INCORPORATING MULTIPLE GOALS INTO THE DECISION-MAKING PROCESS: A SIMULATION APPROACH TO FIRM GROWTH ANALYSIS*

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Although the importance of multiple goals in the decision-making process has been recognized for years by economists [1, 3], economic analyses typically are based on the assumption of maximization or minimization of a single goal. Some firm growth analyses have considered two or more goals by maximizing one goal subject to constraints on the remaining goals [4, 11]. In other cases, utility functions that incorporate expected income and income variability have been estimated for individual farm operators [12]. Although these approaches are an effort to incorporate more than one goal in the decision process, firm growth research in general has not been based on multiple-goal decision models.[1]

This paper discusses a multiple-goal decision model used to select farm plans in a study of farm firm growth. The procedure is a modification of the standard lexicographic utility analysis and utilizes information on farm operator goals reported in an earlier paper [8]. Empirical results are included to illustrate the effects of changes in personal and firm characteristics on the goal hierarchy and the strategy selected.

The multiple-goal decision model discussed in this paper is designed to determine the effects of selected factors on the survival capability and the growth of dryland and irrigated farms in the south central Great Plains. Specific factors considered to be of major importance include the goals of farm operators, initial tenure status, yield variability, consumption by the farm family, land acquisition alternatives, beginning farm size, and availability and cost of irrigation water. The study area includes eight counties in the northern high plains of Texas, the three Oklahoma Panhandle counties, eight counties in southwestern Kansas, and two counties in southeastern Colorado. The primary basis for delineating this study area is the location of the underground aquifer (the Central Ogallala Formation) that can be used as a source of irrigation water [2].

THE MODIFIED MULTIDIMENSIONAL UTILITY APPROACH

Models designed to select the financial and production strategies for a farm firm over time required a detailed specification of the farmer's goals, how the goals are used in decision-making, and how the goals change over time. The model developed in this study (1) estimates a hierarchy of goals, (2) evaluates a specified set of plans, and (3) chooses between alternative plans taking into account the estimated goal hierarchy. This procedure, like multidimensional utility analysis [5, 7], uses a hierarchy of goals in conjunction with satisficing levels for each goal. In addition, tradeoff or substitution between goals is not acknowledged.

The basic difference between the approach used in this study and multidimensional utility analysis is the method of selecting the plan to be implemented. Assume a decision-maker with a two-dimensional goal

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[1] See [13] for an exception.

hierarchy ranks net farm income (X_1) as dominant and leisure time (X_2) second. Given estimates of the satisficing level of both goals, X_1^* and X_2^*, respectively, the decision-maker's plans can be located on a graph such as Figure 1. In multidimensional utility analysis, the seven plans shown in Figure 1 would be ranked $X^7 = X^6 > X^5 > X^4 > X^3 > X^2 > X^1$ (where > is read as preferred to and = implies the decision-maker is indifferent between the two plans). Plans X^6 and X^7 meet the satisficing level for both goals. Multidimensional utility analysis assumes the decision-maker does not derive additional utility from units of net income and leisure time beyond the satisficing levels. Thus, he is indifferent between X^6 and X^7.

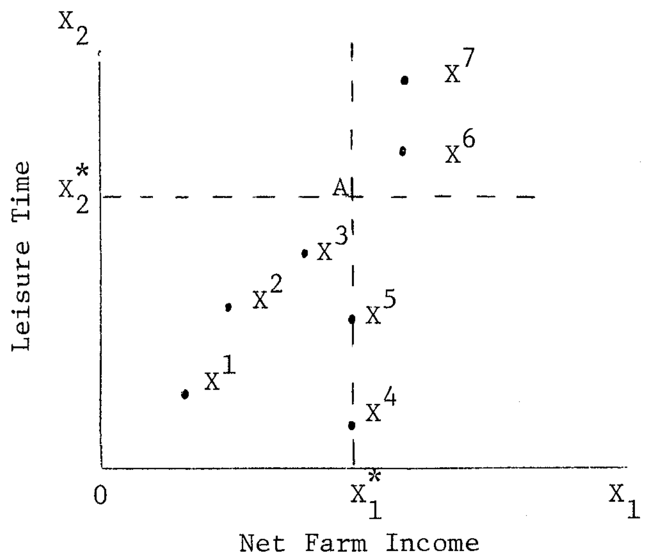

Figure 1. AN ILLUSTRATION OF MULTIDIMENSIONAL UTILITY ANALYSIS

The modified multidimensional utility approach used in this study selects the plan that maximizes the highest ranking goal, while requiring the plan to meet or exceed the satisficing level of all other relevant goals. Assuming that both net farm income and leisure time are relevant in the decision-making process, the modified approach would exclude X^1, X^2, X^3, X^4, and X^5 in Figure 1 because all of these plans fail to meet at least one of the satisficing levels. Plans X^6 and X^7 are not equally preferred in the modified approach. The criterion used in this study specifies that if two plans are tied with respect to the top-ranked goal, then the second-ranked goal is used as the choice criterion. In this case, X^7 is chosen over X^6 since the level of leisure time is greater in X^7.

The modified approach has several advantages over multidimensional utility analysis. First, a plan or strategy is not considered a relevant alternative unless the satisficing levels of all goals deemed to be important in the decision-making process are met. Second, the model avoids indifference between plans by including decision-making criteria based on the estimated goal hierarchy. Third, changes in the goal hierarchy over time are estimated as a function of specified characteristics of the decision-maker and of the firm. Finally, modified multidimensional utility analysis assumes marginal utility is greater than zero even though the satisficing level of a goal is met. Therefore, the plan is selected that maximizes or minimizes the top-ranked goal, depending on the nature of the goal.

THE SIMULATION MODEL

The General Agricultural Firm Simulator developed by Hutton and Hinman [10] was adapted to incorporate the modified multidimensional utility decision model. Procedures were included to estimate the operator's goal hierarchy and to use the hierarchy to select the farm plan to follow. These changes involved the use of an external data file and the addition of four subroutines: GOALS, STRAT, CHOOSE, and TIE.

Developing the Goal Hierarchy

The eight goals included in this study are: (1) control more acreage by renting or buying; (2) avoid being forced out of business; (3) maintain or improve family's standard of living; (4) avoid years of low profits or losses; (5) increase time off from farming (leisure time); (6) increase net worth from farm or off-farm investments; (7) reduce borrowing needs, and (8) make the most profit each year (net above farm costs).

A cross-section survey of farmers in the study area provided data on the ranking of the eight goals. The scalar values associated with the ranking were estimated for each farmer. These observed scalar values were regressed on the personal and firm characteristics of the surveyed farms. The resulting set of eight equations (one for each goal) reported by the authors [7, 8] is used to predict the scalar values of the eight goals as a function of personal and firm characteristics within the simulator. The personal characteristics of the operator required to estimate the goal hierarchy are age, tenure, education, years of farming experience, number of dependents, and off-farm income. These data are not required for the usual operation of the General Agricultural Firm Simulator and are provided via an external data file. Other variables required for estimating scalar values and establishing a hierarchy of goals that are generated within the simulator are: farm income, assets, debts, net worth, debt-asset ratio, land operated (total land and cropland), acres of owned land (total land and cropland), and proportion of land owned (total land and cropland).

The GOALS subroutine uses the equations to estimate a scalar value for each goal using the above mentioned data. The eight goals are ranked from high to low on the basis of the estimated scalar values, and the estimated values are converted to a zero-to-one scale. Conceptually, all eight goals and their satisficing levels should be used in evaluating alternative plans each time a decision is made. In an effort to reduce computational costs, it was deemed necessary to reduce the number of goals considered. Simply dividing the goals into two groups based on the largest scalar difference would result in basing some decisions on only one goal. Arbitrarily selecting the highest ranking four (or five) goals would have typically resulted in excluding one or more goals having only a slightly lower scale value than the last goal considered. As a compromise, the goals were divided into three groups based on the largest scalar differences observed in the zero-to-one scale. The goals in the top two groups are classified as primary goals, and the bottom group are classified as secondary goals. The primary goals are used in the multiple-goal, decision-making process; whereas, the secondary goals are assumed to be irrelevant and are not used in the decision-making process for that year.

Satisficing levels for the eight goals are calculated in the CHOOSE subroutine. With the exception of the leisure time goal, each satisficing level is based on data from the previous production period. The rationale for this assumption is that it seems unlikely that a farm operator would deliberately make a decision that worsens his position with respect to a particular goal. For example, if increasing net worth is one of the relevant goals, our assumption is that he would not implement a plan that would result in a lower net worth than he had at the end of the previous production period. The "leisure time" satisficing level is a function of total acres operated and was estimated from survey data obtained from farmers in the study area [9, pp. 46-52].[2]

Selecting the Plan

Having determined the primary goals and their satisficing levels, four alternative plans are simulated using expected yields and prices. The STRAT subroutine uses the simulated results of each plan to calculate strategy decision values. A strategy decision value is computed for all goals in each plan simulated. After all plans are simulated, a plan is selected for implementation in the next production period. The CHOOSE subroutine checks the strategy decision values of all goals in the primary group against their respective satisficing values. If all satisficing values for primary goals are met by the plan that maximizes or minimizes the top-ranked goal, then that plan is chosen for implementation. The nature of the goal determines whether the goal is actually maximized or minimized in a numerical sense.

If none of the alternative plans meet the satisficing levels of the primary goals, a default option of continuing with the current organization is assumed in order to allow the firm to continue operating until plans are evaluated again. The rationale for this assumption is as follows. If satisficing levels of primary goals are not met, one of two choices seems feasible: (1) a strategy can be specified for implementation or (2) satisficing levels can be modified until a decision can be made in accordance with the existing goal hierarcy. Since we did not have data available for estimating the disutilities associated with the failure to meet satisficing levels, the alternative of specifying a strategy was chosen. Continuing with the current organization seemed preferable to forcing expansion in terms of total acres operated in situations where satisficing levels were not met.

If two or more plans (for which the satisficing levels of all primary goals are met) happen to be tied with respect to the top-ranked goal, the subroutine TIE evaluates successively lower-ranked goals until one of the tied plans maximizes (or minimizes) the first non-tied goal in the hierarchy. For plans to be tied, thus activating this subroutine, the strategy decision values for the dominant goal must be equal (out to the last recognized decimal fraction) in at least two plans. The default strategy of continuing operation with the current organization is selected if *all* strategy decision values for the primary goals are tied.

APPLICATION OF THE MODEL

The simulation model described was used to compare the rate of growth for representative dryland farm situations in the study area. Survey data and the 1969 Census of Agriculture were used to select three farm sizes: (1) a 960-acre farm, (2) a 1,600-acre farm, and (3) a 2,560-acre farm. The operation of the three

[2]See [9, pp. 39-52] for a thorough explanation of this procedure. The satisficing level for leisure time varies according to total acres operated: (1) farms with 640 acres or less require seven days; (2) farms with 641 to 1,279 acres require 10 days, and (3) farms with 1,280 acres or more require 14 days. Thus, the satisficing level can change over the planning horizon if a firm experiences appropriate increases in physical size.

farm sizes was simulated for full owners, part owners, and full tenants. Each of the nine tenure-size combinations was analyzed assuming an initial operator age of 25 and 45 years. The 18 situations were simulated for 20 years and replicated 15 times using stochastically determined yields.

Four plans or strategies have been selected to represent alternatives available to farm operators in this study. The selected plans are not the complete set of opportunities available to an individual farm operator in an actual situation. However, limited computing funds necessitate considering only a small number of alternatives. The specific plans or strategies included are: (1) no change in the physical size (or acres operated) of the firm; (2) cash rent an additional 320 acres; (3) purchase an additional 320 acres, and (4) release 320 acres of rented land and purchase an equivalent amount.

The number of acres to be rented or purchased in Plans 2, 3, and 4 is controlled by a parameter and can be changed from one run to the next. A critical assumption associated with the plans is that all new land brought into the organization (whether rented or purchased) has the same proportion of crop enterprises and the same cropland-rangeland distribution as the basic organization of the farm. The frequency with which plans are evaluated is also controlled by a parameter that can be specified by the user. The parameter value selected for this study is 4. Thus, plans are evaluated five times in the 20-year planning horizon (prior to years 2, 6, 10, 14, 18). The plan that releases rented acres and purchases an equivalent amount (plan 4) is only evaluated when the acreage operated includes rented land.

THE EMPIRICAL RESULTS

Available space does not permit a detailed examination of the changes in net worth, acres operated, the goal hierarchies, or the plans selected for each of the 18 starting situations. The situations simulated represent a relatively wide range of financial situations, and the results indicate that both the hierarchy of goals and plan selections are very responsive to changes in operator and firm characteristics.

Ending Net Worth and Solvency

The average ending net worth position of replicates remaining solvent over the 20-year planning horizon is given for each of the 18 starting situations in Table 1. Comparisons across ages within size and tenure situations indicate small differences in either survival rates or change in net worth that can be attributed to the operator's starting age. However, the initial tenure status has a more pronounced impact on both the survival rate and the change in net worth. Although the size of farm is certainly important, the amount of cropland (576, 1,264, and 1,050 acres for the 960-, 1,600- and 2,560-acre farms, respectively) had a much greater impact.

Frequency of Selection of Alternative Strategies

Percentage distributions for strategy selections are shown in Table 2. A total of 270 decisions was made in each decision year (18 situations times 15 replicates per situation). The land-rental strategy was the one most frequently selected in year 2. All 15 replicates in 12 of the 18 situations chose plan 2. The selection of the no-change strategy in year 2 occurs in the 1,600-acre, full-owner situations. The rental alternative is chosen less frequently in future years, while the purchase alternative is used more often.

The frequency with which plan 1 is selected by default is disturbing. It is difficult to assess the total impact that defaults had on survival capability, growth rates, and total capital accumulation. However, the number of defaults emphasize the need for trade-off criteria and/or basic changes in some of the decision rules built into the simulator. The satisficing levels associated with two goals (reduce borrowing needs and increase leisure time) account for almost all of the defaults that occur.

Dominant Goals

Percentage distributions that show the relative frequency with which each goal was dominant (or top-ranked) in the five decision years are shown in Table 3. The percentages are based on 270 observations in each decision year and on 1,350 observations for the total table. In year 2, to make the most annual profit was dominant about 80 percent of the time. However, the relative importance of profit maximization was considerably less in the other four decision years. The goal of increasing net worth became relatively more important in the latter years of the planning horizon. This goal is dominant about 50 percent of the time in year 18; whereas, it was never the top-ranked goal in year 2. The importance of avoiding years of low profits or losses was restricted primarily to full-owner and part-owner situations. The relative importance of this goal increased from year 2 to year 6, but decreased in each of the three remaining decision years.

CONCLUSIONS

The basic assumptions of lexicographic utility models are that the decision-maker has a hierarchy of goals (identification and ranking are possible) and that each goal in the hierarchy has a related, quantifiable satisficing level. A major advantage of

Table 1. **SUMMARY OF INITIAL AND ENDING NET WORTH POSITIONS OVER A 20-YEAR PLANNING HORIZON**

Situation Identification	960 Acres Initial Net Worth	960 Acres Average Ending Net Worth[a]	1,600 Acres Initial Net Worth	1,600 Acres Average Ending Net Worth[a]	2,560 Acres Initial Net Worth	2,560 Acres Average Ending Net Worth[a]
25-Year-Old Operator						
Full Owner	119,932	202,885 (15)	204,042	543,497 (15)	278,890	410,308 (15)
Part Owner	66,963	89,288 (14)	91,076	337,441 (15)	160,155	179,519 (15)
Full Tenant	26,170	64,247 (4)	30,147	213,207 (15)	47,302	18,026 (2)
45-Year-Old Operator						
Full Owner	120,006	201,962 (15)	204,197	549,587 (15)	279,423	449,226 (15)
Part Owner	67,658	90,690 (15)	91,191	347,505 (15)	160,245	199,576 (15)
Full Tenant	24,895	58,396 (5)	30,237	224,170 (15)	46,640	47,560 (3)

[a]All averages are based on the number of replicates remaining solvent at the end of the 20-year planning horizon. The number of replicates remaining solvent is indicated in parentheses below the average ending net worth.

the approach used in this study is that the goal hierarchy can change over time in response to changing family and operator characteristics and to changing economic conditions (reflected through prices used and financial characteristics of the firm).

The development and use of a multiple-goal, decision-making framework includes many pitfalls and limitations. However, the authors' conclusion based on this study is that such an approach does provide needed information with respect to survival capability and growth potential of farm firms. The most critical points in such a study are associated with goal selection and evaluation and with the development of relevant strategies available to the decision-maker.

An operational model designed to be representative of the real world faced by decision-makers will necessarily be very complex. Perhaps it is possible to construct a model that is useful in developing normative recommendations for farmers. However, the authors feel that the approach may be of much greater use in predicting the adjustments farmers will make to changes in technology, prices, and institutional restrictions.

Table 2. **SUMMARY OF STRATEGY SELECTIONS IN DECISION YEARS AS A PERCENT OF TOTAL DECISIONS PER YEAR**

Strategy Chosen[a]	Percent of Total Choices by Decision Year[b]				
	Year 2	Year 6	Year 10	Year 14	Year 18
	Percent	Percent	Percent	Percent	Percent
Plan 1 by choice	3.0[c]	13.7[d]	5.9[e]	13.3[f]	8.5[g]
Plan 1 by default	0.0	28.1	44.5	24.8	38.5
Plan 2	83.7	48.1	27.4	24.1	19.6
Plan 3	13.3	9.3	22.2	37.0	33.0
Plan 4	0.0	0.8	0.0	0.8	0.4
Total	100.0	100.0	100.0	100.0	100.0

[a]Alternative strategies in each of the 18 situations simulated are defined as follows:
Plan 1–no change in farm size;
Plan 2--rent an additional 320 acres;
Plan 3–buy an additional 320 acres, and
Plan 4–replace 320 acres of rented land by purchasing 320 acres.

[b]Across the 18 situations with 15 replicates in each situation, a total of 270 decisions are made in each decision year. Percentages shown are calculated by dividing the total number of times each plan was selected by 270.

[c]Actual choice between all four strategies; based on a dominant goal of avoiding being forced out of business.

[d]Out of 37 choices, 13 are between plans 1 and 4; four are between plans 1 and 2; and in 21 only plan 1 meets all required satisficing levels.

[e]Out of 16 choices, two are between plans 1 and 4; one is between plans 1 and 2; and in 13 only plan 1 meets all required satisficing levels.

[f]Out of 36 choices, 10 are between plans 1 and 4; one is between plans 1 and 2; and in 25 only plan 1 meets all required satisficing levels.

[g]Out of 23 decisions, 14 are between plans 1 and 4; and in nine plan 1 only meets all required satisficing levels.

Table 3. **DISTRIBUTION OF DOMINANT GOALS OBSERVED IN DECISION YEARS FOR 18 DRYLAND FARM SITUATIONS, SOUTH CENTRAL GREAT PLAINS[a]**

Goal number[b]	Decision Year					
	Year 2	Year 6	Year 10	Year 14	Year 18	Total
	Percent	Percent	Percent	Percent	Percent	Percent
1	0.00	0.00	0.74	0.00	0.00	0.15
2	2.97	0.00	0.00	0.00	0.00	0.59
3	0.00	0.00	0.38	0.00	0.00	0.07
4	16.67	35.19	32.96	30.37	27.41	28.52
5	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	30.00	32.96	47.41	50.74	32.22
7	0.00	1.48	0.00	0.00	0.00	0.30
8	80.36	33.33	32.96	22.22	21.85	38.15
Total	100.00	100.00	100.00	100.00	100.00	100.00

[a]A dominant goal is defined as the top-ranked goal in the hierarchy. Each of the 18 situations was replicated 15 times; thus, the total number of observations in each decision year is 270.

[b]Goal numbers in this column refer to the following goal statements:

1. Control more acreage by renting or buying;
2. Avoid being forced out of business;
3. Maintain or improve the family's standard of living;
4. Avoid years of low profits or losses;
5. Increase time off from farming (leisure time);
6. Increase net worth from farm or off-farm investments;
7. Reduce borrowing needs, and
8. Make the most profit each year (net above farm costs).

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