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# Optimum Allocation of Required Fertilizer Combination in Rice Cultivation Using Approach of Goal Programming, Case Study: Mazandaran city

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## Abstract

**Rice is highly nutrient grains and as high most food consumed two- thirds world population is considered to be due to its specific characteristics, as a fill food consumption need of human food. The purpose of this study is determination of the optimum combination of fertilizers used in cultivation of this product, including Nitrogen fertilizer, Ammonium phosphate, Di Ammonium phosphate, Triple superphosphate, Potassium chloride and Potassium sulfate according to the nutrients (NPK) in the crop year 2008-2009. The study uses Euclidean distance function to measure distances of all possible solutions from the ideal solution. The results showed that the total cost equal to 28600, 31800 and 26400 Rials, the optimum combination of fertilizer related to priority levels of (P1, P2, P3), (P1, P2, P3) and (P1, P3, P2) with Euclidean distances, 142.77, 147.53 and 131.7 respectively. Also, results showed that the highest amount in optimum combination is related to Mono Ammonium phosphate fertilizer and the highest and lowest amount of nutrients is related to phosphor and Potassium, respectively.**

***Keywords:*** Goal Programming, Rice, Fertilizer, NPK, Mazandaran, Iran.

## Introduction

Mazandaran province is the largest rice producer in the country, that in the crop year of 2008-2009, it allocated 35.9 percent of the whole rice production of country to itself. The plant is one of the oldest plants that after wheat have allocated the most cultivated lands in the world. In addition, according to the consumption pattern, it is the most significant energetic food. In recent years, cultivation of rice has been developed in relatively highly- irrigated regions of country (Agricultural Jihad Institute of Mazandaran province, 2009).

Azote is the main element forming of protein and makes protoplasm in rice. Generally, some of the roles are played by azote in the plant structure, specially leaves and stalk. The primary activity of Azote is making required protoplasm protein for expanding, stalk, palmate and leaf production. The average amount of it in dry matter of plants is 1-2 percent which occasionally reaches (4-6) percent. Among 16 main elements for the production of a yield, Azote takes the $4^{th}$ place. The plant absorbs Azote in the form of nitrat and it causes the synthesis of proteinaceous materials.

Also, potassium element activates the enzyme complex in biochemical processes and plays a crucial role for activating carbonic gas regenerative enzymes. In plants which have potassium shortage, the amount of starch and protein in leaves is reduced and adverse effects of additional Azote is intensified. By the way phosphor is one of the most important elements in rice. It has an role in plant photosynthesis and its shortage is a restrictive factor for plant photosynthesis. This element is one of the constituents of nucleic acid and it is the fundament of core composition in live cells of rice. As results, phosphor is necessary to expand palmate and palmate is dependent on the reproduction of cells. In addition, as a main constituent of high energetic materials (Adenosine Di- phosphate and Adenosine tri- phosphate). It has a crucial role in application and maintenance of energy. Some of the effects of phosphor shortage consist of thin and dark leaves, reduction in plant's length, reduction in palmate number and dilation in productivity and ripping of the seed (Dolco, 2001).

The aim of this study is use the Euclidean distance function to measure distances of all possible solutions from the ideal solution. The optimum solution is determined from the minimum distance between the ideal solution and other possible solutions of the problem. Have been done many local and foreign studies about Goal Programming Model which will be mentioned that as follow:

Barallian *et al*., (2010) determined the optimum amount of land for maximize income and mass-production of energy under 3 limitations water, land and labor using Fuzzy Goal Programming. Results showed that among the others limitations of available water are most important. Also, results were indicated competition among optimization of two objectives (income and energy).

Lin *et al*., (2009) studied the effect of plant density and nitrogen fertilizer rates on grain yield and nitrogen uptake of hybrid rice (*Oryza sativa* L). According to these experimental results, applications of N fertilizer can be effectively reduced with concomitant increases in yield. Increasing plant densities associated with SRM[1] were found to decrease the crop performance as increase in yield per unit of input (seeds, water, N fertilizer) were negative at the margin.

Jafari *et al*., (2008) in a study, have been considered the lexicographic linear goal programming (L. L. G. P) model for identifying the optimal compound of agriculture product in the rice farmland of Maydonsar Koshteli village from Babol country, a city in the north of Iran. Results showed that there are many differences among allocated surfaces in different rice. In other words, the planting sample in the region isn't an optimal sample, and owing to this, the difference among incomes of this region is too less than the cases can gain more because of the optimal using of the total production elements.

Esfahani *et al*., (2008) demonstrated that there was a statistically significant ($p < 0.01$) relationship between leaf N concentration and chlorophyll meter (SPAD- 502) readings. Therefore, the results suggest that nitrate and agrochemicals discharge from agriculture cause surface water pollution, due at least in part to high rates of N fertilizers. Nitrates and agrochemicals can also be accumulated in groundwater stores.

Ayoola and Makinde, (2007) in a study with subject complementary organic and inorganic fertilizer application: influence on growth and yield of cassava/maize/melon intercrop with a relayed cowpea, their results showed that maize performed best in terms of growth and yield with complementary application of inorganic and organic fertilizers. Melon yield under the various fertilizer treatments did not differ statistically in both years. Cassava root yield with complementary application was comparable with yield from sole inorganic fertilizer treatment in the first year of experimentation when sole organic fertilizer had a significantly lower yield.

Dinesh *et al*., (2003) had studied a goal- programming (GP) model for management decision- making for sugarcane fertilizer mix problems. Sensitivity analysis on the priority structure of the goals has been performed to obtain all possible solutions. The study uses Euclidean distance function to measure distances of all possible solutions from the ideal solution. The optimum solution is determined from the minimum distance between the ideal solution and other possible solutions of the problem.

Konstantina *et al*., (2003) showed how to construct equity mutual fund portfolios involving two opposing financial goals, risk and return. They have applied GP to Greek Mutual funds data under a set of different policy scenarios to provide decision support for investor/portfolio managers in composing efficient mutual fund portfolios that meets the investment preferences.

Also, Wheeler and Russell, (1977) used the GP technique. Similarly, Ghosh, Pal and Basu (1993) and (1995), presented a GP model for the allocation of land under cultivation for production of different crops.

Also, Minguez, (1988) used GP for fertilizer combination problem for sugar beet production problem. Gunes and Umarosman, (2005) used a Fuzzy Goal Programming.

## Materials and Methods

The goal programming (GP) technique in solving agriculture management decision- making problems involves multiple objectives. It has become a widely used approach in Management Science/ Operations Research Studies (Romero, 2004).

The general mathematical form of priority based GP model can be written as follow (Dinesh *et al.*, 2004):

$$Min \quad \overline{X} = \left[P_1(d^-),....,P_k(d^-),...,\overline{P}_K(d^-)\right] \tag{1}$$

$$P_k(d^-) = P_k(\mu_{jk}^- d_{jk}^- + \mu_{jk}^+ d_{jk}^+ \quad , \quad k = 1,2,....,K(\leq m) \tag{2}$$

$$Subject \quad to:$$

$$f_j(\overline{x}) + d_j^- - d_j^+ = b_j \quad , \quad \overline{x}, d_j^-, d_j^+ \geq 0 \quad , \quad d_j^- + d_j^+ = 0 \qquad j = 1,2,...m \tag{3}$$

[1] Standard rice management

$$\sum_{j=1}^{J} C_j X_j + d_1^- - d_1^+ = T \quad , \quad j = 1,2,..., J \tag{4}$$

$$\sum_{j=1}^{J} A_j^{(q)} X_j + d_{q+1}^- - d_{q+1}^+ = L^{(q)} \qquad q = 1,2,..., Q \tag{5}$$

$$\sum_{j=1}^{J} A_j^{(q)} X_J + d_{Q+q+1}^- - d_{Q+q+1}^+ = U^{(q)} \tag{6}$$

$$(-p)\sum_{j=1}^{r} A_j^{(q)} X_j + (100-p)\sum_{j=r+1}^{J} A_j^{(q)} X_j \le 0 \tag{7}$$

This model includes (6) decision variables such as Azote fertilizer ($x_1$), Di Ammonium phosphate ($x_2$), Mono Ammonium phosphate ($x_3$), Super phosphate triple ($x_4$), Potassium chloride ($x_5$) and potassium sulfate ($x_6$). Also, model includes (7) restriction related to total expenditure and upper and lower limits of nutrients available in fertilizers (NPK) in 3 priority levels ($p_1$, $p_2$, $p_3$) which their priority structure is as follows:

$$P_1 = \mathrm{d}_2^+ + d_3^+ + d_4^+ \tag{8}$$

$$P_2 = \mathrm{d}_5^+ + d_6^+ + d_7^+ \tag{9}$$

$$P_3 = \mathrm{d}_1^+ + \mathrm{d}_5^+ + d_6^+ + d_7^+ \tag{10}$$

Equations 1-3 shows the general form of the goal programming (GP) techniques with relevant constraints in which , $\overline{X}$ Vector of *K* priority achievement functions, $P_k$ The *k*–th, ($k = 1,2,...., K(\le m)$) priority factor assigned to the set of goals that are grouped together in the problem formulation and the priority factors have the relationship of ($P_1 \ge P_2 \succ ... \succ P_K$), which indicates that the goals at the highest priority level $P_1$ are achieved to the extent desired before the attainment of the goals at the second priority level $P_2$, $f_i(0)$ *i*–th goal constraint function, $\overline{x}$ Vector of decision variables, $d_{ik}^-$ , $d_{ik}^+$ Under and over deviations respectively, from the *i*–th goal level $b_i$, at the priority level $P_k$. $\mu_{ik}^-, \mu_{ik}^+$ Numerical weights associated with deviational variables $d_{ik}^-$ , $d_{ik}^+$ respectively, the *k*–th priority level $P_k$.

Applied the above priority based GP model to the fertilizer mix problem, the equations 4-7 as goal constraints appear in the model:

Equation (4) shows that a certain amount of money should be provided for fertilizer expenditure for a planning year. The expenditure should take into account the possible returns on the amount investment and as such the amounts spent should not exceed the existing expected value of perfect information. Where $X_j$ amount of fertilizers (j = 1, 2, ..., J) in the mixture, $C_j$ unit cost for fertilizers, T total cost of fertilizers.

Equation (5) shows that to maximize the rice production, there should be a minimum amount of nutrients L (*q*) in fertilizer combination, where $A_j^{(q)}$ unit amount of nutrient, $q = 1,2,..., Q$ in fertilizer $X_j$.

Equation (6) shows that the determination of the amount of fertilizer application takes into consideration the soil content, soil fertility, especially low N and P in the soil. To avoid any excess application of nutrient in the fertilizer combination, there should be an upper limit of nutrients ($U^{(q)}$) in the combination.

Equation (7) shows that to assure the process of complimentary application of nutrients in the soil between the previous application and new application, therefore is assumed that the p percentage of primary nutrients is applied in the previous year by consuming (J- r) fertilizers.

The objective function of the model is the inclusion of deviational variables with their respective weights in the decision- making environment at different priority levels. The performance of the model depends on the appropriate priority structure of the model. To select the appropriate priority structure of the model, sensitivity analysis on all priorities is performed. The ideal solution is then calculated from all different solution obtained from different priority structures. The Euclidean distance function is used to measure distances of all possible solutions from the ideal solution. The distance can be measured as follows:

$$D_n = \sqrt{\left(\sum \left([X]_j^* - [X]_j^n\right)^2\right)} \quad , \quad n = 1,2,....., N \tag{11}$$

$$j = 1,2,......, J = Max\{[X]_j^n\}$$

Where, $[X]_j^*$ is the ideal solution, $D_n$ distances of all possible solutions from the ideal solution and N are number of priority structures?

Data used in this study that consist of percentage of NPK element which is available Azote, Phosphate (Super Phosphate Triple, Di ammonium phosphate and Mono ammonium phosphate and Potassium). Fertilizer (Potassium Chloride and Potassium Solphate) and the cost of per unit of studied fertilizers are collected of agricultural jihad institute of Mazandaran which is related to rice productions in crop year of 2008 – 2009.

## Results and Discussion

The amounts of fertilizers costs and percentage of nutrients available in each kind of fertilize is demonstrated in table 1:

Table 1. Amounts of cost and percentage of nutrient in fertilizers

| Title Fertilizer | N(%) | P(%) | K(%) | Cost |
|---|---|---|---|---|
| N ($X_1$) | 46 | - | - | 450 |
| Di ammonium phosphate ($x_2$) | 19 | 20 | - | 530 |
| Mono Ammonium Phosphate (X3) | 11 | 24 | - | 530 |
| Super Phosphate Triple ($x_4$) | - | 48 | - | 515 |
| Potassium Chloride ($x_5$) | - | - | 51 | 305 |
| Potassium Solphate ($x_6$) | - | - | 42 | 530 |

Source: research findings

According to the results of Table (1), in this study 6 kind of important fertilizer are used which play an effective role in the period of plant growth. Azoth fertilizers have the most amount of Nitrogen; Super phosphate triple fertilizers have the maximum amount of phosphor and potassium chloride fertilizer have the maximum amount of potassium. Also, Di Ammonium phosphate, Mono Ammonium phosphate and potassium solphate have the most cost per unit of rice production and potassium chloride has the lowest cost per unit of rice production.

Table 2. Priorities and corresponding solution

| Run | Priorities | Cost (Rials) | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | Distance |
|---|---|---|---|---|---|---|---|---|---|
| 1 | $p_1 = d_2^+ + d_3^+ + d_4^+$<br>$p_2 = d_5^+ + d_6^+ + d_7^+$<br>$p_3 = d_1^+ + d_5^+ + d_6^+ + d_7^+$ | 28600 | 22.5 | 37.3 | 0 | 122.5 | 0 | 4.63 | 142.77 |
| 2 | $p_1 = d_2^+ + d_3^+ + d_4^+$<br>$p_3 = d_1^+ + d_5^+ + d_6^+ + d_7^+$<br>$p_2 = d_5^+ + d_6^+ + d_7^+$ | 28600 | 18.3 | 32.05 | 0 | 119.62 | 0 | 3.57 | 145.07 |

Source: research findings

According to the results of table (2), the optimum combination of fertilizer with the expenditure of 28600 Rials is related to priority level ($p_1$, $p_2$, $p_3$) or in other words, the first scenario with Euclidean distance of 142.77 and with amounts 22.5, 73.3, 0.0, 122.5, 0.0, 4.63 which suggests the optimum solution than second scenario, because of lesser Euclidean distance.

According to obtained results of table 3, the optimum combination of fertilizer under 2 scenarios of expenditure by values of 37800 and 26400 Rial is related to Euclidean distance of 147.53 and 131.7, respectively. The optimum combination of fertilizer amounts in the first priority level consist of Azote 63.4 (kg), Mono Ammonium phosphate 115.6 (kg), potassium chloride 37.3 (kg) and potassium soleplate 28.01 (kg). Also, results showed that Di ammonium phosphate and super phosphate triple fertilizers have been removed from optimum combination. Also, optimum combination of fertilizer amounts in the second priority level consists of Azote 6.8 (kg), Mono Ammonium phosphate 108.19 (kg), super

Table 3. Sensitivity analysis on cost of combination of fertilizers

| Run | Priorities | cost | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | Distance |
|---|---|---|---|---|---|---|---|---|---|
| 1 | $p_1 = d_2^+ + d_3^+ + d_4^+$<br>$p_2 = d_2^+ + d_3^+ + d_4^+$<br>$p_3 = d_1^+ + d_5^+ + d_6^+ + d_7^+$ | 31800 | 28.01 | 37.3 | 0 | 115.6 | 0 | 63.4 | 147.53 |
| | $p_1 = d_2^+ + d_3^+ + d_4^+$<br>$p_2 = d_1^+ + d_5^+ + d_6^+ + d_7^+$<br>$p_3 = d_5^+ + d_6^+ + d_7^+$ | 26400 | 42.18 | 24.15 | 22.36 | 137.51 | 0 | 3.57 | 145.91 |
| 2 | $p_1 = d_2^+ + d_3^+ + d_4^+$<br>$p_3 = d_5^+ + d_6^+ + d_7^+$<br>$p_2 = d_1^+ + d_5^+ + d_6^+ + d_7^+$ | 31800 | 24.15 | 30.21 | 0 | 112.38 | 0 | 0.07 | 152.11 |
| | $p_1 = d_2^+ + d_3^+ + d_4^+$<br>$p_3 = d_1^+ + d_5^+ + d_6^+ + d_7^+$<br>$p_2 = d_5^+ + d_6^+ + d_7^+$ | 26400 | 36.21 | 26.21 | 32.14 | 108.19 | 0 | 6.8 | 131.7 |

Source: research findings

Phosphate triple 32.14 (kg), potassium chloride 26.21 (kg) and potassium sulphate 36.21 (kg) fertilizers. In this combination Di ammonium phosphate has removed from the combination. Also, results showed that the highest amounts in optimum combination are related to Mono Ammonium phosphate and the maximum amounts of nutrient are related to phosphor.

In this section, the optimum combinations of fertilizer in three scenarios in the form of table (4) as follow:

Table 4. Decision Table

| cost | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | N | | P | | K | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Percent | kg | Percent | kg | Percent | kg |
| 28600 | 22.5 | 37.3 | 0 | 122.5 | 0 | 4.63 | 12.45 | 17.437 | 73.19 | 65 | 10 | 2 |
| 31800 | 28.01 | 37.3 | 0 | 115.6 | 0 | 63.4 | 14.14 | 19.8 | 71.7 | 62.8 | 10 | 2 |
| 26400 | 36.21 | 26.21 | 32.14 | 108.19 | 0 | 6.8 | 35.15 | 21.5 | 65.19 | 57.1 | 15 | 3 |

Source: research findings

Also, according to table(4), results showed the optimum combination of fertilizers amount and their nutrient (Azote, phosphate and potassium) in 3 scenarios of expenditure with amounts 26400, 31800, 28600 Rials, respectively. In the first, second and third scenarios, the optimum combination related to priority level of ($p_1$, $p_2$, $p_3$), ($p_1$, $p_2$, $p_3$) and ($p_1$, $p_3$, $p_2$). In addition, result showed that in all of the obtained optimum combination of fertilizers, among the most important nutrient, phosphor and potassium have the highest and the lowest amount respectively. Considering obtained results in the third scenario, Di Ammonium phosphate has been removed from optimum combination and Ammonium phosphate the highest amount among studied fertilizers.

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