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ODC 892.51--015

GOAL PROGRAMING: A NEW TOOL FOR THE CHRISTMAS TREE INDUSTRY

FOREST SERVICE RESEARCH PAPER NE-378
1977
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
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MANUSCRIPT RECEIVED FOR PUBLICATION 27 DECEMBER 1976

ABSTRACT

Goal programing (GP) can be useful for decision making in the natural Christmas tree industry. Its usefulness is demonstrated through an analysis of a hypothetical problem in which two potential growers decide how to use 10 acres in growing Christmas trees. Though the physical settings are identical, distinct differences between their goals significantly influence the recommendations made to them. Included also is a simplified presentation of the general GP model plus a discussion of its applicability to production and marketing problems in the industry.

INTRODUCTION

BECAUSE OF CHANGES in the production and marketing of Christmas trees during the past several decades, the number and importance of management decisions facing producers of natural Christmas trees have increased dramatically. The move from speculative harvests of wild trees to production on a managed plantation basis has brought with it a need to estimate market potential, to make adequate investment analyses, and to schedule various production and marketing activities. In addition, competition from artificial trees has forced the natural Christmas tree industry to better identify consumer preference and to develop and promote its product accordingly.

Not only have they increased in number and importance, but the decisions facing the Christmas tree industry today are far more complex than those in the past. Often many factors, both economic and noneconomic, need to be evaluated. And goals considered important by one group may not necessarily be given the same importance rating by another. Adding to this complexity is the variety of alternatives, often only partially acceptable.

Thus, in many operations a quantitative evaluation of specific alternatives is needed, one that reflects both the available resources and the particular goals of the individual grower. Goal programing (GP) is an analytical tool that seems well suited to such evaluations.

Since its introduction to the decision sciences in the early 1960's, goal programing has been applied to a variety of problems in business, industry, and government. Two recent applications of GP in forestry have addressed problems similar to those of the Christmas tree industry. Porterfield (1974) evaluated several tree improvement programs in southern pine. GP was used to compare projected genetic gains with desired goals for straightness, crown form, specific gravity, volume, and fusiform rust resistance. Where such gains fell short of program goals, GP identified the trade-offs involved in various modifications of the initial goal set.

Similar efforts aimed at improving Christmas tree species are underway in a number of states. Disease resistance, form, color, and needle retention are some of the characteristics in which improvements are being sought. GP should be well suited to evaluating such programs, by measuring achievements in relation to stated goals and identifying the effects of modifications where goals are not met.

Schuler and Meadows (1975) applied GP to the multiple-use management of a 10,000-acre tract on the Mark Twain National Forest. GP helped management personnel select the alternative that best met selected goals for production of timber, recreation, hunting, and grazing within given acreage and budget limitations.

The decision to grow Christmas trees is often only one part of an overall land-use plan developed by a private landowner; he may have a variety of other goals similar to those of the national forest manager. Such goals might include provisions for hunting, recreation, timber production, and wildlife refuge. Like the national forest manager, the private landowner must evaluate his goals in light of various limitations. GP can help him analyze his land-use assignments more objectively. Conflicts in the overall land-use plan, such as between Christmas tree production and recreation, can be readily identified. And if necessary, trade-offs among the goals of the landowner can be clearly delineated before final decisions are made.

GOAL PROGRAMING

GP is simply a mathematical technique which investigates the relationships among a set of desired goals and the resources available to achieve them.[1] Goals may be either economic or noneconomic. Goals are achieved according to priority; the higher priority goals being given precedence in the allocation of resources over those of lower priority. Within a particular priority level, subgoals may be specified by use of a weighting factor.

[1]Those interested in a more comprehensive review of goal programing and a discussion of how it differs from linear programing should see Lee's (1972) text.

In its most basic form, GP consists of an objective function which minimizes deviations from specified goals:

$$\text{minimize } Z = \sum_{i=1}^{n} w_i P_i (d_i^- + d_i^+) \qquad [1]$$

and a set of constraint equations:

$$\sum_{j=1}^{m} a_{ij} X_j + d_i^- - d_i^+ = b_i \qquad [2]$$

The constraint equations specify various goal or physical constraint levels (b_i). Assignment of activities (X_j), which may be in the form of hours of labor, dollars, trees, acres, etc., is dictated by the objective function, which minimizes both negative (d_i^-) and positive (d_i^+) deviations from specified goals according to their respective priority (P_i), and a weighting factor (w_i), if any. Production coefficients (a_{ij}) represent the relationship between the particular activity and the magnitude of its contribution to achieving the specified goal.

AN EXAMPLE

In the following example two growers—Mr. Leisure and Mr. Profit—use GP to analyze the requirements and potential returns of growing Christmas trees on 10 acres of land. Although hypothetical, their situations reflect many of the same considerations regularly faced by Christmas tree producers.

The large investments and long-term commitments required to grow Christmas trees make it desirable that growers develop and consider various production and marketing alternatives long before any trees are sent to market, in fact, the chances of success are improved if these alternatives are analyzed before the first tree is planted. A few obvious questions are: What species should I grow? How much labor shall or must I invest? What are the capital requirements and limits of the operation? What return can I expect?

However, the decisions will reflect more than purely economic considerations. Growers range from pure businessmen to pure hobbyists with many degrees in between. While some growers would simply choose the tree species that provides the greatest dollar return, others would choose a lower return with a guarantee that a variety of trees would be grown, or that idle land or time would be utilized, or simply that contact with nature would be insured. Ideally, decisions should reflect those considerations important to each individual.

For comparison, we will assume that both Mr. Leisure and Mr. Profit incur the same cost and receive the same price for each tree produced. The cost and price figures are those reported from Michigan by Rudolph (1972):

	*Cost**	*Price*
Scotch pine	$ .96	$2.95
White spruce	1.06	2.70
Douglas-fir	1.11	4.25

*Costs were compounded at 6 percent to the selling year.

The labor expended per tree grown and harvested was assumed to be constant for each grower but differed with species. Scotch pine required 45 minutes, white spruce 30 minutes, and Douglas-fir 40 minutes for the various production activities during an 8-year cycle.

Both growers want to use their land fully in growing Christmas trees, both will plant 1,200 trees per acre, and both will harvest all the trees at the end of 8 years.

While Mr. Leisure and Mr. Profit operate under virtually identical conditions, they have strongly contrasting personal interests. Mr. Leisure, a retired forester, grows trees as a hobby. His chief concern in growing trees is to occupy some of his idle time. Still, he wishes to commit no more than 3,200 hours of his time in one growing cycle. While hired labor is acceptable, Mr. Leisure prefers to hire as little as possible, and no more man-hours than he himself puts into the business. He prefers to grow trees of all three species (Douglas-fir, Scotch pine, white spruce), and does not want any one species to amount to fewer than 1,000 trees or more than 60 percent of the total planting. Further, he wants to limit his total investment to $10,000.

Mr. Profit is a self-employed economic consultant. Unlike Mr. Leisure, he is chiefly concerned with maximizing profits. He prefers to use hired labor for all production operations and there is no limit to the investment he is willing to make, provided there is a sufficient return for each dollar invested.

Results

The solutions obtained by GP for Mr. Leisure and Mr. Profit reflect the differences in their objectives (table 1). The solution for Mr. Profit was completely compatible with his limited objective. It suggested the obvious—plant 12,000 Douglas-fir to maximize profits. Since there were no restrictions on labor or investment, all 10 acres were fully utilized. Mr. Profit need not have turned to GP to solve his problem since, all the constraints were nonconflicting and all the goals were commensurate and easily achieved. A linear programing model or financial investment model would have provided Mr. Profit with an identical solution.

This is not true of the solution for Mr. Leisure. While satisfying most of his goals, he failed to achieve complete land utilization. The solution called for planting 2,771 Scotch pine, 1,000 white spruce, and 5,657 Douglas-fir, to meet the species requirements. An investment of $10,000 was required, just meeting the maximum allowed. And labor requirements were 29 hours below the 6,400-hour combined maximum. This solution netted a return of $24,919.

The solution might be satisfactory in actual practice, but it is also possible that using less than 80 percent of the available acreage would be unacceptable to Mr. Leisure. By reordering his original goal structure, Mr. Leisure can examine those alternatives that provide complete land utilization. All of them require compromise among some of the other goals previously established for his operation.

One obvious alternative that guarantees complete land use is that chosen by Mr. Profit—profit maximization. However, it would require a labor commitment that would exceed the goal level of 6,400 hours by 41 percent and an investment that would exceed the targeted amount of $10,000 by 33 percent. In addition, this solution called for the planting of only one species.

Table 1.—Initial goal programing solutions for Mr. Profit and Mr. Leisure

Item	Mr. Profit	Mr. Leisure
Investment	$13,320	$10,000
Acres	10.0	7.86
Net return	$37,680	$24,919
Scotch pine (no.)	0	2,771
White spruce (no.)	0	1,000
Douglas-fir (no.)	12,000	5,657
Labor: owner (man-hours)	0	3,200
Labor: hired (man-hours)	9,000	3,169

Table 2.—An alternative solution for Mr. Leisure providing complete land utilization

Item	Mr. Leisure
Investment	$12,678
Acres	10.0
Net return	$21,502
Scotch pine (number)	920
White spruce (number)	10,080
Douglas-fir (number)	1,000
Labor: owner (man-hours)	3,200
Labor: hired (man-hours)	3,200

Another alternative presented in table 2 provides for complete land use and still achieves some of the other goals Mr. Leisure selected. The total labor commitment is kept at 6,400 hours. It allows Mr. Leisure to grow trees of all three species, although not in the proportions prescribed. Unfortunately, the investment required still exceeds the prescribed amount by 27 percent while the net return is more than $3,400 less than that of the initial solution.

In actual practice it would now be up to Mr. Leisure to select among the alternative solutions presented or further restructure his goal priorities and/or levels to obtain other, more acceptable, solutions. GP cannot make the decision for Mr. Leisure, but it will allow him to investigate a variety of alternative solutions and choose among them objectively with clear recognition of the trade-offs and benefits involved.

DISCUSSION AND CONCLUSION

The decision problems presented in the example for Mr. Leisure and Mr. Profit were simplified. Costs were attached to trees produced and not to labor input. Labor was estimated and assigned to each tree produced, with no regard to its distribution within the 8-year cycle. The returns cited assume 100 percent survival and market acceptance.

Direct application of GP to specific operations, however, would require that various criteria be added to the model to allow for mixed length rotation, survival factors for the various species, seasonal and annual needs and availability of labor, and other criteria unique to a particular operation.

Because the example was hypothetical, problems inherent in GP (or, for that matter, any mathematical programing technique) were avoided. Bell (1975) cites several problems encountered by the Mt. Hood National Forest Planning Team in using GP to prescribe activities on the 93,000-acre Bull Run Planning Unit. Among these were: (1) specifying various goal levels, i.e., how many days of recreation, how many board feet of timber, etc.; (2) assigning priorities and weights within priorities to particular goals, i.e., what is more important? How much more? And to whom?; (3) development of input-output coefficients, i.e., how many days of recreation will result from varying management activities, etc.

The most critical of these three problems is development of the input-output coefficients. As seen in our example, priority ordering and even goal specification are often changed to reflect the decision maker's indecisiveness. In a sense, it is the resulting interaction between the decision maker and the model, caused by initial specification problems, that eventually allows the decision maker to define his final goal ordering and specification levels precisely and meaningfully.

Accuracy in developing input-output coefficients is essential, since it is these relationships that seek to duplicate the actual environment surrounding the decision. Should these be loosely conceived and inaccurate, the outcomes of the subsequent modeling might or might not be repeated in the real world. Imperfect information for developing the necessary coefficients must be allowed for by consciously weighing the risks involved.

The usefulness of goal programing to the Christmas tree industry goes far beyond the type of application illustrated. GP could help growers to develop and evaluate various marketing strategies and activities, on an individual or industrywide level. Individual growers may find GP helpful in developing an overall marketing strategy to guide decisions on price, market area selection, outlet, sales method, and other factors that relate directly to the total sales effort.

Industrywide applications might center on improving the overall effectiveness of the industry's promotional and public relations activities, including the selection of advertising media.

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