A COMPARISON OF OBJECTIVE FUNCTION STRUCTURES USED IN A RECURSIVE GOAL PROGRAMMING-SIMULATIONS MODEL OF FARM GROWTH

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Adjustments in enterprise organization and resource use by firms in response to changing prices, yields, technology, and expectations are of interest to production economists and farm management specialists. Comparative statics has been the primary means of analyzing the impact of changes in these variables on the firm. Within this framework, linear programming is a widely used and important analytical tool.

Increased interest in the dynamics of decision making and firm growth has resulted in the development of analytical techniques that are capable of tracing the time path associated with comparative static solutions. Some of these techniques include multi-period or dynamic linear programming, recursive programming, dynamic programming, and simulation. In some cases, two of these techniques have been combined in an effort to utilize the advantages associated with each individual technique. For example, Chien and Bradford combine a multi-period linear programming model and a simulation model to study firm growth.

Simultaneously, efforts have been made to incorporate multiple objective decision criteria into firm level and aggregate models used in agricultural research (Barnett; Candler and Boehlje; Hatch; Lee; Lin et al.; Neely et al.; Patrick and Blake; Vocke et al.). Nonprofit maximizing goal structures have been incorporated, using Bernoullian utility functions, lexicographic utility functions, and modified lexicographic utility functions. Maximization of expected utility and multi-goal decision criteria has sought to recognize the importance of price and yield risk, desired consumption levels, asset ownership, and the use of leverage in production and investment decisions.

This paper employs a recursive model consisting of goal programming and simulation components as a method of incorporating multiple objectives into a firm growth decision model. The model demonstrates the impact that the alternative forms of the goal programming objective function and goal orientations have on the annual organization of production, goals achieved, and trends in farm net worth, given a long-term farm coordination-growth plan.

MODEL DEVELOPMENT

Figure 1 presents the flow of the model. The simulation component of the model portrays the decision-making environment and contains accounting functions suitable for representing farm business during the period of time that ownership of farm assets is being transferred from parents to son.[1] The simulation model maintains the data representing business organization, asset ownership, financial parameters, and planning information. Adjustments in these data are made to reflect the changes called for by the coordination-growth plans.

The goal programming component combines expected prices, yields, and resource availabilities with the multiple goal structure to formulate annual production plans. Information on the production levels of alternative enterprises is then combined by the simulation component with a set of actual yields and prices to calculate net returns. These returns are distributed among individual members of the family in accordance with the resource contribution made by each. Social security and income tax liabilities, and in the event of a death or gift, federal and state estate and gift taxes, are calculated following the rules that existed prior to the Economic Recovery Tax Act of 1981. If the end of the planning horizon has not been reached, the financial parameters and planning information are updated. At the end of the planning horizon, results are summarized.[2]
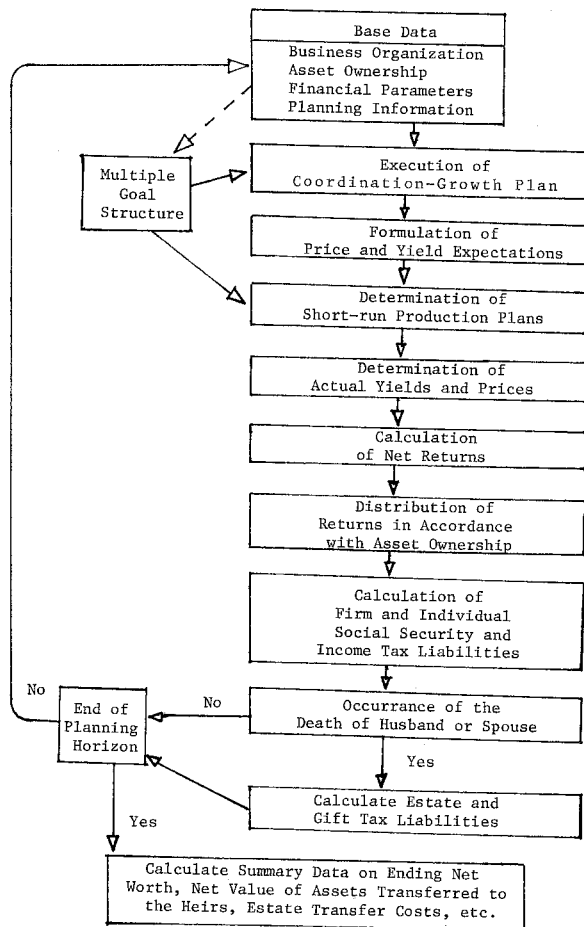
The goal programming model used to develop the annual production plan for the firm is an extension of linear programming. The major difference between goal programming and linear programming is the representation of the objective

[1] This represents a rather specific and critical decision period in the life cycle of the farm firm and a rather specific but common family situation. However, the approach could be adopted for other decision periods and family situations.

[2] Space does not permit a detailed description of the firm growth simulation model. Since the emphasis of this study is on the impact of alternative forms of the goal programming objective function and goal orientations, readers interested in the detail of the simulation model are referred to Roush.

Base Data
Business Organization Asset Ownership Financial Parameters Planning Information

| Multiple
Goal
Structure |

| Execution of
Coordination-Growth Plan |

| Formulation of
Price and Yield Expectations |

| Determination of
Short-run Production Plans |

| Determination of
Actual Yields and Prices |

| Calculation
of Net Returns |

| Distribution of
Returns in Accordance
with Asset Ownership |

| Calculation of
Firm and Individual
Social Security and
Income Tax Liabilities |

| End of
Planning
Horizon | No | Occurrence of the
Death of Husband or Spouse |

Yes

| Calculate Estate and
Gift Tax Liabilities |

| Calculate Summary Data on Ending Net
Worth, Net Value of Assets Transferred to
the Heirs, Estate Transfer Costs, etc. |

FIGURE 1. Schematic Diagram of Goal Programming/Simulation Model

function. While objective functions of both models are expressed as linear functions, the objective function in goal programming recognizes that decision makers have multiple and ofter conflicting goals.

Two linear goal structures have been used in programming models. While both of these structures require the specification of a satisfying level for each of the goals, one structure assumes that the various goals can be ranked in order of priority by the decision maker. This ranking is used to assign preemptive priority factors to the deviational variables in the model.[3] If two or more goals are identified as having the same priority, weights reflecting the trade-offs or rates of substitution allowed between these goals are assigned to the appropriate deviational variables. If all goals are assigned unique preemptive factors, this structure would represent a lexicographic utility function (Ferguson). This structure allows consideration of the less important goals only

after higher priority goals are satisfied, or when a point has been reached beyond which no further improvements are achievable. The structure is referred to as the "ranked goal structure" in the following discussion.

The second goal structure assumes that all goals are of equal priority and that weights, which reflect the importance of the goals in some measure of utility, can be assigned to the deviational variables. This formulation of the programming model allows achievement levels of one goal to be substituted for any other; thus the weights also represent the relative importance of the goals. This structure is referred to as the "substitution goal structure" in the ensuing discussion.

Under both structures, the objective function of the goal programming model seeks to minimize the difference between desired levels of goal achievement and the actual level of achievement.[4] Thus, goal programming uses a satisfying criterion, rather than the optimizing criterion of linear programming in determining the best plan.[5] The general programming model containing m goals with k priority levels may be represented by:

(1) Minimize $z = cd$
      Subject to:
(2) $Ax + Rd = g$
(3) $Ux \leq b$
(4) $X, d \geq 0$

where $c = [P_{j1}w_1P_{j2}w_2 \ldots P_{j1}w_2], i = 1, 2, \ldots,$ 2m and $j = 1, 2, \ldots, k$, is a row vector representing the products of the preemptive priority factors, P_{ji}, and the weights, w_i, assigned to deviational variables; $d = [d_1^- d_2^- \ldots d_m^- d_1^+ d_2^+ \ldots d_m^+]$ is a 2m component column vector of deviational variables, where deviations arising from underachievement are represented by d^-, and deviations arising from overachievement are represented by d^+; A is an mxn matrix of coefficients representing the interactions of production alternatives and goals; x is an n-component column vector of production alternatives; R is an mx2m matrix comprised of the identity matrix and its negative; g is an m-component column vector of goal satisfying levels; U is a qxn matrix of production coefficients and b is a column vector of available resources. When all goals are assumed to be of the same priority (the substitution goal structure), $k = 1$, assignment of the P_j's is not necessary. In this case, $c = [w_1 w_2 \ldots w_i]$ $i = 1, 2, \ldots 2m$. With this modification, the statement of the model remains the same as in equations (1) through (4).

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[3] The relationship between preemptive priority factors P_i is defined by Lee as follows: If $P_i > P_{i+1}$, then multiplication of priority factor P_{i+1} by n will never make the product greater than or equal to P_i, regardless of how large n may be.

[4] Candler and Boehlje have suggested an alternative method for solving programming models that contain multiple goals. Using their formulation, the specification of satisfying levels is not needed. Weights are assigned directly to each of the goals, and the objective function is then maximized.

[5] If the satisfying level for a particular goal cannot be achieved, minimizing the deviations associated with this goal will result in the same solution as maximizing the achievement level.

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FARM SITUATION AND METHOD OF ANALYSIS

Goal programming models using each of these goal structures are employed to determine annual production plans for an Oklahoma farm. The analysis assumes that the farm is organized as a sole proprietorship, and that ownership of selected farm assets is being transferred from the parents to the son to assist him in becoming established in farming. The farm, located in north central Oklahoma, originally consists of 2,400 acres, with 800 acres owned outright by the father and the remainder rented on a cash basis.

Initially, labor is provided by father and son in equal proportions, with seasonal labor hired as needed. In year 10 of the planning horizon, the father's labor contribution is reduced to zero to reflect his retirement. To replace this loss, a full-time employee is hired. Management of the farm is also shared. The father at first provides 60 percent of the management, with the percentage declining to zero upon retirement.

The transfer of farm assets and the overall growth of the farm is guided by the coordination-growth plan—based on a case farm situation and developed by interviewing family members. When the model is employed to compare goal structures, the plan is exogenously specified. The same coordination-growth plan is used for each structure. Thus, the goals of importance in formulating this plan are only implicitly contained in the model and do not vary with changing goal structures of the programming model.[6]

The coordination-growth plan in this analysis specifies that the parents sell 160 acres of land to the son in the first year of the planning horizon; in the second year, the farm machinery is sold to the son. Both of these sales are made on the installment basis, with small down payments. Land contract payments are spread over 30 years, while the machinery contract payments are spread over 10 years. The son also receives aid in the form of cash gifts from the parents during years 7, 8, and 9. The size of the farm is expanded through the rental of an additional 320 acres during year 2 and an additional 320 acres during year 4 of the planning horizon. Livestock production is expanded during years 10 to 15 by the purchase of 25 additional beef cows each year. These adjustments are included as part of the combination growth plan developed in cooperation with family members.

Annual crop and livestock production decisions are based on resource restrictions, goals, production alternatives, and price expectations. Production alternatives include wheat, small grain grazeout, grain sorghum, alfalfa hay, common bermudagrass pasture overseeded in the fall with small grain, common bermudagrass hay, winter and spring stocker cattle, and cow-calf production. Resource restrictions include cropland acreage, pasture land acreage, monthly labor and cash availability, and availability of pasture AUMs on a monthly basis.

The returns for each of the enterprises contained in the goal programming model were based on price and yield expectations formulated by the producer (Table 1). The expected prices for wheat, grain sorghum, and alfalfa hay were based on information available to the producer at the time the expectation was formulated—price received the previous year and U.S. aggregate stocks. The price expectation for feeder cattle was based on the price of feeder calves in Oklahoma during the preceding year, total U.S. calf crop, and cattle marketings the previous year. The March stocker price expectation was based on the price of stockers in the preceding November and on pasture conditions. The May stocker price expectation was based on the price of stockers in the previous March.

Yield expectations were based on a weighted average of past yields, using exponential-smoothing. The most recent yield observation (Y) was given a weight of 0.333 (Table 1). Weights associated with earlier observations decreased geometrically. This exponential smoothing equation provides results similar to a five-year moving average (Brown).

While multiple goals are considered important

TABLE 1. Price and Yield Forecasting Equations

Commodity	Unit	R^2	Equation Coefficients and Standard Errors[a]
Wheat grain	$/bu	0.72	$0.016 + 0.801 WP_{t-1} - 0.00000028 WS_t + 0.13t$ (0.362) (0.113)
Grain Sorghum	$/cwt	0.73	$-0.256 + 0.776 GSP_{t-1} - 0.00735 FGS_{t-1} + 0.0189t$ (0.419) (0.152) (0.0056) (0.011)
Alfalfa Hay	$/ton	0.80	$6.533 + 0.713 AHP_{t-1} - 0.0913 FGS + 0.329t$ (5.037) (0.160) (0.061) (0.161)
Feeder Calves	$/cwt	0.79	$30.305 + 0.646 FCP_{t-1} - 0.001 CC + 0.0009 CM_{t-1}$ (11.525) (0.118) (0.0005) (0.0002)
March Stockers	$/cwt	0.80	$14.262 + 0.98 NVSP_{t-1} - 0.17 PAST_t$ (6.779) (0.095) (0.078)
May Stockers	$/cwt	0.95	$1.891 + 0.925 MRSP_t$ (0.836) (0.346)
Crop Yields[b]	per acre	N.A.	$0.33 Y_{ti} + 0.667 EY_{t-1i}$

[a]Variable abbreviations used for price equations are WP for wheat price, WS for January 1 U.S. wheat stocks, GSP for grain sorghum price, FSG for U.S. feed-grain stocks, AHP for alfalfa hay price, CM for total U.S. cattle marketings, CC for total U.S. calf crop, FCP for feeder calf price, PAST for U.S. pasture conditions, MRSP for March stocker price, MYSP for May stocker price, NVSP for November stocker price, and t for the time period. Coefficients of the price expectation equations were estimated with ordinary least-squares regression using 36 years of data. The standard errors for each of the estimated coefficients are reported in parenthesis. Data for estimating these equations was taken from published USDA data series.

[b]The expected crop yields, EY, for crop i were estimated using exponential smoothing.

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[6] Only one long-term coordination-growth plan is described here. Other plans could be evaluated using this approach (Dobbins).

TABLE 2. Goal Structures Used in Goal Programming Model

Goal	Production and Transfer Activities X_1 X_2 . . . . . X_n			DG1	DG2	DG3	DG4	DG5	DG6	Satisficing Levels[a]
Objective Function[b]				$P_{j1}W_1$	$P_{j2}W_2$	$P_{j3}W_3$	$P_{j4}W_4$	$P_{j5}W_5$	$P_{j6}W_6$	
Cash Balance	a_{11}	a_{12} . . . . . a_{1n}		1						$\geq$ 84600
Consumption	a_{21}	a_{22} . . . . . a_{2n}			1					$\geq$ 24828
Short-term Borrowing	. .		.			-1				$\leq$ 0
Seasonal Labor	.	.	.				-1			$\geq$ 2250
Leisure	.		. .					1		$\geq$ 160
Current Assets	a_{61}	a_{62} . . . . . a_{6n}							1	$\geq$ 150000

[a] Satisficing levels for the goals represent the target levels for each goal. The level for the cash balances goal was based on the estimated cash needs of the farm for debt repayment, payments for insurance and property taxes, and future investment. The level for consumption was estimated to provide for two families a level of consumption comparable to others in the area. The level of the seasonal labor goal permits hiring the equivalent of a full time employee working 45 hrs. per week for 50 weeks per year. The level of the leisure goal was selected to allow both families a two week vacation. The level of current assets was based on the value of current assets included in the balance sheet.

[b] The P_{ji} represent the priority level of the ith goal. When using the ranked goal structure $P_{j1} = P_{j3} = P_{j6}$ and $P_{j4} = P_{j5}$. When using the substitution goal structure $P_{j1} = P_{j2} = P_{j3} = P_{j4} = P_{j5} = P_{j6}$.

in planning, there is little agreement on the importance of goals or their description. Identifying goals to include in a decision model and their importance can be determined in one of three ways (Barnett). The first method (used here) is to choose a set of goals and an arbitrary set of initial weights, adjusting the weights until the results resemble the decision maker's actual behavior or are satisfactory to him. A second approach is to establish goals and weights based on the decision maker's past activities—a revealed preference approach. A third method is to elicit preferences directly from farmers by using survey techniques.

The goals contained in the model relate to (1) year-end cash balances, (2) level of family consumption, (3) level of short-term borrowing, (4) amount of seasonal labor hired, (5) amount of time available for leisure, and (6) value of current assets.[7] It is assumed that the operators are concerned only with deviations that arise from the underfulfillment of a goal. That is, the operators are concerned about the minimum level of family consumption, year-end cash balances, value of current assets, and the amount of leisure time only if they are less than the satisfying level. Similarly, they are concerned if short-term borrowing and seasonal hired labor become too high and

are above the satisfying level. Because of this behavioral assumption, each goal required only one deviational variable. The goal structure and levels used in the programming model are summarized in Table 2.

Solutions to the model containing the ranked goal structure were achieved through an iterative approach. The first step of the process was to minimize the weighted value of the deviational variables associated with the first preemptive level P_{1i}, or the goals considered as the most important. Second, an additional constraint was added to the model that restricted the solution space by preventing the weighted deviations from exceeding the minimum level established in the first step. The third step required specifying the goals of the next preemptive level as the objective function. This process is continued until all preemptive levels have been considered.

When one uses the substitution goal structure, objective function changes are unnecessary because all goals have the same priority level. Thus, a direct solution to the problem was obtained, and the above stepwise solution procedure was not needed.

Alternative goal rankings and weights were used to represent general goal orientations. For the ranked goal structure, an income orientation

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[7] These goals were selected on the basis of previous research. Harmon et al. identified eight goals as important to farmers: control more acreage by renting or buying; avoid being forced out of business; maintain or improve family's standard of living; avoid years of low profits or loss; increase time off from farming; increase net worth; reduce borrowing needs; and, make the most profit each year. Smith and Capstick identified ten basic goals: provide a college or vocational education for children; reduce borrowing needs; increase net worth; increase time devoted to family, personal, church, and community needs; increase efficiency of production; operate the farm to realize the highest long-run profit possible; improve family living standard; increase farm size by expanding acreage; avoid being forced out of business; and organize the farm to stabilize income. Patrick and Eisgruber conclude that goals can be grouped into four major areas: living standard; farm ownership; leisure-children, referring to the desire for leisure time and a family; and credit-using, risk-taking behavior that is characterized by the willingness to sacrifice in the farm operation in order to achieve other goals. The additional goal related to the hiring of seasonal labor was included to reflect the desire of area producers to limit the amount of seasonal labor. This desire was included in the model as a goal rather than as a constraint because additional labor could be hired at the current wage rate.

was represented by assigning the highest priority to consumption. Goals related to cash balances, short-term borrowing, and current assets were given second priority. Goals related to part-time labor and leisure were assigned the lowest priority. A labor orientation was reflected by assigning the highest priority to the consumption goal, followed by goals associated with part-time labor and leisure. The lowest level of priority was assigned to those related to cash balances, short-term borrowing, and current assets. Because more than one goal was assigned to some priority level in the ranked structure, weights were also assigned to some of the goals in the structure (Table 3).

The same orientations were reflected with the substitution goal structure by assigning different weights to the goals. The weights which reflect the income and labor orientations are reported in Table 3.

To assess the impact of the alternative goal structures on production plans and firm growth, a 15-year planning horizon is used. For each year of the horizon, the enterprise organization was determined by the goal programming model, using expected prices and yields. For each of the simulated comparisons, prices and yields as well as the coordination-growth plan are the same. The effect of selecting alternative goal structures was evaluated by comparing annual production plans, goals achieved, and changes in net worth, over the planning horizon.

RESULTS

Production Plans

For each goal structure, the acres of wheat and grain sorghum planted, head of feeder cattle sold, and head of stockers pastured are reported in Table 4. The income orientation under the ranked objective function resulted in more emphasis on wheat production and stocker production when compared to the labor orientation. During the first 6 years of the planning horizon,

TABLE 3. Goal Weights Used in Substitution and Ranked Goal Structures

Goal	Substitution Goal Structure		Ranked Goal Structure[a]	
	Income	Labor	Income	Labor
Cash Balance	.25	.05	.25	.25
Consumption	.40	.50	--	--
Seasonal Short-term Labor	.05	.25	.05	.05
Borrowing	.10	.05	.10	.10
Leisure	.05	.10	.05	.05
Current Assets	.15	.05	.15	.15

[a] Cash balance, borrowing and current asset goals were assigned the same priority. Part-time labor and leisure goals were also assigned the same priorities.

grain sorghum was not produced under the income orientation. The number of stockers pastured during years 1 through 3 was also larger. For years 7 through 10, crop production plans were quite similar for the two ranked goal orientations. During years 11 through 15, crop production plans under the labor orientation continued to be dominated by grain sorghum production. Feeder cattle were sold, and no stockers were produced during this period. Production plans under the income orientation during this period were much less stable. Large shifts were made from year to year in wheat and grain sorghum acreage; similarly, the number of stockers pastured also varied widely.

The increased stability of production plans under the ranked labor orientation is the result of the goal ranking and the solution procedure. Under the ranked goal structure, the highest priority goal was income for family consumption—achievable by concentration on crop production. In trying to meet the goals ranked second (labor-related), grain sorghum production was more attractive than wheat production, because the labor requirements for grain sorghum were more evenly distributed over the growing season than those for wheat. This allowed a better utilization of the fixed labor supply and reduced the quantity of seasonal labor hired. Requiring the deviational levels of the first two preemptive ranks to remain at their minimum levels, while attempting to minimize the deviations of the goals ranked third (income), did not allow the adjustments that were possible under the income orientation.

The production plans that were developed under the substitution objective function were more similar for the goal orientations than those developed under the ranked objective function. However, some of the same tendencies were still exhibited. During the early years of the planning horizon, crop production was dominated by wheat production under the income orientation. Grain sorghum production became an important part of the plan during year 5 under the labor orientation, and stocker production was lower. For years 7 through 10, crop production plans were quite similar for both orientations. For years 11 through 15, both goal orientations exhibited substantial year-to-year adjustments. During this period, the production plans under both substitution goal orientations were more similar to those of the ranked income orientation than those of the ranked labor orientation.

Goal Achievement

The goals that were gained in each solution of the GP model are reported in Table 5. Those achieved for each structure (substitution and ranked) are quite similar for the two general goal orientations. For the ranked structure, the consumption goal (ranked highest) was achieved in

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TABLE 4. Acres of Wheat and Grain Sorghum Planted, Feeder Cattle Sold, and Stockers Pastured for Different Objective Functions

	Ranked Objective Function [a]								Substitution Objective Function [b]							
	INCOME				LABOR				INCOME				LABOR			
YEAR	WHEAT PLANTED (A)	GRAIN SORGHUM PLANTED (A)	FEEDER CATTLE SOLD (Hd)	STOCKERS PASTURED [c] (Hd)	WHEAT PLANTED (A)	GRAIN SORGHUM PLANTED (A)	FEEDER CATTLE SOLD (Hd)	STOCKERS PASTURED [c] (Hd)	WHEAT PLANTED (A)	GRAIN SORGHUM PLANTED (A)	FEEDER CALVES SOLD (Hd)	STOCKERS PASTURED [c] (Hd)	WHEAT PLANTED (A)	GRAIN SORGHUM PLANTED (A)	FEEDER CATTLE SOLD (Hd)	STOCKERS PASTURED [c] (Hd)
1	1172	113	0	564	1131	113	0	538	1172	113	0	565	1172	113	0	565
2	1313	0	0	556	950	40	0	335	1313	0	0	556	1313	0	0	556
3	1313	0	0	442	818	363	0	300	1313	0	0	441	1313	0	0	441
4	1525	0	90	0	995	546	90	0	1531	0	90	0	568	51	90	0
5	1503	6	0	90	918	511	0	90	1531	0	0	90	398	963	35	55
6	346	3	90	0	341	563	90	0	351	0	90	0	349	1125	90	0
7	349	1160	90	0	343	1140	90	0	354	1180	90	0	352	1174	90	0
8	307	1158	90	0	301	1138	90	0	321	1202	90	0	319	1196	90	0
9	378	1173	53	37	310	1155	90	0	331	1210	90	0	477	1204	0	90
10	637	1078	0	212	304	1156	86	4	459	1175	0	90	646	1021	0	207
11	342	819	113	0	346	1162	113	0	352	1021	113	0	352	835	113	0
12	644	1114	0	171	406	1120	136	0	902	1129	0	346	605	1129	0	136
13	1431	812	0	686	485	1070	160	0	1403	533	0	687	1431	851	0	687
14	538	25	183	0	547	1001	183	0	537	25	183	0	538	25	183	0
15	894	918	1	205	638	939	197	9	895	917	0	206	619	917	206	0

[a] Income ranking assumes that family consumption is the goal of highest priority; cash balance, short-term borrowing, current assets are of second priority; leisure time and seasonal labor were the third priority. The labor ranking assumes that consumption has the highest priority; leisure and seasonal labor were second in priority, and the cash balance, short-term borrowing and current asset goals were the lowest in priority. Weights used for goals of the same rank are reported in Table 3.

[b] Income goal weights were assigned as: cash balances—.25, family consumption—.40, short-term borrowing—.10, seasonal labor—.05, current assets—.15, leisure time—.05. Under the labor orientation weights are assigned as: cash balance—.05, family consumption—.50, short-term borrowings—.05, labor—.25, current assets—.05, leisure time—.10.

[c] Stockers were placed on pasture in November.

all production plans. Under the ranked structure, the labor orientation led to the seasonal labor goal being achieved more frequently than under the income orientation as expected.

The goals achieved under the substitution structure were also quite similar for the two orientations. It is difficult to distinguish between the two orientations, based on achievement. Under the substitution structure, the consumption goal was not achieved in any of the production plans, even though the weight attached was 1.6 to 2.0 times larger than the next largest weight. In addition, the seasonal labor goal was not achieved more frequently under the labor orientation, even though the weight attached was five times larger than under the income orientation.

TABLE 5. Goals Achieved Under Alternative Goal Structures and Goal Orientations

	Substitution Goal Structure		Ranked Goal Structure	
Year	Income	Labor	Income	Labor
1	4,5,6	4,5,6	2,4,5,6	2,3,4,5,6
2	4,5,6	4,5,6	2,4,5,6	2,3,4,5,6
3	4,5,6	4,5,6	2,4,5,6	2,3,4,5
4	4,5,6	4,5,6	2,4,5,6	2,3,4,5
5	4,5,6	4,5,6	2,4,5	2,3,4,5
6	3,4,5	3,4,5	2,3,4,5	2,3,4,5
7	3,4,5,6	1,3,4,5,6	2,3,4,5	2,3,4,5
8	3,5	4,5,6	2,3,5	2,3,5
9	3,5	4,5	2,5	2,3,4,5
10	5	4,5,6	2,5	2,3,4,5,6
11	3,4,5,6	1,4,5,6	2,3,4,5,6	2,3,4,5,6
12	4,5,6	4,5,6	2,4,5	2,4,5
13	4,6	4,5,6	2,4,5,6	2,4,5
14	4,5,6	4,5,6	2,4,5,6	2,4,5,6
15	4,5,6	4,5,6	2,4,5,6	2,4,5,6

Note: 1 = cash balance, 2 = consumption, 3 = short-term borrowing, 4 = seasonal labor, 5 = leisure, 6 = current assets.

Net Worth Trends

The trends in the firm's net worth are quite similar under each of the goal structures (Figures 2 and 3). In each case, the net worth declined early in the planning horizon, reflecting the increasing debt against existing farm assets, as assets were transferred from father to son through installment sales. This initial downward trend is followed by a general upward trend for the remainder of the planning period. The trends in farm net worth were more similar under the income orientation than under the labor orientation, because there were greater similarity between the production plans under the income orientation for the two goal structures.

SUMMARY AND CONCLUSIONS

The results of this analysis indicate, as expected, that the type of goal structure established
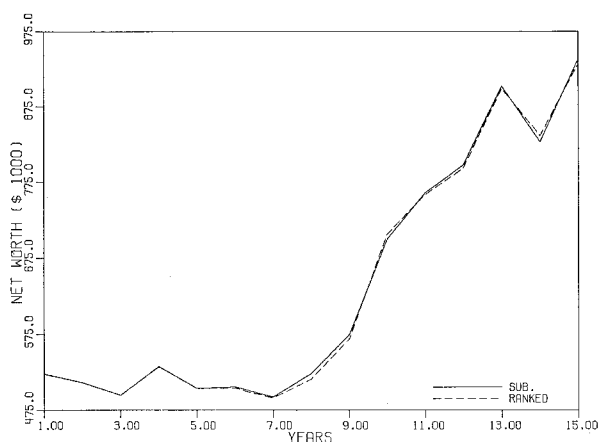
FIGURE 2. Farm Net Worth Using Income Orientation
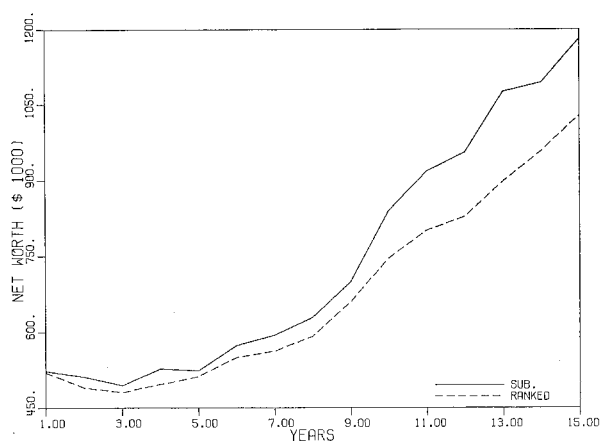
FIGURE 3. Farm Net Worth Using Labor Orientation

in the programming model has an important effect on resultant annual production plans and financial positions. Using the ranked structure, the first unachievable goal has a large impact on the production plan. Use of an income-orientated set of goals resulted in larger annual shifts in production, when compared to a labor-oriented set. The results obtained in a goal programming model with a ranked objective function will be strongly influenced by the ordering of the goals and the specification of the satisfying level.

Using the objective function that allows trade-offs between all goals, the weights assigned to the deviational variables influence the production plans. While production plans could still be dominated by a single goal, plans developed with models using this type of structure are less likely to be dominated by a subset of the goals. Under the two orientations, the annual production plans were more similar when using this objective function structure in contrast to the ranked objective function.

The objective function form is likely to affect the conclusions about what can be achieved. For example, under the ranked objective function, the consumption goal was always achieved. However, under the substitution objective function, the consumption objective was not, even though its weight was 1.6 to 2.0 times larger than that of the other goals. Although not tested, the choice of the objective function form may also have an impact on the quantity of resources needed to gain a particular set of goals.

In order to determine which of these structures most accurately reflects the decision-making criteria of farmers, additional research is needed. While the literature was searched to obtain the goals and initial weights used in this study, questions remain as to their appropriateness in reflecting the decision criteria employed by agricultural producers. Additional research is needed also to determine satisfying levels, weights, or ranking for the goals, and changes in these values through time.

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