A DRY MATTER QUALITY APPROACH TO PLANNING FORAGE-BEEF SYSTEMS*

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Forage quality and quantity vary by species, time of year, level and time of fertilizer application and grazing system [6].[1] Livestock nutritional requirements change with age, rate of gain, weight, date of calving and percentage calf crop [7]. Pasture forage production and livestock forage requirements depicting both quality and quantity need to be compiled by calendar periods to determine optimal pasture programs and livestock systems.

Animal unit months (AUM) and total digestible nutrients (TDN) are the predominant measures of forage quantity produced and required.[2] Neither measurement adequately reflects quality and quantity in forage production and beef requirements throughout the production cycles. Therefore, optimal forage-beef systems obtained from planning models using AUM or TDN may in fact be infeasible or non-optimal. This paper explains development and use of a dry matter (DM) quality measurement concept for formulating forage-beef management programs in a linear programming (LP) framework [1].

Forage-beef systems obtained using the DM quality concept in an LP model showed a distinct complementarity between cow-calf and stocker steers based on their different forage requirements. A diversified organization of warm and cool season pastures and spring cow-calf, fall cow-calf and October to June stockers was obtained. The forage mix meets livestock quality and quantity requirements throughout the year. Results from models using AUM or TDN did not show these relationships [4, 5].

The authors benefited from work completed by cooperators in Southern Regional Project S-67, "Evaluation of the Beef Production Industry in the South." Most LP models in that study used net energy, digestible energy, metabolizable energy or total digestible nutrients, dry matter and digestible protein as measures of nutrient production and requirement. DM was used as a maximum constraint relating to stomach capacity and intake. When the forage is broken into two month or smaller calendar periods and allocated by animal class, a massive LP matrix results from the S-67 model.

The study presented here sought to simplify the model while retaining many desirable developments produced in S-67. One goal was to derive a tool suited to applications at the farmer level through cooperation of pasture, livestock and economic specialists. User understanding and acceptance are important. The model must be of manageable size and complexity. Most importantly, needed data must be readily accessible.

THE DM QUALITY APPROACH

Estimates are available for DM production by forages and requirements by livestock. Pounds of DM by quality, measured by megacalories (Mcal) of metabolizable energy per kilogram of DM (ME/kg) and calendar periods, were used to measure forage production and livestock nutritional needs. This concept of dry matter quality ties quality and quantity of forage together.

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[1] In this paper, the term 'forage' is used to include pasture and harvested feedstuff, excluding grains and concentrates.

[2] An animal unit month is defined as the amount of feedstuff required for an animal unit for one month. An animal unit is defined as $AU = W^{.75}/1000^{.75}$. However, many farm management specialists have used $AU = W/1000$.

The DM quality approach is not limited by experimental forage quality data. Experiments or experience with animal performances on specific forages can be used to classify those forages. These techniques, along with published data on ME/kg, were used to classify forages into three quality groups by five periods of the year.[3] The pasture DM quality groups are pasture DM 1.8 including Mcal of ME/kg in the 1.71 to 2.0 range, pasture DM 2.2 with ME/kg from 2.01 to 2.35, and pasture DM 2.6 with ME/kg from 2.36 to 2.80. Hay 2.2 and hay 1.8 are equivalent to pasture DM 2.2 and pasture DM 1.8, respectively.

Energy density requirements for beef cattle range from 1.71 to 2.0 Mcal of ME/kg for dry pregnant cows, from 2.01 to 2.35 ME/kg for lactating cows and steers gaining one pound per day or less and from 2.36 to 2.8 ME/kg for stocker steers gaining more than one pound per day [7]. In southcentral Oklahoma, pasture DM 2.6 includes small grain forages and clover pastures during rapid growth. Examples in the pasture DM 2.2 category are bermudagrass in spring and early summer and fescue with less than 200 pounds of nitrogen. Pasture DM 1.8 is produced by any warm season forage deferred for winter grazing.

A study centered on a livestock farm situation in southcentral Oklahoma was used to develop and evaluate use of the DM quality groups for beef-forage planning. In the remainder of the paper, the forage and cattle systems, the model and the results are described.

FORAGE

Monthly total DM production was derived by using forage yield data or converting experimental data on steer grazing grains to forage production. Agronomists and animal scientists reviewed production estimates and made judgemental adjustments. Total DM was then adjusted for grazing loss and divided into quality classifications; pasture DM 2.6, pasture DM 2.2, pasture DM 1.8 or hay by DM 2.2 or DM 1.8 (Table 1).

The quantities of pasture dry matter were the remainder of total dry matter after grazing losses of 15-50 percent and haying. Hay comprised approximately one-third of the total DM. Some pastures produced three quality classes during the course of the year. Interaction of fertilizer levels with quality and timing of pasture is illustrated in Table 1.

CATTLE

The nutrient and DM requirements for cattle were calculated on a monthly basis using a computer program developed by Dillard [3] and by using National Research Council and other experimental data. Fall and spring cow-calf activities were identified according to the feedstuffs combined to maintain the cow-calf unit during the winter period. For example, the unit can be wintered on pasture 2.2, hay 2.2 or hay 1.8 with a protein supplement.

DM requirements by quality and quantity through the production cycle are shown for cow-calf and steer activities in Table 2. Pastures are supplemented with digestible protein or energy when necessary. Three alternative cow-calf and steer systems are shown. It was assumed that October-May DM 2.2 steers gain .75 to 1.0 pounds per day and the steers on pasture DM 2.6 gain 1.5 to 2.0 pounds per day.

THE LP MODEL

The LP model is summarized in Table 3 by submatrices. Components of selected submatrices are explained in the footnotes. The forage rows include five pasture DM rows and eight hay rows. The pasture DM rows are divided into three forage quality groups for each of five time periods—March-April, May-June, July-August, September-October and November-February.

Fifty-two accounting rows are used to summarize resources produced or utilized within the model and to determine forages used by cow-calf and steer enterprises. These rows also summarize pasture DM yield by quality classification and production of DP in each time period.

There are 11 pasture varieties: midland bermuda, weeping lovegrass, tall fescue, native, improved native, bermuda-lovegrass, bermuda-fescue, bermuda-clover, fescue-clover, bermuda-vetch and bermuda overseeded with small grains. Cropland can be utilized by any of the improved pastures, small grain, or sorghum-sudan pasture. Several nitrogen levels are included with most pasture varieties.

Beef production activities consisted of five spring calving cow-calf activities, five fall calving cow-calf activities and seven stocker steer activities. They are distinguished by winter feeding and calving programs used and by selling weights.

Buy activities include inputs of nitrogen, phosphorus, potassium, protein supplement, hay,

[3] Data and experience might support more groups—say 4 or 5. However, models implying infinitely many groups such as the S-67 models probably have data requirements which exceed data obtainable.

TABLE 1. ESTIMATED MONTHLY DRY MATTER PRODUCTION BY QUALITY FOR SELECTED PASTURES IN SOUTH CENTRAL OKLAHOMA

Pasture	Nitrogen Level	Item	Unit	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
								Dry Matter							
Midland Bermuda Above Ave. Soil Rotation Grazing	200	Bermuda Hay	Ton	0.00	0.00	0.00	0.00	1.18	0.42	0.00	0.00	0.26	0.00	0.00	0.00
		Total DM	Cwt.	0.00	0.00	0.00	11.52	28.06	19.54	15.03	12.53	11.02	2.51	0.00	0.00
		Pasture DM 2.2	Cwt.	0.00	0.00	0.00	0.00	10.10	10.10	8.35	8.35	8.27	1.88	0.00	0.00
		Pasture DP	Cwt.	0.00	0.00	0.00	0.00	0.75	0.75	0.51	0.51	0.55	0.17	0.00	0.00
	100	Bermuda Hay	Ton	0.00	0.00	0.00	0.00	0.00	0.81	0.00	0.46	0.00	0.00	0.00	0.00
		Total DM	Cwt.	0.00	0.00	0.00	7.84	19.09	13.29	10.23	8.52	7.50	1.70	0.00	0.00
		Pasture DM 2.2	Cwt.	0.00	0.00	0.00	0.00	6.85	6.85	5.68	5.68	5.63	1.28	0.00	0.00
		Pasture DP	Cwt.	0.00	0.00	0.00	0.00	0.51	0.51	0.35	0.35	0.37	0.08	0.00	0.00
	50	Bermuda Hay	Ton	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.36	0.00	0.00	0.00	0.00
		Total DM	Cwt.	0.00	0.00	0.00	5.74	13.97	9.73	7.49	6.24	5.49	1.25	0.00	0.00
		Pasture DM 2.2	Cwt.	0.00	0.00	0.00	0.00	6.09	6.09	0.00	0.00	4.06	0.94	0.00	0.00
		Pasture DM 1.8	Cwt.	0.00	0.00	0.00	0.00	0.00	0.00	4.06	4.06	0.00	0.00	0.00	0.00
		Pasture DP	Cwt.	0.00	0.00	0.00	0.00	0.45	0.45	0.22	0.22	0.25	0.06	0.00	0.00
Weeping Lovegrass Average Soil Rotation Grazing	200	W. Love Hay	Ton	0.00	0.00	0.00	0.00	0.00	0.97	0.00	0.41	0.00	0.00	0.00	0.00
		Total DM	Cwt.	0.00	0.00	0.00	11.04	16.79	16.79	12.99	11.75	10.51	8.39	0.00	0.00
		Pasture DM 2.6	Cwt.	0.00	0.00	0.00	7.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Pasture DM 2.2	Cwt.	0.00	0.00	0.00	0.00	7.15	7.15	7.15	7.15	0.00	0.00	0.00	0.00
		Pasture DM 1.8	Cwt.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.08	0.00
		Pasture DP	Cwt.	0.00	0.00	0.00	0.75	0.54	0.54	0.44	0.44	0.00	0.00	0.18	0.00
	100	W. Love Hay	Ton	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.39	0.00	0.00	0.00	0.00
		Total DM	Cwt.	0.00	0.00	0.00	9.21	14.00	14.00	10.84	9.80	8.77	7.00	0.00	0.00
		Pasture DM 2.6	Cwt.	0.00	0.00	0.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Pasture DM 2.2	Cwt.	0.00	0.00	0.00	0.00	6.00	6.00	6.00	6.00	0.00	0.00	0.00	0.00
		Pasture DM 1.8	Cwt.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.00	0.00
		Pasture DP	Cwt.	0.00	0.00	0.00	0.63	0.40	0.40	0.37	0.37	0.00	0.00	0.13	0.00
	50	W. Love Hay	Ton	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00	0.27	0.00	0.00	0.00
		Total DM	Cwt.	0.00	0.00	0.00	6.23	9.46	9.46	7.32	6.63	5.93	4.73	0.00	0.00
		Pasture DM 2.6	Cwt.	0.00	0.00	0.00	4.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Pasture DM 2.2	Cwt.	0.00	0.00	0.00	0.00	4.04	4.04	0.00	0.00	0.00	0.00	0.00	0.00
		Pasture DM 1.8	Cwt.	0.00	0.00	0.00	0.00	0.00	0.00	4.04	4.04	0.00	0.00	8.00	0.00
		Forage DP	Cwt.	0.00	0.00	0.00	0.36	0.36	0.23	0.23	0.23	0.00	0.00	0.09	0.00

stocker steers and hired labor. Sell activities include wheat, soybeans, grain sorghum, stocker steers, cull cows and steers and heifer calves. Base prices for cattle are approximate 1965-75 average prices, seasonally adjusted [2]. Base prices for crops are 1972-75 average prices. Input prices approximate 1975 levels.

OPTIMAL LIVESTOCK FARM ORGANIZATIONS—AN EXAMPLE

The optimal organization for a 700-acre livestock farm in southcentral Oklahoma was derived with base assumptions concerning prices and available resources. Livestock activities consist of 62 spring cow-calf units wintered on pasture DM 2.2, 11 fall cow calf units wintered on pasture DM 2.2, 55 cow-calf units wintered on hay 2.2, 15 fall cow-calf units wintered on pasture DM 1.8 supplemented with pasture DM 2.6, and 124 head of October to June stocker steers on pasture DM 2.6.

Production and distribution of pasture forage is summarized in Table 4. Spring cow-calf and a small group of fall cow-calf units utilized the pasture DM 2.2 produced by the fescue pasture. Pasture DM 2.6 produced by the fescue-clover and bermuda-wheat for grain activities were allocated to stocker steers. A small proportion was limit grazed (grazing alternated between high and poor quality forages) by the fall cow-calf units as a protein and energy supplement combined with pasture DM 1.8.

An excess of pasture DM 1.8 in the July-August and September-October time periods and hay 1.8 suggests a need for activities which use low quality

TABLE 2. ESTIMATED MONTHLY DRY MATTER REQUIREMENTS BY QUALITY FOR SELECTED CATTLE ACTIVITIES

Activity	Item	Unit	Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Fall Cow-Calf							Dry Matter							
Pasture DM 2.2	Pasture DM 2.2	Cwt.	7.26	6.74	8.71	9.53	10.22	10.24	0.00	0.00	0.00	7.00	6.63	8.23
	Pasture DM 1.8	Cwt.	0.00	0.00	0.00	0.00	0.00	0.00	5.72	5.79	5.68	0.00	0.00	0.00
	Hay 2.2	Ton	0.07	0.08	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	DP Required	Cwt.	0.52	0.50	0.57	0.58	0.65	0.64	0.20	0.20	0.20	0.34	0.32	0.50
Hay 2.2	Pasture DM 2.2	Cwt.	0.00	0.00	0.00	4.77	10.22	10.24	0.00	0.00	0.00	3.50	0.00	0.00
	Pasture DM 1.8	Cwt.	0.00	0.00	0.00	0.00	0.00	0.00	5.72	5.79	5.68	0.00	0.00	0.00
	Hay 2.2	Ton	0.44	0.43	0.50	0.25	0.00	0.00	0.00	0.00	0.00	0.18	0.35	0.43
	DP Required	Cwt.	0.52	0.50	0.57	0.58	0.65	0.64	0.20	0.20	0.20	0.34	0.32	0.50
Hay 1.8	Pasture DM 2.2	Cwt.	0.00	0.00	0.00	4.77	10.22	10.24	0.00	0.00	0.00	3.50	0.00	0.00
Protein Supplement	Pasture DM 1.8	Cwt.	0.00	0.00	0.00	0.00	0.00	0.00	5.72	5.79	5.68	0.00	0.00	0.00
	Hay 1.8	Ton	0.40	0.39	0.45	0.22	0.00	0.00	0.00	0.00	0.00	0.16	0.33	0.39
	41-45% Pro Sup[a]	Cwt.	1.27	1.24	1.42	0.71	0.00	0.00	0.00	0.00	0.00	0.38	0.75	1.24
	DP Required	Cwt.	0.52	0.50	0.57	0.58	0.65	0.64	0.20	0.20	0.20	0.34	0.32	0.50
Stocker Steers														
Oct.-Feb.	Pasture DM 2.6	Cwt.	3.85	3.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.12	3.53
Pasture DM 2.6	Hay 1.8	Ton	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00
	41-45% Pro Sup[a]	Cwt.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00
	DP Required	Cwt.	0.34	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.29	0.32
Oct.-May	Pasture DM 2.6	Cwt.	3.85	3.75	4.73	4.90	5.39	2.77	0.00	0.00	0.00	0.00	3.12	3.53
Pasture DM 2.6	Hay 1.8	Ton	0.04	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00
	41-45% Pro Sup[a]	Cwt.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00
	DP Required	Cwt.	0.34	0.32	0.46	0.47	0.52	0.27	0.00	0.00	0.00	0.17	0.28	0.31
Oct.-May	Pasture DM 2.2	Cwt.	3.27	3.06	4.25	4.19	4.65	0.00	0.00	0.00	0.00	2.42	2.94	3.15
Pasture DM 2.2	Hay 1.8	Ton	0.03	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	DP Required	Cwt.	0.24	0.23	0.35	0.36	0.39	0.00	0.00	0.00	0.00	0.22	0.22	0.24

[a]Units in this row are cwt. of cotton seed cake or soybean cake as fed rather than dry matter.

forage or need for a way to produce a higher quality forage. All hay 2.2 produced was utilized by the fall cow-calf activity.

MODEL EVALUATION

The organization obtained shows a distinct complementarity between cow-calf and stocker steers based on their different forage quality requirements. Use of the AUM concept in traditional LP models in the same farming area has favored stockers, usually to the exclusion of cow-calf activities in the solution. Thus, attention to forage quality made an important difference in the solution.

The forage mix in Table 4 was clearly designed to meet forage quality needs across the year. The mixture includes warm and cool season forages. The quality of hay harvested was important. Low quality hay was in excess and high quality hay was completely utilized. Previous LP studies in the same area using only the AUM measure tended to suggest fewer forages, mostly bermuda fertilized at low levels and wheat pasture. The quality measure was effective in changing the organization to include higher quality sources of forage.

The model can analyze a wide range of livestock farm questions. Effects of changes in fertilizer or other prices from year to year can be evaluated. Sensitivity of pasture and livestock programs to forage production or animal rates or gain can be studied. Accounting equations can be used to develop detailed plans for feeding different classes of cattle. Most importantly, animal nutrient needs can be closely matched to forage production, and vice versa, by using the DM quality concept. At the same time, a readily available and easily understood measure of livestock forage requirements and forage production by quality is used.

TABLE 3. COMPONENT SUBMATRICES OF THE LIVESTOCK FARM MODEL

	Hired Labor	Borrow Capital	Pasture Production	Crop Production	Beef Production	Transfer	Buy	Sell	RHS
Net Revenue	$-NR^a$	$-NR^a$	$-NR^a$	$-NR^a$	$-NR^a$		$-NR^a$	NR^b	
Labor	$-A^c$		A^c	A^c	A^c				H^d
Soils			B^e	B^e					I^f
Capital	C^g	$-C^g$	C^g	C^g	C^g				
Forage			$-D^h$	$-D^h$	D^h	$\pm D^h$			
Variable Inputs			$\pm E^i$	$\pm E^i$	$\pm E^i$	$\pm E^i$	$-E^i$		
Sale				$-F^j$	$-F^j$			F^j	
Accounting			G^k	G^k	G^k				

[a]These submatrices contain costs other than for land, operator labor, risk, management, fixed machinery and fixed equipment.

[b]This submatrix shows net return to the entire firm unit for the sale of one unit of the product.

[c]These submatrices include coefficients of the labor required for each activity.

[d]This submatrix contains hours of operator labor assigned to each time period.

[e]This submatrix shows soil requirements for each crop.

[f]This submatrix is the soil resource situation and amount of each soil group.

[g]These submatrices show capital requirements of the respective activities and include coefficients for borrowing capital.

[h]These submatrices include forage production by pastures and crops and the forage required by the beef activities.

[i]These submatrices allow the purchase of variable inputs for pasture, crop and beef activity utilization.

[j]These submatrices of coefficients enable selling of beef and crop production.

[k]These submatrices provide an accounting of machinery use, forage and pasture forage production and livestock forage requirements in pounds of DM and pounds of DP.

TABLE 4. OPTIMAL ENTERPRISE ORGANIZATION AND FORAGE PRODUCTION AND UTILIZATION FOR A SOUTH CENTRAL OKLAHOMA LIVESTOCK FARM

Pasture - Crop Plan					
Love Grass 37 Ac.	Bermuda-Clover	64 Ac.	Bermuda	44 Ac.	Native 60 Ac.
Bermuda-Love 4 Ac.	Bermuda-Wheat for Grain	237 Ac.	Fescue-Clover	95 Ac.	Grain Sorghum 115 Ac.

Total Pasture (cwt. DM)	Period Mar.-Apr.	May-June	July-Aug.	Sept.-Oct.	Nov.-Feb.	Total
DM 2.6	1262	1012			1897	4171
DM 2.2	23	2636	1104	927	1820	6510
DM 1.8			1704	1214	1775	4693
Total Hay (cwt. DM)						
DM 2.2						2900
DM 1.8						10600

Livestock Plan			
Spring Cow Calf 62 hd.	Fall Cow Calf 81 hd.		Nov.-May Steers 124 hd.

Total Pasture Needed (cwt. DM)		Period Mar.-Apr.	May-June	July-Aug.	Sept.-Oct.	Nov.-Feb.	Total
Cows:	DM 2.6	68				130	198
	DM 2.2	23	2635	1104	927	1820	6510
	DM 1.8			921	794	1775	3490
Steers:	DM 2.6	1194	1012			1767	3973
Total Hay Needed (cwt. DM)							
Cows:	DM 2.2	840			200	1860	2900
	DM 1.8	40				180	220
Steers:	DM 1.8	60			280	60	400
Excess Pasture (cwt. DM)							
	DM 1.8			783	420		1203
Excess Hay (cwt. DM)							
	DM 1.8						9840

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