temperature during the same period was negatively related to total forage produced. In all, these factors explained 59% (P>F=.0049) of the total forage production measured over the three years of this study (Table 6). Only season-long grass production was significantly related to beef production and accounted for 32% (P>F=.0148) of the variation in total beef gains observed (Table 6). The factors isolated and quantified by simple and multiple stepwise regression as significant to forage and beef production in kg/ha are prime candidates for management or modification.

Season-long grass, forb, total forage, and beef production per unit of water used were in each case positively related to the amount of each component of production and negatively related to the amount of free-water pan evaporation that was measured during the April through July growing season each year (Table 7). Since free-water pan evaporation was used instead of total water used, the R^2 values dropped from the expected 1.00 to .98, .96, .97, and .93 for the grass, forb, total forage, and beef production per unit of water used, respectively, during the 3 years of study.

Table 6. Multiple stepwise regression of season-long grass, forb, total forage, and beef production over three years.

	Yi = B0i + BiXi + ... +BnXn			R^2	P>F
Grass					
Y1 =	B01=42,218.30 (P>F=.0472)	B10=1.31	X10=litter	0.21	.0032
		B11=25.43	X11=% grass	0.18	.0242
		B15=-4168.02	X15=temperature	0.16	.0442
		B21=294.25	X21=precipitation	0.12	.0505
Total				0.67	.0039
Forb					
Y2 =	B02=1084.48 (P>F=.0597)	B9=1.82	X9=recharge	0.38	.0100
		B12=7.62	X12=% forbs	0.09	.0315
		B10=0.33	X10=litter	0.09	.0096
		B4=-8.47	X4=fall evaporation	0.14	.0291
Total				0.69	.0023
Total forage (grass+forb)					
Y3 =	B03=60,634.26 (P>F=.0246)	B10=1.77	X10=litter	0.24	.0017
		B15=-5714.04	X15=temperature	0.19	.0286
		B21=404.30	X21=precipitation	0.16	.0329
Total				0.59	.0049
Beef					
Y4 =	B04=53.92 (P>F=.0001)	B23=0.02	X23=grass	0.32	.0148
Total				0.32	.0148

Table 7. Multiple stepwise regression of season-long grass, forb, total forage, and beef production per unit of water used over three years.

Yi = B0i + BiXi + ... +BnXn				R^2	P>F
Grass					
Y5 =	B05=9.58 (P>F=.0001)	B23=.0031	X23=grass	0.87	.0001
		B13=-.0158	X13=growing season evaporation	0.11	.0001
Total				0.98	.0001
Forb					
Y6 =	B06=3.19 (P>F=.0001)	B24=.0028	X24=forb	0.83	.0001
		B13=-.0052	X13=growing season evaporation	0.13	.0001
Total				0.96	.0001
Total forage (grass+forb)					
Y7 =	B07=12.52 (P>F=.0001)	B25=.0031	X25=total forage	0.85	.0001
		B13=-.0208	X13=growing season evaporation	0.12	.0001
Total				0.97	.0001
Beef					
Y8 =	B08=0.56 (P>F=.0001)	B26=.0030	X26=beef	0.50	.0001
		B13=-.0009	X13=growing season evaporation	0.43	.0001
Total				0.93	.0001

Table 8. Environmental and site factors related to forage and beef production.

Season	Pptn. (mm)	Mean Max. Temp. (C)	Free Water Evap. (mm)	Soil Water Recharge (mm)	Grass (%)	Forb (%)	Litter (kg/ha)
Sep - Oct '82			187				
Oct '82 - Apr '83				111[1/]			
Apr - Jul '83	140	20.6	648				
Apr - Oct '83					75	25	1426
Sep - Oct '83			167				
Oct '83 - Apr '84				100			
Apr - Jul '84	127	19.6	566				
Apr - Oct '84					76	24	1028
Sep - Oct '84			172				
Oct '84 - Apr '85				29			
Apr - Jul '85	172	22.9	622				
Apr - Oct '85					78	22	1062

[1/] Increase in soil water from previous October through April starting date.

Discussion

Past differences in forage production among reclaimed pastures observed during a grazing intensity study (Hofmann and Ries 1988) had equalized over time when grazed at the same stocking rate. Both reclaimed pastures still produced equal or better total forage than the adjacent native pastures supporting earlier conclusions that reclamation for grazing or occasional hay was successful (Ries and Hofmann 1984).

In 1985, significantly less grass and total forage production occurred. Mean-maximum air temperatures and precipitation received during April through July of each year were isolated as significant environmental factors controlling this yearly production (Table 6). A review of the level of environmental and site factors for each year of the study (Table 8) shows why 1985 was low producing. The amount of litter at the end of grazing and % grass in the stand were nearly the same as the other 2 years studied. However, even though precipitation during April through July was highest in 1985, mean-maximum air temperatures during the April through July growing season were also the highest observed during the three years. Not enough precipitation was received to overcome the negative effect of the high mean-maximum air temperatures (Table 6).

Lower free-water evaporation the fall before and increased over winter recharge water resulted in increased forb production the next growing season (Table 6). This indicates that the forb production was more dependent on stored soil water and less on growing season precipitation than was grass production.

Both grass and total forage production were reduced by higher temperatures and increased by more precipitation during the growing season of April through July each year. Beef production was positively related to grass production. This indicates that beef production may be increased by increasing the grass produced during the growing season and grazing this grass later in the grazing season. These results strongly endorse the adage that a successful cattle rancher is first and foremost a grass farmer. Perhaps, the production of beef produced per unit of water used should be based only on the water used to produce the forage during the optimum growing season.

The amount of grass, forb, and total forage production per unit of water used was greatest during 1984. In the equations presented in Table 7, production and free-water evaporation are the factors explaining the production per unit of water used each year. Since production was the numerator, it is highly related with the ratio of grass, forb, total forage, and beef production per unit of water used calculated by the conventional WUE mathematical equation (Table 4). Total water used during the complete grazing season each year is positively and significantly related to free-water pan evaporation during the April through July growing season each year. Free-water evaporation is more readily measured than total water used and in this study provided a reliable estimate of total water used. The R^2s in Table 7 are not equal to 1.00 because free-water evaporation replaced the total water used. It is interesting to note that the decrease in R^2 was greater for beef than for forages. Free-water evaporation is reflective of the water demand for evapotranspiration (ET) and is used to estimate ET for scheduling irrigation (Hane and Pumphrey 1984). A review of the yearly level of the environmental factor of free-water evaporation (Table 8) during this study shows why 1984 was the best production per unit of water used year. During 1984, free-water evaporation was the lowest of any year of the study.

The significant treatment* year interaction shows that grass and total forage production per unit of water used decreased to a greater extent in the native pastures in 1985 than in the reclaimed pastures. Pastures under heavier grazing pressure appear to decrease to a greater extent in production per unit of water used in poor water use years (Ries and Hofmann 1985, Hofmann and Ries 1989). Beef production and production per unit of water used did not vary statistically over years and pastures. Animal production variation was high because only 2 animals of different genetic constitution were grazed in each pasture. However, this may also indicate that forage consumers are less sensitive to initial environmental and pasture conditions than the forage plants and that some initial buffering of beef production from environmental and pasture conditions may exist. Downward trends in pasture conditions caused by continued adverse environmental conditions and/or overgrazing would, over time, result in lower beef production.

Since only 32% of the variation in beef production was explained by independent variables used in this study, it appears that animal characteristics, such as age, weight when put on pastures, and other animal factors need to be considered to explain more of the beef production observed.

Even though no statistical significant differences in beef production were observed among pastures or years, this paper presents a comparison of production and production per unit of water used for both forage and beef not commonly found in the literature. Averaged over all years, reclaimed pastures produced 1728 kg/ha total forage with a corresponding 76.4 kg/ha of resultant beef production over the season-long period. This is a conversion factor of 1 kg/ha of live beef produced per 22.6 kg/ha of forage. On the native pastures, 861 kg/ha of total forage produced 62.5 kg/ha of beef for a conversion factor of 1 kg/ha of live beef produced per 13.8 kg/ha of forage.

Total forage production averaged over all pastures of 1508, 1662, and 1148 kg/ha produced 76.3, 69.0, and 70.0 kg/ha of live beef during 1983, 1984, and 1985, respectively. This provided a conversion factor of 1 kg/ha of live beef produced per 19.8, 24.1, and 16.4 kg/ha of forage, respectively.

Reclaimed pastures produced 5.2 kg/ha of forage per mm of water used averaged over the 3 years of study. Native pastures produced 2.4 kg/ha of forage per mm of water used during the same years. Averaged over all pastures, forage production per mm of water used was 3.7, 5.9, and 3.2 kg/ha during 1983, 1984, and 1985, respectively. During the same years, .19, .24, and .20 kg/ha of beef was produced per mm of water used.

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