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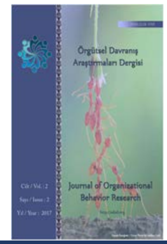

MODELING OF AGRICULTURE SECTOR OF IRAN AFTER TARGETED SUBSIDIES USING MULTIPLE CRITERIA DECISION MAKING TOOL

Ataollah RASOOLIZADEH[1*], Monirahmad RASOOLIZADEH[2]

[1]MSc in Commercial Management, Department of Financial and Trading Management, Faculty of Management and Economics, University of Sistan and Baluchestan, Zahedan, Iran.
[2]PhD Student in Economic Agriculture, Department of Economic Agriculture, Faculty of Agriculture, University of Zabol, Zabol, Iran.

Corresponding Author:
Email: at.rasoolizadeh@gmail.com

ABSTRACT

Subsidy with distortion of prices prevent optimal allocation of resources and decrease economic growth and on the other hand has an irreparable effects on country economic sectors including the agricultural sector by creating the budget deficit and increasing social costs. If the trend of these variables be determined, economic policymakers with choose of appropriate support packages and fiscal and monetary policy is closer to the goals One of the methods that can be a suitable solution is input - output table. In the present study performed by input - output analysis (2007) and production predictive models, effects of rising the price of energy carriers (gasoline, white oil, gasoil, black oil, liquid gas,electricity and natural gas) during first(2010) and second (2014) phases of Iranian. One conomicvariables (changes in production, pricechanges, changes incosts, changes inimports, changes ininvestmentand changes indemand) in agricultural sector (plantation and gardening, fishing and foresty) have been studied. After this changing in agricultural sector, optimized solution was suggested to the problem of planning in this sector and the agricultural sector was modeled by using the linear programming and multiple criteria decision making (MCDM). A crop-planning problem is usually formulated as a single objective linear programming model. The objective is either the maximization of return from cultivated land or the minimization of cost of cultivation. This type of problem, however, normally involves more than one goal. We thus formulate a crop-planning problem as a goal program (an MCDM tool) and discuss the importance of three different goals for a case problem. We solve the goal program with a real world data set, and compare the solution with that of linear program. We argue that the goal program provides better insights to the problem and thus allows better decision support.

Keywords: *Linear Programming, Goal Programming, Multiple Criteria Decision Making.*

INTRODUCTION

Nationwide crop planning problem is a complex decision making problem involving multiple objectives and multiple stake holders. Literature, however, has mostly treated this type of problem as single objective optimization problem. In this paper, we first model the crop planning as a single objective linear programming (LP) problem. We then convert it to a goal program (GP) where the goal values are derived from the LP solutions. The paper thus contributes in two aspects: (i) it shows how 'nationwide' crop planning problem can be modeled as a goal programming model for a third world country, and (ii) highlights how useful information from the LP model can be used effectively in GP version for better insights and decision support.

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For our chosen third world country, crop planning is related to many factors such as the type of lands, yield rates, weather conditions, availability of the agricultural inputs, crop demand, capital availability, government preferences on the crops and the cost of production. Some of these factors are measurable and can be quantified from available historical information. The factors like rainfall, weather conditions, floods, cyclones, and other natural calamities are difficult to predict. However if the available information can be utilised properly, it may give valuable suggestions despite the exclusion of non-quantifiable factors.

This type of problem can be formulated as a linear programming (LP) model and solved using existing packages. A variety of models reported in the literature show the applicability of LP to crop and related agricultural planning problems (Bari, 2007; Butterworth, 2008; Glen, 2009; Lara and Romero, 2010; Lin, 2002; Quaddus, Atkinson, and Levy, 2006; Sarker, Talukdar, and Haque, 2009; Turban and Meredith; 2011, White, 2010; Yates and Rehman, 2012).

Following this introduction, a brief review of multiple criteria decision making and goal programming is presented in Section 2. The linear programming model for the present problem is formulated in Section 3. Then a goal programming formulation is presented in Section 4. The computational experience and Comparison of solutions are provided and discussed in Section 5. Finally the conclusions are given in Section 6.

Multiple criteria decision making and goal programming

Multiple criteria decision making (MCDM) is a relatively new field emerging as a separate discipline only in the early sixties. Over the last four decades MCDM has attracted many researchers because of its theoretical challenge and practical applications to a wide variety of problems. Literature on MCDM is plentiful, for example see Hwang and Masud (2010), Hwang and Yoon (2008), and Zeleny (2005), among many others. Several terms are used in the literature in connection with MCDM, for example multi-attribute, multi-objective, multi-dimension, etc. We lump all MCDM problems under either multi¬ attribute decision making (MADM) or multi-objective decision making (MODM) as follows.

- ***Multi-attribute decision making (MADM)***

Consider a non-profit making community based organization that provides vocational training to disadvantaged people in the community and help them to find job with their acquired skills. The organization depends on government and public donations for its funding. Due to uncertainty over these funding sources the organization embarked on a planning exercise to find alternative ways of funding its projects. After a comprehensive brainstorming session the organization came up with three alternatives as: (i) reduce scope of different training schemes (A1), (ii) lobby government bodies for extra funding (A2), and (iii) reorganize to cut costs (A3). The brainstorming session also revealed several attributes which differentiate various alternatives, such as: (i) time to implement (C1), (ii) risk (C2), (iii) staff morale (C3), (iv) image (C4), (v) politics (C5), etc.

Above is a real world decision problem (Quaddus et al., 2006). It is characterized by a small number of distinct alternatives (A1- A3) evaluated on a number of attributes (C1- C5). We shall call it an MADM problem. Mathematically MADM problem can be represented as follows:

Select: {Alternative A1,..., Alternative Am}
Subject to: {Attribute,…, C1(Attribute Cn}

The selection is always based on maximizing a multi-attribute value or utility function. In the literature MADM is also known as a discrete MCDM (Korhonen, Moskowitz, and Wallenius, 2006), multiple criteria decision analysis, or evaluation problem (Belton, 2011).

- ***Multi-objective decision making (MODM)***

Consider the long-term energy-planning model of Dutch economy (Kok and Lootsma, 2003). The model explicitly considers nine objective functions. Some of them are: (i) minimize total costs ($f_1(X)$),(ii) minimize SO_2 emissions ($f_2(X)$), (iii) minimize NO emissions ($f_3(X)$), (iv) minimize dust ($f_4(X)$), (v) minimize electricity production by nuclear power plants ($f_5(X)$), etc. The model also considers a number of explicit constraints (restrictions) as: (i) energy demands in various sectors of the economy ($g_s(X) > b_s$, $s = 1,\ldots,$ number of sectors), (ii) supply restrictions ($g_r(X) < b_r$, $r = 1,\ldots,$ number of supply restrictions), (iii) capacity limitations ($g_c(X) < b_c$, $c = 1,\ldots,$number of capacity limitations), etc. It is observed that the model first considered a vector of decision variables (X), then developed the objective functions ($f_i(X)$) and constraints ($g_j(X) < b_j$) The energy alternatives are implicit in the feasible set characterized by the constraints that could be infinitely many. Above is an example of MODM model. Mathematically MODM can be represented as follows

$$\text{Maximize}(f_1(X),\ldots,f_L(X)\}$$
$$\text{Subject to}: g_j(X) < b_j,\ j = 1,\ldots,m$$

Where $x = (x_1, \ldots, X_n)$ denotes n decision variables, ($f_i(X)$), represents L conflicting objectives, and $g_j(X) < b_j$ represents m constraints. It is noted that MODM is mathematical programming type and in the literature it is also known as continuous MCDM (Korhonen et al., 2006), or design problem (Belton, 2011).

Goal programming falls in the category of MODM. It is one of the most widely used tools to solve MODM problems (White, 2010). In goal programming, some goals (aspiration levels) for the objectives are identified. The objective functions are then transformed into constraints and the undesirable deviations from the goals form the new minimizing objective function. There are two versions of goal programming. The simpler version is known as non-preemptive goal programming. Here the minimizing objective function of the goal is taken as a weighted (linear) sum of the undesirable deviations. In the preemptive version, some priority structure is assigned to rank the objectives ordinally. For theory and applications goal programming, see (Charnes and Cooper, 2001; Ignizio, 2000; Lin, 2002).

LP formulation

For convenience of modeling and analysis, all the crops of the country are classified into a number of major groups (plantation and gardening, fishing and forestry) the above considerations, the following variables, coefficients and data can be identified and defined:

Variables

X: the area (hectare) of land to be using (plantation and gardening, fishing and forestry) after increasing prices energy carries (first phase 2010 and second phase 2014)

I: the amount (metric tons) of crop (plantation and gardening, fishing and forestry) that should be imported after increasing prices energy carries (first phase 2010 and second phase 2014)

Coefficients

A: yield rate coefficient that is the amount of production (metric tons) per hectare of crops (plantation and gardening, fishing and forestry) after increasing prices energy carries (first phase 2010 and second phase 2014)
C: cost coefficient that is the cost (Rial) of production per hectare of lands (plantation and gardening, fishing and forestry) after increasing prices energy carries (first phase 2010 and second phase 2014)

B: contribution coefficient that is the benefits (Rial) that can be obtained per hectare of land $=(P_{ijk} \times A_{ijk} - C_{ijk})$ after increasing prices energy carries (first phase 2010 and second phase 2014)

P: the market price (Rial) of crop per metric ton after increasing prices energy carries (first phase 2010 and second phase 2014)

IC: contribution (in Rial per ton) from import of crop (market revenue - import cost) for after increasing prices energy carries (first phase 2010 and second phase 2014) crops

Data

D: yearly demand (metric tons) of crops (plantation and gardening, fishing and forestry) after increasing prices energy carries (first phase 2010 and second phase 2014)

C_a: capital available (Rial), this indicates the total amount of money that can be invested for cropping after increasing prices energy carries (first phase 2010 and second phase 2014)
The linear programming model for the crop planning is described below.

- ***Objective function***

The objective function of the model is to maximize the total contribution (cultivated + imported)

$$MaximazeZ = \sum_i \sum_j \sum_k B_{ijk} X_{ijk} + \sum_i \sum_j \sum_k I_{ijk} CI_{ijk} \quad (1)$$

- ***Constraints***

(i) Food demand constraint. This constraint represents that the sum of local production and the import quantity of crops in a year must be greater than or equal to the total requirements in the country. The constraint may be of two kinds

$$\sum_i \sum_j \sum_k A_{ijk} X_{ijk} + I_{ijk} \geq D_{ijk} \quad (2)$$

$$\sum_i \sum_j \sum_k A_{ijk} X_{ijk} \geq D_{ijk} \quad (3)$$

(ii) Capital constraint. The total amount of money that can be spent for crop production must be less than or equal to the capital available/budget.

$$\sum_i \sum_j \sum_k C_{ijk} X_{kij} \leq Ca \quad (4)$$

(iii) Area and import bound constraint. Sometimes, the amount of area to be used for certain crops is restricted

Area bound

$$\sum_i \sum_j \sum_k X_{ijk} \le a \quad (5)$$

Import bound

$$\sum_i \sum_j \sum_k I_{ijk} \le b \quad (6)$$

GP formulation

Goal programming deals with multiple goal situations within the linear programming structure. The GP takes the advantage of LP structure to solve it using the widely available LP packages. As mentioned earlier, the goals in GP are ranked in order of their importance. For example, reducing import may be more important than capital requirements in our case problem. The allocation decisions are made such that the sum of the undesirable deviations from the goals is minimized. It is assumed that the deviations from target goals are allowed with appropriate penalty. It makes GP more flexible decision making tool than LP. Although there are a number of multiple criteria decision making tools, we chose goal programming (GP) because of its simple structure, and it is easy to use and understand. The other reasons for choosing GP as the decision tool for this situation are as follows:

- In practice, we like to find a 'satisfactory' solution rather than an optimal one.
- The requirements and constraints in the real world are not always rigid; that is, deviations from targets may be acceptable, especially when trade-offs are permitted. Goals in GP are prioritized in three different ways: ordinal, cardinal, and a mixture of the two (Turban and Meredith, 2011)
- Ordinal ranking. Goals are listed in the order of their importance. P_1 designates the priority level of the most important goal, P_2 designates the second most important goal, and so on.
- Cardinal ranking. A specific weight is assigned to each of the deviations. These weights show the relative importance of each deviation.
- A mix of the two. Mix of ordinal and cardinal ranking.

The priorities of the goals are expressed in the objective function's coefficients of the GP.
To formulate the goal program, we first convert the given goals into goal constraints. Import reduction is chosen as the first goal and then capital requirements. The goals are written according to their importance as follows:

1. Import restriction: minimize the dependency on import of basic food like cereal.
2. Capital restriction: minimize the investment required for cultivation.
3. Contribution maximization: maximize the return from cultivated land.

The goal constraints of the case problem are given below.
Import goal restriction

$$\sum_i \sum_j \sum_k I_{ijk} + d_1^{-} - d_1^{+} = b \quad (7)$$

Capital goal restriction

$$\sum_i \sum_j \sum_k C_{ijk} X_{ijk} + d_2^- - d_2^+ = C_a \tag{8}$$

Contribution goal restriction

$$\sum_i \sum_j \sum_k B_{ijk} X_{ijk} + \sum_i \sum_j \sum_k I_{ijk} CI_{ijk} + d_3^- - d_3^+ = EC \tag{9}$$

Where EC is the expected contribution per year, and d^- and d^+ are the underachievement and overachievement deviations from the goals.
In GP, it is required to set a target for each goal. These target values are used as the right hand side (RHS) value of the goal constraints. The RHS values for import goal restriction and capital goal restriction are same as the corresponding LP value. We need to set a target for the RHS (defined as EC) for the contribution goal restriction.
The objective of the goal program is to minimize the weighted sum of undesirable deviations. In our case, the undesirable deviations are:

- Excess import than the set target or overachievement of import expectation d_1^+
- Over use of capital or overachievement of capital availability d2+
- Less contribution or underachievement of contribution target d_3^-

So the objective function of the GP is

$$Minimize Z_1 = w_1 d_1^+ + w_2 d_2^+ + w_3 d_3^- \tag{10}$$

Where w_1, w_2 and w_3 are the weight assigned to the undesirable deviations.
We use cardinal ranking since the dimensions of the deviations are different. In this case problem, we assume that $w_1 > w_2 > w_3$.
So the resulting goal programming formulation is:
Minimize the objective function in (7)
Subject to Goal constraints: (8)-(10)
System constraints: (2)-(6) and
Non-negativity constraints.

RESULTS AND DISCUSSION

There are three sectors (plantation and gardening, fishing and forestry) in the country the decision makers are interested in an aggregate.
Results of modeling agricultural sector in order to investigate effects of rising the prices of energy carriers.
Decision making for agricultural sector modeling is highly complicated and difficult. Hence, it's divided into subsets including plantationand, gardening, fishing and forestry. Required information for modeling such as prices levels, production level, costs, imports with prices of indigenous products and boundary prices, indigenous demands and capital was calculated after changing prices of energy carriers during first and second phases of Iranian (table 1) subsidy reform plan evaluated using input - output tables in 2011. Moreover, area of

cultivated lands (plantation and gardening) production area of fishing products and forests area (table 4) without accounting for pastures and shrubberies were achieved from agricultural statistic reports during 2007-2012.

Results of modeling Agricultural sector based on linear programming

Linear programming model is currently consisted of decision variables cultivated area, imports and restrictions. According to results of linear programming (table 6) in first subsidy reform plan, area of cultivated lands (both in plantation and gardening) has drastically declined to 10345789, whereas import of crop products has significantly increased to 24279001 and subsequently, investment has considerably dropped (table 5). One main cause of the excessive imports of plantation and gardening crops is inclusion of grains. With respect to high per capital consumption of grains (including wheat, barley, corn and rice) and in one hand in gardening sector because of more costly combinations of inputs and rather greater contribution of energy carriers generally it has higher intermediate costs than other subsets of agriculture resulting in investment level decrease and whereby increase in imports of strategic crops. Also, according to results of linear programming in second phase of subsidy (table 6) reform plan (2014), area under cultivation of plantation and gardeninghas decreased to 13243567. Although, imports of these products have reached to 17890675 and input investment has declined but in comparison to first phase of the plan, area of cultivated lands and input investment have risen (table 5). Because of their strategic and pivotal role of grains during second phase, investment has increased on these crops and used area for fishing has extended to 823456 compared to the times before reform plan and under forestry lands have reached 2878945 and on the other hand, imports of forestry and fishing productshavereached zero. During second phase, fishing and forestry areas were 703557 and 2345672, respectively and no related imports were made.

Results of modeling modelingAgricultural sector based on goal programming

According to the results of goal programming in first phase of subsidy (table 7) reform plan and, in comparison with linear programming, area of plantation and gardeninglands has increased to 12546789 and imports of plantation and gardening crops have decreased to 19876567. Also, input investment has experienced a significant growth suggesting decrement in their imports and greater investment in this part, whereby increasing in under cultivation area (table 5). Under forestry and fishing areas were 923456 and 278955, respectively and imports related to these subjects were zero. Also, based on results of goal programming in second phase of subsidy (table 7) reform plan and compared with goal programming in first phase (2014), area under cultivation of plantation and gardening cropshas risen to 15067564 and imports of plantation and gardening cropshave decreased to 18987689 and input investment has considerably increased(table 5). It indicates thedecrease in imports of plantation and gardening cropsand enhanced investment in this area and consequently an increasing in under cultivated lands. Under utilization area for forestry and fishing is 945678 and 2775672, and their related imports are 12345 and zero, respectively. Based on results of goal programming in second phase of subsidy reform plan, compared to it's first phase, imports have increased and used area (hectar) has drastically risen and also input investment has enhanced.

CONCLUSIONS

Planning of any kind essentially involves decision making of some kind. This paper presents a national crop planning problem of a third world country. Crop planning involves a complex set of decision-making activities that are interrelated. Two versions of the crop-planning problem are described in the paper. One uses single objective linear programming approach. It's then argued that crop planning must deal with multiple conflicting objectives and a goal programming model is then presented. To compare the solutions of the two models the objectivesin GP model are derived from the LP model. The LP model offers a unique optimal solution and thus it's rigid in nature and suggests using less capital, more imports and cultivation of less amounts of plantation and gardening crops. On the other hand, the GP model generates alternative satisfactory solutions and thus provides more insights into the crop-planning problem and suggests using more capital, less imports and cultivation more of plantation and gardening crops. Also agriculture officials sought to achieve a desired profit and cost reduction and thereare other objectives such as reducing import. The goal programming model allows authorities to take into account the concerns and import fees and simultaneously maximize your profits This model is able to collect set of mutual goals, and sometimes the opposite farmmanagers who are concerned aboutside effects of production processthismodel can usetoexaminethe situation under control and take appropriate decisions and because of the central role of strategic plantation and gardening crops especially the cereals (wheat, corn, barley) and their role in food security in the country, the decision makers can choose one of the satisfactory solutions based on other factors like implementabilty, limitations, politics and etc.

Our immediate future plan is to use the crop-planning problem in a multiple objective decision support system (MODSS) framework (Korhonen et al., 2006). This will enable the decision makers to interact with the system on-line and carry on various what-if analyses to learn more about the possible solutions and thus obtain more insights about the problem.

Appendix A

Table A. The names of crops/crop-group are given in table A

Crop number	Crop/group name
1	Plantation and Gardening
2	Fishing
3	Forestry

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Table 1: price rising of energy carriers during first(2010) and second (2014) phases of Iranian Price (rial)

Energy carriers		Befor targeting	First Phase(2010)	Second phase(2014)
Gasoline	Liter	1000	4000	7000
White oil	Liter	165	1000	1500
Gasloil	Liter	165	1500	2500
Black oil	Liter	95	2000	2500
Liquid gas	M^3	400	5400	6500
Electricity	Kw/h	129	450	550
Natural gas	Kw/h	122	700	840

Resource: Results of research

Table 2: forecast import stodomestic prices after rising pricesof energy carriers (million rial)

Agricultural sector	Plantation andGardening	Fishing	Foresty	Agricultural sector
The first Phase targeted	25910098	20000	70001	The first Phase targeted
The second Phase targeted	26490000	25678	79765	The second Phase targeted

Resource: Results of research

Table 3: forecast import stoborder prices after rising pricesof energy carriers (million rial)

Agricultural sector	Plantation andGardening	Fishing	Foresty
The first Phase targeted	24276000	22340	55000
The second Phase targeted	24600456	20987	50034

Resource: Results of research

Table 4: the area used for Agricultural sector

Agricultural sector Year	Plantation	Gardening	Fishing	Foresty
85-86	13420000	2700000		
86-87				
87-88				
88-89			535938	2660000
89-90	12000000		539943	
90-91	12740000		532437	2660000

Resource:Agricultural statistic reports

Table 5: available capital and costs after rising pricing energy carries (million rials)

Agricultural sector	Capital	Cost	Capital	Cost
PlantationandGardening	98649456	153963817	110549448	267298294
Fishing	12654000	6025244	14682010/1	8203043/9
Foresty	15506879	3721688	17506585/5	4760299/7

Resource: Results of research

Table 6: area (hectar) and import(million rial) on results liner programing

Shocks				
Agricultural sector	Area	Import	Area	Import
PlantationandGardening	10345789	24279001	13243567	17890675
Fishing	823456	0	703557	0
Foresty	2878945	0	2345672	0

Resource: Results of research

Table 7: area (hectar) and import(million rial) on results goal Programing

Shocks	The first phase of targeted subsidies		The first phase of targeted subsidies	
Agricultural sector	Area	Import	Area	Import
Plantation and Gardening	12546789	19876567	15067564	18987689
Fishing	923456	14789	945678	12345
Foresty	2768955	0	2775672	0

Resource: Results of research