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# Analysis of soil nutrient management for rice production in Mazandaran

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**ABSTRACT**

*Rice is one of the main products of Mazandaran province in Iran. Ratio of nitrogen, potassium and phosphorus in soil is important to increase rice yield and improves economic position of farmers. Fertilization is the most common way to feed soil. In this study according to data from the province's rice research institute in 2010, the optimal combination of different kinds of fertilizer for rice cultivation is obtained by using the goal programing. Sensitivity analysis with respect to price and value of various fertilizers in rice production, shows the optimum amount of nutrients. By using game theory the contribution of each nutrient is obtained.*

**Keyword:** rice, goal planning, fertilizer, game theory, Mazandaran

## INTRODUCTION

Rice is one of the oldest plants after the wheat, that has the highest under cultivation of world's agricultural land, But in terms of energy production is the first in world ranking and It's cultivation in many regions relatively high water is extended in recent years.(Van Ittersum, M.K., Rabbinge, R., 1997)

Cultivation of rice in Iran is 615 thousand hectares in 2010, according to Statistical Center of Iran, with average production of 4764 kg/hectare. As the annual consumption per person is 38 kg of rice, the shortage of rice supply from abroad is required. Most rice cultivation in Gilan and Mazandaran in Iran are with 66.12 percent of the total area under cultivated. Mazandaran province has 33.37 percent of land under rice cultivation.

According to Rice Research Institute of Mazandaran local varieties of rice cultivation in 2010 was138 thousand hectares, That this amount of rice needs 27 thousand tons of Urea(N), 7 thousand tons of Phosphorus(P)and 7 thousand tons of Potash(K).Also the area under cultivation of high rice varieties is 101 thousand hectares that needs 25 thousand tons of Urea(N), 5 tons of Phosphorus(P)and 5 tons of Potash(K).A large percentage of phosphorus used in previous years remains for next year. Nitrogen in the soil is not stable and leaches, that causes several stage using. Excessive use of N-P-K in the land caused negative effects on the amount and quality of the product. So for sustainable production of cereals, management of fertilization and soil nutrients by preventing surplus use of fertilizer to prevent damage to the soil is needed. (Minguez, M.I., Romero, C., Domingo, J., 1998)

In agricultural planning, most GP applicationscan be used to address the problem of determiningan optimum-cropping pattern by consideringseveral goals. Wheeler and Russell (1977) used aGP model to analyze the plantation of a farm inthe United Kingdom and Ghosh et al. (1993, 1995) presented a model for the allocation of land undercultivation for production of crops in differentseasons in a year. Also, several studies have beenused in natural resources planning (Romero, 1986) livestock ration formulation (Rehman and Romero, 1984, 1987), and sugar beet fertilizer combination problems. (Minguez et al. 1988)

There are limited studies in goal programming in Iran to use in agriculture. Asadpour et al. (2007) developed a decision model to determine multi objective model were optimum cultured in Dasht Naz of Sari. Keramatzade et al. (2007) optimal allocation of water and use it to prioritize the different areas with use goal programming for Barezu Shirvan dam. Mohammadian and kohansal in 2007 use Fuzzy goal programming for determine optimum culture corps. Faskhodi et al. (2008) analysed land use pattern in East area of Esfahan using the goal programming model. Mozaffari et al.(2008) have acquired decision support model for optimal allocation of water for various uses for Amir Kabir dam. Khosravi and Sabouhi (2009) used the ordinal goal programming model for comparison between the optimal economic culture model and environmental culture in Dasht Razaghan of Fars. Bakhshoodeh and Fatthi (2010) analysed soil nutrition management for corn production using game theory for kooshakak of Fars province.

## MATERIALS AND METHODS

There are several different models of Soil and nutrient management and determine the optimal combination of fertilizers. Nutritional needs of soil and to reach the spending for minimum cost of fertilizer that must be taken in the field of decision-making process. The goal programming is a method that solves the problems with some of farm management, this approach has many applications in operations research (Rehman, T., Romero, C., 1987).

Goal programming based on optimal achieving to several goals, has been developed simultaneously. Linear programming models usually have a purpose, that to maximize profits or minimize that cost. While in the real world, an enterprise can pursue several goals simultaneously. For example, an enterprise may have several objectives such as better quality, increase market share, increase productivity and profitability is up. In this case, the goal programming is able to examine several targets simultaneously.(Ghosh, D., Pal, B.B., Basu, M., 1993)

Goal programming is approach for any purpose which, as a specific goal is determined. In practice this may not achieved goals And there is some deviation between the goals and target that each deviation unit, will be the penalty. Ultimately, the target in goal programming is minimizing these penalties.

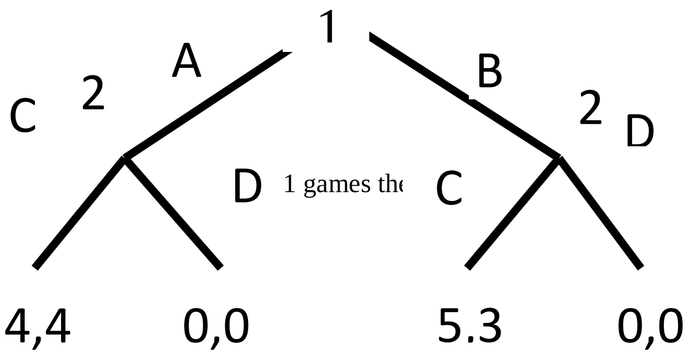
Characteristics of goal programming based on the ideas of Simon (1955) is based on are being met goals. Simon thought in today's complex organizations, decision makers are not trying to maximize a utility function. In fact conflict between the goals and completeness of the information available is a hamper at present mathematical model of consumer preferences. This method is more apparent by describing Charnez and Cooper (1961) andthe goal programming term for the first time was used. Goal programming application usage was low in the economic literature until the mid-'70s. Because of Lee's work (1972) and Ignizio (1976) began his goal programming to succeed.

Goal programming model can be divided into two categories:
a. In the first group to unwanted deviations from the targets due to their relative importance weight is given to the decision maker and their sum is at least. Deviations of target means that it is possible that Greater than or less than the target expected to be achieved. . The diversion created by two variables and the weight to these variables, their sum is at least. This program is called weighted goal programming .

b. Some goals are often more important than others. The goals are a deviation in one direction may be more important than others to have. In this way deviation variables to a number of priority levels are assigned and the minimum. This method is based on the assumption that the decision maker can all purposes related to a project to identify and classify them based on optimal to degree of importance. Game theory is the study of opposites and cooperation and decisions taken by the players, indicating that these decisions are interdependent on each other. Traditional applications of game theory define and study equilibrium in these games. In equilibrium, each player of the game has adopted a strategy that cannot improve his outcome, given the others' strategy. A game consists of a set of players, a set of moves (or strategies) available to those players, and a specification of payoffs for each combination of strategies. Most cooperative games are presented in the characteristic function form, while the extensive and the normal forms are used to define noncooperative games.

The extensive form can be used to formalize games with a time sequencing of moves. Games here are played on trees. Here each vertex (or node) represents a point of choice for a player. The player is specified by a number listed by the vertex. The lines out of the vertex represent a possible action for that player. The payoffs are specified at the bottom of the tree. The extensive form can be viewed as a multi-player generalization of a decision tree. (Fudenberg&Tirole 1991)

In the game pictured to the left, there are two players. Player 1 moves first and chooses either A or B. Player 2 sees Player 1's move and then chooses C or D. Suppose that Player 1 chooses B and then Player 2 chooses C, then Player 1 gets 5 and Player 2 gets 3.




In this paper, a priority based linear GP technique has been used to obtain the nutrient requirement for rice production by determining the optimum fertilizer combination. For the best possible solution, sensitivity analysis has been performed on the cost of various fertilizer combinations with various production levels. Finally, a best combination has been determined by applying the Game Theory technique. The model has beenused for determining the best fertilizer combination for rice production during the 2010 in Mazandaran.

The general priority based GP model (as defined by Ghosh, 2003) can be stated as follows:
Find X $(x_1,x_2,\ldots,x_n)$so as to,

Minimise $P_1(w_{i1}^- d_{i1}^- + w_{i1}^+ d_{i1}^+)$,
Minimise $P_2(w_{i2}^- d_{i2}^- + w_{i2}^+ d_{i2}^+)$,
.
.
Minimise $P_j(w_{ij}^- d_{ij}^- + w_{ij}^+ d_{ij}^+)$,
.
.
Minimise $P_J(w_{iJ}^- d_{iJ}^- + w_{iJ}^+ d_{iJ}^+)$, $i = 1,2,\ldots, m$,

Subject to :
$F_i(x) + d_i^- - d_i^+ = b_i$ , $i = 1,2,\ldots, m$,

and
$w_{ij}^-, w_{ij}^+, d_{ij}^-, d_{ij}^+, d_i^-, d_i^+, X \geq 0$
for $i = 1,2,\ldots, m$, $j= 1,2,\ldots,J$

where $F_i(x)$ $(i = 1,2,\ldots, m)$‹is the ith function (linear) of decision vector X , bi is the aspiration level of the ith goal $P_j(j=1,2,\ldots,J;\ J\leq m)$ is the jth priority factor assigned to the set of goals that are grouped together in the problem formulation, $d_i^-$, $d_i^+$ are the under and over-deviational variables corresponding to the ith goal, $w_{ij}^-$ and $w_{ij}^+$ are the numerical weights associated with the under and over-deviational variables $d_{ij}^-$ and $d_{ij}^+$ at the priority level $P_j$ . Here, $d_{ij}^-$ and $d_{ij}^+$ are renamed for the actual deviational variables $d_{ij}^-$ and $d_{ij}^+$ respectively.

To formulate the model for the problem, the model variables, constants and coefficients are defined as follows:

2.1.Decision variables
$X_n$ Amount of fertilizers (n=1,2,…,N) in the mixture.

2.2. Coefficients and constants
$C_n$ Unit cost for fertilizers $X_n$(n=1,2,…,N) in the mixture
$A_n^q$ Unit amount of nutrient, q(q=1,2,…,Q) in fertilizer $X_n$(n=1,2,…,N)
$L^q$ Lower limit of nutrient, q (q=1,2,…,Q)
$U^q$ Upper limit of nutrient, q (q=1,2,…,Q)
T Total cost of fertilizer
Y Production of rice per unit area of land

a , b Factors that determine the yield of crop per unit consumption of fertilizer combination

2.3. Goal constraints

(i) Total cost: To avoid any types of unwanted expenditure there should be an estimated fertilizer cost (T) for a year. The goal equation can be presented as:

$$\sum_{n=1}^{N} C_n x_n + d^-_1 - d^+_1 = T \quad (1)$$

(ii) Lower limit of nutrient: To ensure a good yield from the rice farm, there should be, at least, a minimum amount of nutrients in the fertilizer combination. The goal equation can be represented as:

$$\sum_{n=1}^{N} A_n^q x_n + d^-_{q+1} - d^+_{q+1} = L^q \quad (2)$$

(q=1,2,…,Q)

(iii) Upper limit of nutrient: To avoid any excess application of nutrient in the fertilizer combination, there should be an upper limit for each nutrient in the combination. The goal equation can be presented as:

$$\sum_{n=1}^{N} A_n^q x_n + d^-_{Q+q+1} - d^+_{Q+q+1} = U^q \quad (3)$$

(q=1,2,…,Q)

(iv) Yield goal: Under normal conditions, application of nutrients to the soil is directly proportional to the yield of crops. That is the yield can be defined in the form of y=ax+b. It is difficult to determine the values ofa and b in any practical situation. However, this form seemed logical and can be determined by various interactions among fertilizers in the combination which have their own separate effects on the soil and yield of crop.So, these have to be measured and taken into consideration for the determination of parameter values of a and b. This can be achieved by defining the relationship of two point estimates and solving simultaneous equations in the same manner as done for linear functions. The Goal equation can be written as:

$$\sum_{n=1}^{N} x_n + d^-_{2Q+2} - d^+_{2Q+2} = Y - b \quad (4)$$

(v) Flow constraint: Rice cropping period is nearly three months in a year. Fertilizers used in previous season may not be utilized fully. So, a maximum of certain percentage (s) of the primary nutrient requirements, applied during the previous season may not be required to apply in the next season. It is assumed that the primary nutrients are applied in the previous season through the use of (N _ r) fertilizers.
So, the flow constraint can be written as:

$$(1-s/100)\sum_{n=r+1}^{N} A_n^q x_n \leq (s/100)\sum_{n=1}^{r} A_n^q x_n \quad (5)$$

(q=1,2,…,Q)

Game model

We used different estimates ($T_1, T_2, \ldots, T_i$) for the costs of different fertilizer combinations, which are the decisions of farmers as per the availability of budget for that season. Farmers have another decision on rice yield ($Y_1, Y_2, \ldots, Y_j$) for that season as per the demand. In Table 1, $b_{ij}$ is the amount of total nutrients (N–P–K) in the fertilizer mixture, which is to be applied per unit area of land. So, $(\sum_{n=1}^{N} A_n^q x_n) b_{ij}$ is associated with the ith decision on availability of fund and jth decision on demand for yield. Here, $T_i$ is the total cost in fertilizer combination corresponding to the decision i on availability of fund and $Y_j$ is the yield of crop corresponding to the decision j on demand for its yield. The saddle point, i.e., $\min_j \max_i (b_{ij}) = \max_i \min_j (b_{ij})$of the game model will show the optimal policy of the farmer to take the decision on fertilizer combination.

**Table 1 Payoff matrix**

| Decision as per availability of fund (i) | Decision on demand (j) | | | | | |
|---|---|---|---|---|---|---|
| | $Y_1$ | $Y_2$ | ... | $Y_j$ | ... | $Y_J$ |
| $T_1$ | $b_{11}$ | $b_{21}$ | ... | $b_{1j}$ | ... | $b_{1J}$ |
| $T_2$ | $b_{21}$ | $b_{22}$ | ... | $b_{2j}$ | ... | $b_{2J}$ |
| ... | ... | ... | ... | ... | ... | ... |
| $T_i$ | $b_{i1}$ | $b_{i2}$ | ... | $b_{ij}$ | ... | $b_{iJ}$ |
| ... | ... | ... | ... | ... | ... | ... |
| $T_I$ | $b_{I1}$ | $b_{I2}$ | ... | $b_{Ij}$ | ... | $b_{IJ}$ |

## RESULTS AND CONCLUSION

Our fertilizer combination plan for rice production is for the State of Mazandaran, in Iran. In 2010, 205Thousand hectares of land was usedfor rice production and the yield was 5664.39 kg/ha.For ever increasing requirements of food grains, farmers at the state level as well as, in the country, have used increasingly high yield varieties (HYV) of crops and are practicing increasing intensities of cropping with high level of N–P–K fertilizers specially during the last four decades. The rice growing soil required these three major nutrients. It is well recognized that N and P are the most limiting factors for rice production, and K also possess limiting status in many districts of the state. Hence high yield of rice cannot possibly be obtained without proper balanced fertilizer of N–P–K.

An investigation was carried out to study the N–P–K requirement on the growth and yields oftransplanted rice. The maximum grain yield can be obtained with the application of N–P–K throughdifferent fertilizers as described in Table 2. The maximum and minimum requirements of those nutrients, for our study region, are recommended by Soil Testing Laboratory of Iranian Council ofAgricultural Research (ICAR) as 120–160 kg/ha of N, 110–140 kg/ha of P and 70–110 kg/ha of K. To demonstrate the model, data for the current year (2010) has been collected from the Directorateof Agriculture, Government of Iran. The costs ($C_n$) and composition of the available fertilizer ($A_n^q$) mixtures are shown in Table 2.

**Table 2 Data definition**

| Variable (in kg) | Fertilizer | N (%) | P2O5 (%) | K2O (%) | Price (Rials/kg) |
|---|---|---|---|---|---|
| $X_1$ | Urea | 46 | - | - | 900 |
| $X_2$ | Single Super Phosphate (SSP) | - | 16 | - | 520 |
| $X_3$ | Super Phosphate Trip | 14 | 35 | 14 | 1030 |
| $X_4$ | Potassiumchloride | - | - | 60 | 820 |
| $X_5$ | Fullmacroof Agriculture | 15 | 8 | 15 | 1150 |
| $X_6$ | Potassium sulfate | - | 50 | - | 1070 |
| $X_7$ | Di Ammonium Phosphate (DAP) | 18 | 46 | - | 1280 |
| $X_8$ | Ammonium Phosphate | - | 45 | - | 1280 |

3.1. Goal constraints
Total cost:

$$\sum_{n=1}^{N} C_n x_n + d^-_1 - d^+_1 = T \quad (n=1,2,\ldots,8) \qquad (6)$$

Lower limit of nutrients:

$$\sum_{n=1}^{N} A_n^{ni} x_n + d^-_2 - d^+_2 = L^{ni} \ (\geq 120) \qquad (7)$$

(n=1,2,…,8) Nitrogen

$$\sum_{n=1}^{N} A_n^{ph} x_n + d^-_3 - d^+_3 = L^{ph} \ (\geq 110) \qquad (8)$$

(n=1,2,…,8) Phosphorus

$$\sum_{n=1}^{N} A_n^{po} x_n + d^-_4 - d^+_4 = L^{po} \ (\geq 70) \qquad (9)$$

(n=1,2,…,8) Potassium

Upper limit of nutrients:

$\sum_{n=1}^{N} A_n^{ni} x_n + d^-_5 - d^+_5 = L^{ni}$ (≤160) (10)

(n=1,2,…,8) Nitrogen

$\sum_{n=1}^{N} A_n^{ph} x_n + d^-_6 - d^+_6 = L^{ph}$ (≤140) (11)
(n=1,2,…,8) Phosphorus

$\sum_{n=1}^{N} A_n^{po} x_n + d^-_7 - d^+_7 = L^{po}$ (≤110) (12)

(n=1,2,…,8) Potassium

Yield goal:
Based on the experience of farmers (as defined in the goal equation (4)), values of a and b have been calculated and presented in the following equation:

$3.59 \sum_{n=1}^{N} x_n + d^-_8 - d^+_8 = Y - 1.73$ (13)

3.2. Flow constraints
It is assumed that a maximum of 40% of primary nutrient requirements are applied during previous year through the use of $X_6$, $X_7$, $X_8$.

3.3. Priority structure
As per the decision-making environment, priority structure of the problem can be defined as follows:

P1 : Minimise $(d^-_2 + d^-_3 + d^-_4)$
P2 : Minimise $(d^+_9 + d^+_{10} + d^+_{11})$
P3 : Minimise $(d^+_1 + d^+_5 + d^+_6 + d^+_7 + d^-_8)$.

The problem has been executed using a GP programming package where Ignizio's (1976) algorithm for GP has been implemented in C++ and solved. The following results are obtained after the execution of 13–18 iterative steps for each set of values of estimated budget and yield target. Payoff matrix of decisions in various conditions is displayed in table3.

The saddle point is $\min_j \max_i (b_{ij}) = \max_i \min_j(b_{ij}) = 442.342$ This implies the optimal policy of the farmer for making decision on fertilizer combination.

**Table 3 Optimum decision under various conditions**

| Decision as per availability of fund (i)(Rial) | Decision on demand (J) (kg/ha) | | $Min_j$ |
|---|---|---|---|
| | 5600 | 5650 | |
| 60000 | 325.986 | 281.980 | 281.980 |
| 55000 | 289.702 | 412.062 | 289.702 |
| 50000 | 442.342 | 489.020 | 442.342 |
| 45000 | 404.453 | 374.965 | 374.965 |
| $Max_i$ | 442.342 | 489.020 | |

Here the fertilizer combination is to be applied at the rate of 442.342kg/ha, the cost of combination of above fertilizers is Rials. 50000 kg/ha and the yield is 5600kg/ha. Moreover, it is observed that with the above combination the rice yield for the year 2010 has been raised from 5450 to 5600kg/ha.

The methodology for optimum fertilizer combinations presented in this paper is an alternative totraditional optimization techniques based on Linear Programming. It may be useful for agricultural planners who can guide the farmers for fertilizer nutrient combinations. This paper attempts to deal with the nutrient management problem using GP technique. Although the work for rice production based on nutrient management is limited to a particular agro-climatic condition of Mazandaran, it may be summarized that the yield of rice can be increased substantially along with maintenance of soilfertility. In the constraint definition some practical aspects may come into consideration in differentagro-climatic conditions. However, those may be included in the model.

**Table 4 The amount of compound fertilizer**

| Typeof fertilizer | Consumption of fertilizers in crop year(kg) |
|---|---|
| $X_1$(0-0-46) | 260.87 |
| $X_2$ (0-16-0) | 675 |
| $X_4$(60-0-0) | 173.32 |
| $X_5$(15-8-15) | 106.03 |
| $X_7$(18-46-0) | 78.26 |

In table 4, the final values are determined by a combination of fertilizers. The number in parentheses is the percentage of nutrients available in (N-P-K). According to the results, using of some fertilizers isn't economically justified. As the values obtained in this study, total amount of fertilizer used in the region is more than requirement.

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