MANAGEMENT OF INTENSIVE FORAGE-BEEF PRODUCTION UNDER YIELD UNCERTAINTY

C. Arden Pope, III, and C. Richard Shumway

Abstract

Forage production variability is incorporated into a decision theory framework for a beef producer in East Texas. The results suggest that the least risky, and also the most profitable, approach to intensive forage beef production is to plan for relatively poor weather conditions and low forage production. This results in a more diverse forage system and a smaller herd size than would be found optimal under the assumption of constant average forage production. These results also demonstrate that the assumption of constant average forage production may result in grossly exaggerated estimates of expected net returns.

Key words: production uncertainty, decision theory, beef, forage.

Both seasonal and year-to-year variability in tame forage production can be tremendous in the South as it can in other predominantly dryland production areas and for other commodities. Such variability can have tremendous impacts on net returns to intensive forage-beef producers.

Although high production uncertainty is evident in tame forage production, little attention has been given to the effects of such uncertainty on management decisions. Most farm management and technological adoption studies have developed recommendations based on expected or average conditions. Yet, several writers (e.g., Pope; Gardner and Chavas) have recently documented by theoretical arguments that management strategies based on average but variable conditions may not achieve a desired behavioral objective, even for a risk-neutral producer.

The objectives of this paper are to (a) examine empirically the extent of such errors for simulated cow-calf producers in East Texas when forage yield variability is ignored and (b) determine the impact of alternative behavioral objectives on the optimal management strategy. This is accomplished by incorporating seasonal and annual forage yield variability into a linear programming (LP) decision theory framework and using information readily available to local producers.

METHODOLOGY

Many procedures have been used to analyze the economics of production uncertainty. They include such procedures as formal simulations (Richardson and Condra), risk-variance quadratic programming (Freund), MOTAD (Hazell), Target MOTAD (Tauer), stochastic dominance (Hadar and Russell), systematically changing production parameters in an LP model (Pope et al.) and Bayesian and non-Bayesian decision theory (Degroot; Eidman et al.).

The decision theory framework for this study is based on the assumption that five general alternative weather conditions and corresponding forage production patterns (states of nature) can occur. The producer has many management alternatives. Because it is uncertain which state of nature will occur, information relating to the returns or payoffs that will result from possible combinations of management alternatives and states of nature is needed. This information is described as the payoff matrix.

Although many management alternatives are possible, five are assumed to be most relevant for this study. They are the alternatives that maximize net returns for each of the five respective states of nature. An LP model that maximizes before-tax net returns to land and management is constructed and used to: (a) find the management plan that maximizes expected net returns for each state of nature and (b) calculate the values within the payoff matrix when states of nature actually occur other than the one for which the selected management plan was optimal. This payoff matrix is subsequently used to determine the preferred management plan under alternative decision criteria.

A six-season (bimonthly) LP model is constructed for an intensified forage-beef producer in East Texas. Costs, "normal" prices, and re-

C. Arden Pope, III is an Assistant Professor in the Agricultural Economics Department, Brigham Young University, and C. Richard Shumway is a Professor, Department of Agricultural Economics, Texas A & M University.

Texas Agricultural Experiment Station Technical Article No. 19651.

turns are calculated in 1979 dollars.[1] The producer has 250 acres of open land suitable for tame pasture, a typical farm size in this area (Albrecht and Ladewig). The producer desires to maintain a cow-calf operation and must determine the herd size and forage system to be used. By planning for a longterm operation, inputs such as labor and capital are considered variable. Only land area is held fixed.

Not all possible production practices are examined in this study. The activities considered closely reflect commercially-implementable practices and performance achieved in forage and beef production experiments conducted at the Texas A & M University Agricultural Research and Extension Center at Overton (Rouquette and Florence). Results of the current study fall within the range of actually achieved physical performance in experiments.

The breeding herd consists of Hereford-Brahman cows maintained through rotational crossing. The calving season centers on October 1. Calves are weaned on July 1, with steers and heifers weighing an average of 675 and 620 pounds, respectively. Calves in excess of replacement requirements are either sold at weaning or after stocking them on pasture for 11 months, with supplementation in the winter as needed. The average weight of the grass-fat steers and heifers after being stocked for 11 months equals 1,069 and 976 pounds, respectively (Saez et al.).

With good management, seasonal conception rates average 80 percent for replacement heifers and 95 percent for cows. A replacement heifer has a 5 percent chance that her calf will die at birth and another 5 percent chance that it will die before being weaned. The corresponding probabilities for a cow are each 1 percent. A 1 percent annual death loss of the breeding herd, 0.5 percent death loss of replacement heifers prior to breeding, and 1 percent death loss of the stockers are assumed. Cows are culled at 12 years of age or when they fail to conceive. This results in a 16.4 percent annual replacement rate. One bull is required per 25 cows and replacement heifers.

Animal nutrient requirements are based on NRC standards (National Academy of Science) for growth, maintenance, and pregnancy, and on requirements summarized by Maddox for milk production and travel. Within the LP model, the year is divided into 2-month periods. Feed consumed in each period is constrained to satisfy both energy and protein nutritive requirements for the modeled performance levels without exceeding voluntary intake capacity (Conrad et al.). Thus, supplementation is required in some periods to attain the necessary ration quality (i.e., energy and protein content of dry matter).

The forage alternatives included in the model consist of the most typical improved pastures used in the area. They include warm-season perennials such as bahiagrass, lovegrass, Coastal and common bermudagrass planted alone or in association with winter annuals like rye, ryegrass, crimson clover and arrowleaf clover, and prepared seedbed production of rye-ryegrass. In any period the forage can be grazed or put up as hay and fed in another period. Hay can be purchased or sold. Hay fed is supplemented with grain sorghum in order to meet minimum feed quality requirements (Conrad et al.).

Yield and quality data for each forage are extrapolated from experiments conducted at the Texas A & M University Agricultural Research and Extension Center at Overton, Texas (McCartor and Rouquette). The forage dry matter yield data were collected for 4 years (1970-1973) using the cage-difference technique (Lineban). The five levels of forage production or states of nature correspond with the levels measured in the years 1970-1973 and the average of those years. These levels are currently commercially attainable in the area.

Because of trampling and refusal, only 70 percent of the total forage dry matter is utilized when the pasture is grazed. Only 60 percent of the total forage dry matter is utilized when the forage is harvested and fed as hay (Saez et al.).

Effective bimonthly dry matter yields under grazing conditions are reported along with total production costs for each of the nine forage options considered in Table 1.[2] Bimonthly energy requirements, receipts, and non-forage production costs for the cow-calf and cow-feeder units are reported in Table 2. Energy content of the grazed forages varies from 0.79 to 1.61 Mcal. digestible energy per pound of dry matter, and crude protein content varies from 8.3 to 25.0 percent, depending on the forage and production season. (See Saez et al. for forage quality data and quality requirements of the animals.)

Average annual rainfall from 1950 to 1980 in this area equaled 44.72 inches with a low of 27.42 inches and a high of 66.16 inches

[1]A 21-year series of monthly prices for relevant livestock categories at the Fort Worth livestock market was inflated to 1979 by the index of prices paid for factors of production (USDA, 1967, 1978, 1979). Finding no significant trend, the simple averages of these inflated prices for livestock categories are used as estimates of 1979 "normal" monthly prices; i.e., what would have been expected had 1979 been the midpoint of the cattle price cycle. Normal 1979 prices per cwt. in the month of sale were: $62 for weaned steer calves, $56 for weaned heifer calves, $59 for grass-fat steers, $55 for grass-fat heifers, and $38 for cull cows.

[2]Details of enterprise costs are available from the authors on request.

TABLE 1. ESTIMATED FORAGE DRY MATTER YIELDS AND 1979 PRODUCTION COSTS, OVERTON, TEXAS[a]

Period	Year	Forage[b]								
		CLB	CLBCR	CLBAR	CLBRR	CBCR	CBAR	LOVE	BAHIA	RR
		pounds per acre								
Dry-matter yields										
Jan. - Feb.	1970	0	0	0	737	0	0	0	0	0
	1971	0	1,698	0	152	1,698	0	0	0	414
	1972	0	280	0	520	280	0	0	0	735
	1973	0	1,056	0	783	1,056	0	0	0	1,133
Mar. - Apr.	1970	1,545	3,138	1,252	2,465	3,138	1,252	2,724	1,325	0
	1971	1,186	2,962	3,186	713	2,962	3,186	2,039	452	1,103
	1972	1,297	1,837	2,098	1,743	1,837	2,098	4,381	520	1,948
	1973	957	3,172	3,716	2,903	3,172	3,716	2,619	625	3,647
May - June	1970	4,783	3,510	3,139	3,828	1,882	2,616	2,269	2,454	0
	1971	6,824	4,532	3,451	6,824	1,899	2,876	2,981	2,283	0
	1972	5,789	4,154	3,504	5,789	2,122	2,920	3,985	2,257	358
	1973	6,221	4,559	3,953	6,221	2,437	3,294	3,982	3,954	0
July - Aug.	1970	5,061	5,061	5,061	4,403	2,235	3,191	1,903	2,524	0
	1971	6,782	6,782	6,782	6,782	3,456	3,456	4,413	2,710	0
	1972	6,115	6,115	6,115	6,115	3,476	3,476	2,877	5,770	0
	1973	7,431	7,431	7,431	7,431	4,593	4,593	2,244	5,686	0
Sept. - Oct.	1970	2,006	2,006	2,006	2,613	1,721	1,401	2,128	1,305	0
	1971	5,286	5,286	5,286	5,286	1,429	1,429	1,678	1,348	0
	1972	2,782	2,782	2,782	2,782	1,910	1,909	2,254	2,110	0
	1973	2,364	2,364	2,364	2,364	2,074	2,074	3,182	4,439	0
Nov. - Dec.	1970	0	0	0	746	0	0	25	0	0
	1971	329	196	196	572	196	196	550	29	591
	1972	309	386	386	472	386	386	282	231	257
	1973	0	0	0	452	0	0	475	0	1,210
Annual total	1970	13,395	13,715	11,458	14,792	8,976	8,460	9,049	7,608	0
	1971	20,407	21,456	18,901	20,329	11,640	11,143	11,661	6,822	2,108
	1972	16,292	15,554	14,885	17,421	10,011	10,789	13,779	10,888	3,298
	1973	16,973	18,582	17,464	20,154	13,332	13,677	12,502	14,704	5,990
Average		16,767	17,327	15,677	18,174	10,990	11,017	11,748	10,006	2,849
		dollars per acre								
Total annual cost per acre	1979	119.62	157.57	158.10	204.52	148.98	149.51	129.94	130.32	128.66

[a]Dry matter yields reported are the estimated consumable quantities under grazing (i.e., 70 percent of experimental clipping yields).
[b]Forage codes: CLB is Coastal bermudagrass, CLBCR is Coastal bermudagrass overseeded with crimson clover and ryegrass, CLBAR is Coastal bermudagrass overseeded with arrowleaf clover and ryegrass, CLBRR is Coastal bermudagrass overseeded with rye-ryegrass, CBCR is common bermudagrass overseeded with crimson clover and ryegrass, CBAR is common bermudagrass overseeded with arrowleaf clover and ryegrass, LOVE is lovegrass, BAHIA is bahiagrass, RR is rye-ryegrass.

(National Climatic Data Center). The forage yield data utilized in this study were obtained in the years 1970-1973. During this period, average annual rainfall equaled 44.48 inches with a low of 29.16 inches and a high of 64.79 inches. While the distribution of rainfall throughout the year and other weather conditions affect forage production, these 4 years seem fairly representative of the range of weather conditions that might occur.

For each anticipated state of nature (i.e., set of forage production patterns), an optimal management plan governing forage system, stocking rate, hay transactions, and calf marketing approach is determined by LP. Once the management plan is selected, the cow herd size and forage system are held constant as the producer responds to alternative actual states of nature. That is, the objective function is maximized independently for each year and for mean yields, and simulations are conducted for other states of nature.

Due to the largely random nature of weather patterns, herd size and forage system are not often varied in anticipation of changing weather conditions. Further, Bentley and Shumway found that current precision in forecasting the cattle cycle is too low to permit much gain by altering the cow herd size in anticipation of a directional change in prices. Thus, producers are left largely with two kinds of choices when responding in the short-run to alternative actual states of nature: (a) alter the timing of calf sales and/or (b) modify planned hay transactions. Consistent with common practice in the area, hay may be bought or sold and/or calves marketed when weaned or after a stocker phase if forage production is less than or exceeds that required to maintain the selected cow herd. Consequently, these are the options considered in computing

TABLE 2. ANIMAL ENERGY REQUIREMENTS, "NORMAL" 1979 RECEIPTS, NON-FEED COSTS, AND NET RETURNS, COW-CALF AND COW-FEEDER OPERATIONS, OVERTON, TEXAS

Item	Livestock category[a] Cow-calf unit	Cow-feeder unit
	(Mcal per unit)	
Digestible energy required:		
January-February	2,233	3,183
March-April	2,569	3,657
May-June	2,686	3,243
July-August	1,412	2,084
September-October	1,626	2,504
November-December	2,060	2,978
Annual total	12,586	17,649
	(dollars per unit)	
Gross receipts	369	525
Non-feed costs[b]	345	191
Returns net of feed costs	245	334

[a]Following calving, the cow-calf unit consists of 1 cow, 0.985 calf, 0.164 replacement heifer, and 0.047 bull. Receipts are based on the sale of 0.033 open heifer, 0.046 open cow, and either 0.805 calf or 0.797 feeder. Progeny sales are 60.2 percent steers and 39.8 percent heifers.

[b]Non-feed costs were adapted from Texas Agricultural Extension Service livestock budgets for East Texas to account for production practices employed in the experiments.

the remainder of the payoff matrix.[3] Since, for any management plan, herd size is not altered in response to the various states of nature, major financial considerations are not posed by the strategies.

Excess hay is sold when harvested for $48 per ton (Texas Department of Agriculture, 1979). Custom hay harvesting and hauling from the field cost $35 per ton (Texas Agricultural Extension Service; Texas Department of Agriculture, 1981). When forage production is insufficient, hay is purchased during the winter months for $63 per ton plus $19 per ton for hauling (Texas Department of Agriculture, 1979, 1981).

Monthly calf prices at the nearest commercial livestock market, Fort Worth, show little correlation with the experimental forage yields for the corresponding years. Consequently, to focus attention more clearly on the adequacy (or inadequacy) of management strategies based on assumed average weather and production conditions, price and financial uncertainties are ignored. Only those uncertainties associated with seasonal (bimonthly) forage yield variability across years are accounted for in the analysis.

RESULTS AND DISCUSSION

The LP model is first used to determine the management plan that maximizes net returns under each anticipated state of nature, Table 3. These net returns would occur if the corresponding state of nature actually was encountered. Two of the forage options (Coastal bermudagrass (CLB) and Coastal bermudagrass overseeded with crimson clover and ryegrass (CLBCR) dominate the other seven in all management plans. Only in plan 1 are both forages included. All hay requirements are produced on the farm. All calves are sold when weaned. Depending on the forage production levels, the cow herd ranges in size from 338 to 502 cows. Pre-tax net returns range from $7,240 to $38,509. If variability associated with forage production is ignored and average forage production is assumed, the management plan that maximizes pre-tax net returns is plan 3, and calculated net returns equal $20,785.

TABLE 3. LP PROFIT-MAXIMIZING ACTIVITIES FOR EACH STATE OF NATURE IN FORAGE PRODUCTION, OVERTON, TEXAS

Item	Unit	Management plans for anticipated states of nature 1 (1970)	2 (1972)	3[a] (Av.)	4 (1973)	5 (1971)
Net returns to land and management	Dollars/yr.	7,240	7,420	20,785	26,765	38,509
Cow herd size[b]	Number	338	400	433	457	502
Weaned calves sold	No./yr.	272	322	348	368	404
Feeder calves sold	No./yr.	0	0	0	0	0
Forage production[c]:						
CLB	acres	122	250	0	0	0
CLBCR	acres	128	0	250	250	250
Hay:						
Produced	tons/yr.	485	737	538	592	710
Sold	tons/yr.	0	0	0	0	166
Bought	tons/yr.	0	0	0	0	0

[a]Management plan for "4-year" means of bimonthly forage yields.

[b]Number of cows that bear a calf (i.e., 93 percent of cows and heifers exposed to bull).

[c]CLB is Coastal bermudagrass and CLBCR is Coastal bermudagrass overseeded with crimson clover and ryegrass.

For each selected management plan, any of the five states of nature could actually occur. In order to construct the complete payoff matrix, the cow herd size and forage system are constrained to reflect each of the five management plans. The LP model is then executed for each management plan with each of the five states of nature (i.e., level of forage production). The number of stockers fed, amount of hay purchased, and amount of hay produced to be sold are reported in Table 4. In general, when weather is better than anticipated, more hay is produced to sell; when weather is worse than anticipated, more hay must be purchased. Although stockers were often a very close economic alternative to selling excess forage as hay, stockers never were part of an optimal solution.[4]

The resulting net returns that correspond with the 25 possible combinations of management

[3]Hay may also be stored in high yielding years for consumption in low yielding years. Previous analyses of this area (e.g., Saez et al.), however, concluded that little, if any, increase in profit can be expected by interyear storage of hay over the buy/sell option permitted here. Little silage is produced in the region so that option is also omitted.

[4]In some cases, however, net returns would have been reduced as little as $4.00 per stocker carried.

TABLE 4. STOCKERS FED, AND HAY BOUGHT AND SOLD UNDER THE 25 COMBINATIONS OF MANAGEMENT PLANS AND STATES OF NATURE, OVERTON, TEXAS

Management plan	State of nature	Stockers fed	Hay bought	Hay sold
1	1	0	0	0
1	2	0	0	240
1	3	0	0	391
1	4	0	0	482
1	5	0	0	838
2	1	0	307	0
2	2	0	0	0
2	3	0	0	58
2	4	0	0	81
2	5	0	0	464
3	1	0	390	0
3	2	0	241	0
3	3	0	0	0
3	4	0	0	57
3	5	0	0	485
4	1	0	498	0
4	2	0	352	0
4	3	0	112	0
4	4	0	0	50
4	5	0	0	374
5	1	0	692	0
5	2	0	692	0
5	3	0	312	0
5	4	0	153	0
5	5	0	0	166

plans and states of nature are reported in the payoff matrix presented in Table 5. Based on the payoff matrix, criteria that incorporate some of the uncertainty associated with annual variations in forage production can be used to select the preferred management plan. For a discussion of various decision criteria, see Agrawal and Heady (pp. 135-156) or Hey (pp. 38-45).

If the "maximin" criterion is used, only the lowest possible net returns for each of the management plans are considered and the plan that has the highest of the lowest possible net returns is selected. As can be seen in Table 5, management plan 1 would be chosen under this criterion because the worst possible outcome under this plan would be a net return of $5,720. Under this criterion, the producer demonstrates pessimistic behavior and in essence plans for relatively poor weather conditions and low levels of forage production.

If the "maximax" criterion is used, only the highest net returns for each of the management plans are considered. Under this criterion, plan 5 would be selected as the one with the highest possible outcome. The producer would demonstrate highly optimistic behavior and plan for relatively good weather conditions and high levels of forage production. However, under the "maximax" criterion, the producer would be almost indifferent between plans 3, 4, or 5. Less optimistic behavior could consequently be exhibited and still retain general consistency with this criterion.

If the "Hurwicz" criterion is used, a weighted average of both the highest and lowest possible outcomes for each management plan is calculated. The sum of the weights equals 1. If each weight equals 0.5, plan 1 would be chosen, the same as under the "maximin" criterion.

A "safety first" criterion, where expected net returns are maximized after a certain minimum level of annual net returns is met, might also be used. For example, if nonnegative annual net returns were required, plan 1 would be the only acceptable management plan because all other plans give negative net returns in years of relatively poor weather conditions and low forage production.

The decision criterion that is often more appealing conceptually to economists is to maximize expected net returns. It is the maximum-profit equivalent for the risk-neutral producer facing uncertain outcomes with known probabilities. This criterion requires that probabilities associated with each state of nature be assigned. In this study, there is not enough experimental data pertaining to annual and seasonal forage production variability and its correlation with weather conditions to develop reliable probabilities. As is common in such cases, the *"principle of insufficient reason"* (Hey, p. 43) is invoked to assign equal subjec-

TABLE 5. PAYOFF MATRIX FROM MANAGEMENT PLAN-STATE OF NATURE COMBINATIONS, OVERTON, TEXAS

Management plan	States of nature 1 (1970)	2 (1972)	3 (Av.)	4 (1973)	5 (1971)	Expected net returns[a]
	dollars					
1[bdef]	7,240	5,720	13,691	16,130	25,236	13,582
2	-8,480	7,420	6,815	3,531	12,149	3,655
3	-10,201	-3,593	20,785	26,174	38,260	12,665
4	-15,151	-7,315	17,064	26,765	38,360	10,665
5[c]	-26,415	-17,606	7,868	19,910	38,509	3,608

[a]Assuming that states of nature 1, 2, 4, and 5 have a probability of 0.25 of occurring.
[b]Maximin choice.
[c]Maximax choice.
[d]Hurwicz choice with equal weights.
[e]Safety first choice if nonnegative annual net returns are always required.
[f]Maximum expected pre-tax net returns choice.

tive probabilities to each state of nature. Further, by assigning a probability of 0.25 to each state of nature 1, 2, 4, and 5, the corresponding weighted means of prices and yields are exactly the same as in state of nature 3, the average state.

Although plan 3 maximizes net returns for the average (or expected) state of nature, it does not maximize expected net returns from all states of nature (even when the states are assigned equal probabilities of occurrence). The management plan that maximizes expected net returns is again plan 1. Although plan 3 gives expected pre-tax net returns only 7 percent less than plan 1, the fact that it is not the highest is empirical confirmation that the theoretical assertions made by Pope and by Gardner and Chavas relative to price uncertainty also apply when production is uncertain. Even a risk-neutral producer may not seek to maximize net returns based on expected prices and yields that are not constant.

Two additional points are of particular interest in examining the results in tables 3 and 5. First, plans 1 and 3 give similar expected net returns even though their cow herds differ by nearly 30 percent. This suggests that there may be a wide variety of intensified forage-beef farm plans that are "almost optimal" relative to a particular behavioral objective. Secondly, net return to the profit-maximizing plan based on average prices and yields (plan 3) is a grossly inflated estimate of expected net return from that plan under varying yields ($20,785 vs. $12,665, a 64 percent overestimate). Although yields are evenly distributed about the mean, the additional costs associated with worse-than-average yields are much greater than the additional revenue associated with better-than-average yields of the same magnitude.

CONCLUSIONS

Clearly, a myriad of decision rules could be used by beef producers to select a management plan. Without reliable information relating to the probabilities of different states of nature facing farmers, it is difficult to determine with great confidence which management plan would maximize expected net returns. However, the results presented in this paper suggest that the least risky, and in this case, also, the most profitable approach to intensive forage beef production is to plan for relatively poor weather conditions and low forage production. This results in a more diverse forage system and a smaller herd size than would be found optimal under the assumption of constant average forage production. These results also demonstrate that the assumption of constant average forage production may result in grossly exaggerated estimates of expected net returns.

To use the specific methodology employed in this study, the following steps are involved. One, obtain production and/or price data for each production period (e.g., year). Two, develop an LP model to select from among multiyear (longrun) as well as annual (shortrun) management options, execute the model for each observation and for the average of all observations (states of nature). Three, hold longrun management options constant at each selected level and rerun the LP model for each of the remaining states of nature. This will provide the management strategies and net returns results to complete the payoff matrix. Four, examine the payoff matrix and select the management strategy that meets a chosen decision criterion.

REFERENCES

Agrawal, R. C. and E. O. Heady. *Operations Research Methods for Agricultural Decisions,* Ames, Iowa: The Iowa State University Press, 1972.

Albrecht, D. and H. Ladewig. *Texas Agriculture: A Statewide Overview of Its Importance, Diversity, and Changing Structure,* Texas Agricultural Experiment Station, Rural Sociology DTR 82-2, 1982.

Bentley, E. and C. R. Shumway. "Adaptive Planning Over the Cattle Price Cycle." *So. J. Agr. Econ.,* 13 No. 1, (1981):139-48.

Conrad, H. R., J. W. Hibbs, and A. D. Pratt. "Regulation of Feed Intake in Dairy Cows: Association Between Digestible Dry Matter Intake and Cellulose Digestibility in Cows Fed Increasing Levels of Grain Concentrate." *J. of Dairy Sci.,* 49(1966):1038-42.

Degroot, M. H. *Optimal Statistical Decisions,* New York, N. Y.: McGraw-Hill, 1970.

Eidman, V. R., J. W. Dean, and H. O. Carter. "Application of Statistical Decision Theory to Commercial Turkey Production." *J. of Farm Econ.,* 49(1967):852-68.

Freund, R. J. "The Introduction of Risk into a Programming Model." *Econometrica,* 24(1956):253-264.

Gardner, B. and J. P. Chavas. "Market Equilibrium with Random Production." Paper presented at the American Agricultural Economics Association meetings, Pullman, Washington, August 1979. (Abstract in *Amer. J. Agr. Econ.,* 61(1979):1142.)

Hadar, J. and W. Russell. "Rules for Ordering Uncertain Prospects." *Amer. Econ. Rev.,* 59(1969):25-34.

Hazell, P. B. R. "A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning Under Uncertainty." *Amer. J. Agr. Econ.,* 53(1971):53-62.

Hey, J. D. *Uncertainty in Microeconomics,* New York, New York: New York University Press, 1979.

Lineban, P. A. "Use of Cage and Mower Strip Methods for Measuring the Forage Consumed by Grazing Animals." *Proceeding of the Sixth International Grassland Conference,* State College, Pennsylvania, 2(1952):1328-33.

Maddox, L. A. *Nutrient Requirements of the Cow and Calf,* Texas Agricultural Extension Service B-1044, November, 1965.

McCartor, M. M. and F. M. Rouquette. "Forage and Animal Production Programs for East Texas." Chapter 9 in *Grasses and Legumes in Texas—Development, Production, and Utilization,* Texas Agricultural Experiment Station Research Monograph 6, January, 1976.

National Academy of Science. *Nutrient Requirements of Beef Cattle,* Fifth revised edition, 1976.

National Climatic Data Center. Climatology of the United States, No. 81, Monthly Normals of Temperance, Precipitation, and Heating and Cooling Degree Days, 1951-1980, Texas (unpublished supplement data set). Ashville, North Carolina.

Pope, C. A., S. Bhide, and E. O. Heady. "Economic of Conservation Tillage in Iowa." *J. Soil and Water Cons.,* 38(1983):370-373.

Pope, R. D. "Supply Response and the Dispersion of Price Expectations." *Amer. J. Agr. Econ.,* 63(1981):161-63.

Richardson, J. W. and G. D. Condra. "Farm Size Evaluation in the El Paso Valley: A Survival/Success Approach." *Amer. J. Agr. Econ.,* 63(1981):430-37.

Rouquette, F. M. and M. J. Florence. "Animal Performance from Common and Coastal Bermudagrass Stocked at Three Levels of Forage Availability." *Forage and Beef Cattle Research, 1980 - Overton,* Texas Agricultural Experiment Station, Research Center Technical Report No. 80-1, (May, 1980):44-48.

Saez, R. R., C. R. Shumway, M. Rouquette Jr., and L. L. Jones. *Profit Potential and Risks in Intensified Forage-Beef Production, East Texas,* Texas Agricultural Experiment Station, Agricultural Economics DTR 81-4, June 1981.

Tauer, L. W. "Target MOTAD." *Amer. J. Agr. Econ.,* 65(1983):606-610.

Texas Agricultural Extension Service. *Crop and Livestock Budgets, Northeast and Deep East Texas,* 1979.

Texas Department of Agriculture. *Texas Prices Received and Paid by Farmers.,* 1979.

Texas Department of Agriculture. *Texas Custom Rates Statistics,* 1981.

U. S. Department of Agriculture. *Farm Index,* Economics, Statistics, and Cooperatives Service, December, 1979.

U. S. Department of Agriculture. *Agricultural Prices. Annual Summary.* Statistical Reporting Service, 1967, 1978.