An Alternative Method for Analyzing Forage/Livestock Systems

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Abstract

A mixed integer program solves for profit-maximizing forage and beef enterprises. Dry matter, total digestible nutrients, and crude protein characterize livestock nutritional needs and production of warm and cool season forages.

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The “Freedom to Farm” bill has enabled Oklahoma producers to consider use of traditional cropland for the production of alternative crops, including forage. In many areas, environmental conditions limit crop alternatives. Forage rather than grain might be more profitable. Cool season grasses such as fescue are increasingly being promoted as a component of a forage system to lower costs of beef production. Cool season forages are capable of providing nutrients at a lower cost than purchased supplements at times when warm season forages such as tall grass prairie, bluestem, and bermuda are not growing or are poor quality. The objective of this paper is to identify profit-maximizing enterprise combinations for alternative scenarios for a given resource base using a new framework for matching beef cows and stockers’ nutritional needs to forage production using crude protein (CP), dry matter (DM) and total digestible nutrients (TDN).

Data and Methods

Animal unit months (AUMs) have traditionally been used to define the carrying capacity of pasture. But, the quantity produced and quality of different forages vary significantly over a year. Forage data were collected from various experiment station reports authored by agronomists and animal scientists, from personal contacts with faculty in both departments, from Natural Resource Conservation Service (NRCS) files and contacts, and from Noble Foundation reports and scientists. Monthly averages of forage total digestible nutrients (TDN) and crude protein (CP) were estimated along with monthly dry matter (DM) production for wheat for forage, dual purpose wheat, bluestem, bermuda, fescue, and native pasture.

Livestock nutritional needs depend on the type, size and gender of the animal.

For breeding livestock, timing of peak needs depends on the breeding season for cows. National Research Council (NRC) equations were used to estimate beef cattle nutrient requirements, specifically TDN, CP, and DM, and bounds on livestock intake.

A mixed integer program was developed to determine the profit-maximizing use of the land resource (Smith). Initial acreage (cropland, improved pasture, native range) is specified by the user, but additional blocks of land may be rented. Rental rates are specified by type of land. Product price, operating costs (excluding cost of livestock nutrients) and operating capital are entered for each enterprise, as are labor requirements by month. Maximums on owner-supplied capital and borrowed capital are needed along with an interest rate. Available owner/operator hours are specified by month; a maximum number of hired labor hours per month can be entered.

A minimum number of acres of a specific forage type may be specified. Annual forage production levels are specified and used with monthly distributions developed from data collected. Harvest efficiencies as well as the percentage of dry matter retained in month-to-month transfers of unused forage may be specified by the user. Unused native pasture and bermuda can be baled and sold. Solutions allow cropland to be transferred to pasture.

Fall and spring calving cows and up to six stocker enterprises are included. For the cow/calf enterprise, average cow weight, body condition score, milk production, calf birth weight, month calves are born and sold, percent calf crop, percent kept for replacements, and weaning weights for steers and heifers must be specified. For each of six potential stocker activities, the user may specify the purchase date and weight, sale date, expected average daily gain, death loss, and shrink percentage. Livestock nutritional requirements may be met either through forage utilization or purchased supplements.

Base Case

For analysis purposes, a case study representing a typical ranch in northwest Oklahoma was developed. The ranch consists of 150 acres of cropland, 200 acres of improved pasture, and 650 acres of native range. In the base scenario, rental tracts were 150-acre blocks of cropland, improved pasture, and native range with rental rates of $30 per acre, $11 per acre, and $7 per acre respectively. Harvest efficiency for forage was assumed to be 45 percent for wheat, 35 percent for bermuda and fescue, 25 percent for bluestem, and 20 percent for native pasture. Month-to-month transfers were set at 75 percent, except for winter months for bermuda, bluestem, and native pasture where they were 60 or 65 percent, and in August when fescue was at 65 percent.

Cows were 1000 pounds with average body condition scores of 5, milking 11 pounds per day. Calf birth weight was 80 pounds. An 85 percent calf crop and 15 percent replacement heifer percentage was assumed. Spring calving cows weaned calves in November; fall calving cows weaned calves in July. All stocker enterprises had 2 percent death losses and 2 percent shrink.

All capital was borrowed at 10.5 percent interest; the maximum borrowing was set at $150,000. The owner/operator provided up to 200 hours of labor per month; labor was hired at $6.50 per hour up to 200 hours per month. Twenty percent range cubes could be purchased for 8 cents per pound; 38 percent range cubes could be purchased for 11 cents per pound. Other enterprise assumptions are listed in Table 1.

Results

For the base case, the profit-maximizing solution used 1,300 acres: 183 acres of cropland for wheat for grain plus forage and 117 acres of wheat for forage only (150 acres of owned and 150 acres of rented cropland), 350 acres of fescue on the improved pasture land (200 acres owned, 150 acres rented), and 650 acres of owned native pasture (Table 2). The livestock enterprises were 139 fall-calving cows plus 252 November-May stockers and 274 March to July stockers. To meet livestock nutritional needs, 40 tons of 20% cubes were purchased. The owner/operator supplied 1,717 hours of labor and hired an additional 102 hours of help. Borrowed capital reached its limit of $150,000. Net returns to land and management before tax was $34,247. The stocking rate seemed high, but otherwise the solution seemed reasonable in selection of enterprises and returns to the operation.

To test the sensitivity of the results to assumptions and robustness of the model, a variety of scenarios were developed. Minimum acreages of other improved forages (bermuda and bluestem) were specified to model an owner's preference for an existing forage type. Both wheat and fescue forage production were halved to test the limits at which other forages might be competitive. Harvest efficiencies were lowered dramatically across the board since the linear program assumes costless, perfectly efficient movement of livestock to consume forage produced. The minimum dry matter requirement for livestock was raised to determine whether use of the relatively low percent contributed to the seemingly high stocking rate. The capital constraint was eased to determine its impact on enterprises and net returns. The size of rental tracts was increased. Hay costs were halved, stocker and wheat prices were modified, and the spring-calving cow enterprise costs were dramatically lowered. Results are summarized in Table 2.

Compared to the base case, constraining the owned improved pasture land to either bluestem or bermuda lowered the net returns. In both cases, additional cropland and improved pasture (fescue) were rented. More wheat was used for forage and stocker numbers increased slightly. With bluestem, cow numbers decreased slightly and additional cubes were purchased; owner labor hours increased and hired labor hours decreased slightly. The bermuda solution was remarkably similarly to the base solution in enterprises selected with some additional owner labor hours, but significantly lower returns.

Halving the wheat forage produced by both the dual purpose wheat and wheat for forage only results in most cropland (207 acres) being harvested for grain with the remainder converted to improved pasture, specifically fescue. The cow herd size is reduced by approximately 1/3 of the base case. Overall, stocker numbers increase--the numbers of November-May stockers is roughly halved and March to July stockers increase by 80 percent. Fewer cubes are purchased, but more than 1/2 of the cubes purchased are 38% cubes. Net returns declined by 20 percent compared to the base.

If fescue forage production per acre is halved, some owned pasture land actually goes unused. Additional cropland is rented for wheat forage and all owned cropland is devoted to wheat for forage. Compared to the base case, the fall-calving cow herd is approximately half the size, November to May stocker numbers are similar, and March to

July stockers increase significantly. Owner labor hours decrease. Net returns are 26 percent lower than the base case.

If forage harvest efficiencies are reduced dramatically to 25% for wheat, 20% for bermuda and fescue, 15% for bluestem, 12.5% for native, net returns fall dramatically as well. More than 2/3 of the wheat is harvested for grain and the cow/calf enterprise shrinks to 41 cows, compared to 139 in the base case. Stocker numbers decrease, but only 13 percent, because of their profitability relative to the cow/calf enterprise. The borrowing maximum is not reached.

Increasing the minimum dry matter requirement for both cows and stockers to 2 percent of bodyweight leads to wheat being harvested for grain. Three tons of native hay is produced, cow numbers fall to a level similar to the reduced forage harvest efficiencies, and stocker numbers increase greatly, with a shift to primarily March to July stockers. Cube purchases decrease and hired labor increases relative to the base case. Net returns are 61 percent of the base case returns.

Easing the limit on borrowed capital primarily boosts the stocker enterprise and, consequently, wheat for forage production relative to dual-purpose wheat. November-May stockers increase by 50 percent and March-July stockers increase by 45 percent. Cube purchases increase by more than 50 percent as does hired labor.

Allowing rental of 300 acre tracts rather than 150 acre tracts shifts wheat to entirely dual use as 350 acres of fescue are available for use in livestock production. Cow numbers increase by 20 percent, November-May stockers increase by 27 percent, March-July stockers decrease to 79 head from 274 head. Net returns to management and land increase to $38,286, approximately 12 percent.

Halving the hay costs relative to the initial assumptions leads to rental of all available acreage, including native pasture from which 216 tons of native hay is produced for sale. Cow numbers decrease and stocker production shifts more to November-May stockers and away from March-July stockers.

Lowering the sale price of purchased stockers by $5 per hundredweight and increasing the sale price of raised stockers by $5 per hundredweight shifts livestock production to primarily a cow/calf operation. Native pasture is rented and all wheat is dual-purpose. No November-May stockers are used and only 53 March-July stockers are included.

A lower wheat price of $2 per bushel results in slightly fewer overall livestock numbers with relatively more November-May stockers. A higher wheat price of $3 per bushel leads to all wheat acreage being used for grain as well as forage. Here, March-July stocker numbers increase at the expense of cows and November-May stockers.

Assuming that the average daily gain is 2 pounds per day for all stocker enterprises causes a very small increase in cow numbers and a reduction by half of stocker numbers. Dramatically lowering costs of production and operating capital costs of spring-calving cows results in rental of native pasture, with both fall and spring-calving cows in the solution (relatively more spring-calving cows).

Summary and Conclusions

The enterprises in the solution did not vary with changes in assumptions about types of improved forage used, forage harvest efficiency, capital constraints, size of rental tracts, or changes in wheat price. The maximum on available capital was constraining in all scenarios except the low harvest efficiency scenario and most affected the size of the stocker enterprise. Easing the capital constraint and increasing the size of rental tracts increased net returns relative to the base case. Owner labor hours were not constraining in any of the scenarios studied.

Fescue, because of its bimodal growth pattern plus volume and quality of production, dominated improved pasture forage solutions despite its higher cost. In all scenarios, owned and rented pasture was fescue unless production is halved or acreage of other forage was forced into the solution. Some wheat was harvested as forage, except when expected annual wheat forage production was halved or the dry matter minimum on livestock consumption was raised. Wheat was harvested for grain only when wheat forage production was halved, harvest efficiency was dramatically lowered, or the dry matter intake requirement raised. Native pasture was used, but additional acres were rented only in the scenarios where hay costs were halved or spring-calving cow costs were greatly reduced. Bermudagrass and bluestem only came into the profit-maximizing solution when forced.

Discussion

The model unrealistically assumes intermingling of livestock and costless movement among forages. Additional forages are expected to be added as is internal hay use and modeling of forage use by calves not yet weaned off cows. Deficiencies in forage data forced reliance on expert opinion in many cases. Differences in methods for collecting data (both quantity and quality) by animal scientists and agronomists became apparent as the forage data base was being developed and discussed by the interdisciplinary project team.

Several ideas for additional research have been generated. Better documentation of monthly production of forage and changes in forage quality over time under different conditions (weather, precipitation, grazing management system) and for different soil types is needed. Likewise, more accurate measures of the ability of livestock to utilize available forages are needed. However, comparing the solutions using different assumptions and resource bases has been insightful thus far.

Table 1. Enterprise Assumptions

Enterprise	Operating costs ($/unit)	Operating capital ($/unit)	Production per Unit	Price
Wheat for grain	50	25	35 bu.	$2.50/bu.
Dual-purpose wheat	68	34	30 bu., 1000 lbs. forage	$2.50/bu.
Wheat for forage	60	30	6300 lbs. forage	
Bermudagrass	37	18.5	8,000 lbs. forage	
Fescue	52	26	7000 lbs. forage	
Bluestem	33	16.5	6,500 lbs. forage	
Native pasture	4	2	5,000 lbs. forage	
Bermuda hay	55	27.5		$60/ton
Native hay	25	12.5		$50/ton
Spring calving cows	77	139	525 lb. steers, 475 lb. heifers weaned	$90/cwt. $80/cwt.
Fall calving cows	79.5	159	630 lb. steers, 580 lb. heifers weaned	$85/cwt $78/cwt
Stocker 1 400 lbs. Oct.-Mar.	63	175.05	2 lb. average daily gain	Buy Oct. @ $100/cwt Sell Mar. @$85/cwt
Stocker 2 400 lbs. Nov.-May	69	245.42	2.2 lb. ADG	Buy Nov. @ $100/cwt Sell May @$80/cwt
Stocker 3 400 lbs. Mar.-July	69	166.12	2.2 lb. ADG	Buy Mar. @ $100/cwt Sell July @$85/cwt
Stocker 4 400 lbs. May-Aug.	63	136.78	2 lb. ADG	Buy May @ $100/cwt Sell Aug. @$80/cwt
Stocker 5 500 lbs. May-Aug.	63	148.98	2 lb. ADG	Buy May @ $100/cwt Sell Aug. @$75/cwt

Table 2. Profit Maximizing Solutions under Alternative Scenarios

	Base Case	200 a. of bluestem	200 a. of bermudagrass	Wheat forage halved	Fescue forage halved	Harvest efficiency halved	DM minimum increased	Borrowing max increased
Acres Used	1,300	1,300	1,300	1,300	1,027	1,300	1,300	1,300
Owned	1,000	1,000	1,000	1,000	877	1,000	1,000	1,000
Rented	300	300	300	300	150	300	300	300
Wheat - Grain				207		235	300	
Wheat - Dual	183	55	52			65		59
Wheat - Forage	117	245	248		300			241
Bermudagrass			200		77			
Fescue	350	150	150	443		350	350	350
Bluestem		200						
Native pasture	650	650	650	650	650	650	650	650
Cropland to pasture				93				
Production								
Hay (tons)							3	
Wheat (bu.)	5,496	1,639	1,549	7,234		10,175	10,500	1,771
Spring Calving Cows								
Fall Calving Cows	139	129	139	103	74	41	42	123
Stocker 2 (Nov.-May)	252	257	263	135	243	97	92	383
Stocker 3 (Mar.-July)	274	291	271	493	400	359	616	397
Purchases								
20% cubes (tons)	40	48	40	11	48	26	13	68
38% cubes (tons)		2	1	13		4		
Hired labor hours	102	87	86	140	103	13	168	332
Capital borrowed	150,000	150,000	150,000	150,000	150,000	108,316	150,000	200,000
Owner labor hours	1,717	1,733	1,762	1,638	1,584	1,363	1,610	1,831
Net Returns ($)	34,247	26,085	28,523	27,042	25,230	9,489	20,911	38,286

Table 2 (continued). Profit Maximizing Solutions under Alternative Scenarios

	300 acre rental blocks	Hay costs halved	Lower stocker sale price, higher raised calf sale price	Wheat = $2/bu.	Wheat = $3/bu	ADG on all stockers = 2 lb.	Spring cow w/much lower cost
Acres Used	1,600	1,450	1,450	1,300	1,300	1,300	1,450
Owned	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Rented	600	450	450	300	300	300	450
Wheat - Grain							
Wheat - Dual	450	190	300	175	300	300	165
Wheat - Forage		110		125			135
Bermudagrass							
Fescue	500	350	350	350	350	350	350
Bluestem							
Native pasture	650	800	800	650	650	650	800
Cropland to pasture							
Production							
Hay (tons)		216					
Wheat (bu.)	13,500	5,700	9,000	5,263	9,000	9,000	4,948
Spring calving cows							97
Fall calving cows	168	101	189	134	117	143	41
Stkr 2 (Nov.-May)	327	309	0	292	242	202	305
Stkr 3 (Mar.-July)	79	203	53	220	307	60	229
Purchases							
20% cubes (tons)	44	56	7	52	56	36	54
38% cubes (tons)	1				3		
Hired labor (hrs.)	121	75		86	99		121
Capital borrowed	150,000	150,000	63,837	150,000	150,000	102,950	150,000
Owner labor hours	1,833	1,621	1,249	1,695	1,683	1,415	1,718
Net Returns ($)	38,286	35,763	24,842	31,576	38,001	23,687	34,762

References

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