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Designing a Multi-objective Decision Making Model to Determine the Optimal Cultivation Pattern in Dasht-e Naz Region in Sari City

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Abstract: In this paper we address a general Goal Programming (GP) model with linear objective, convex constraints and arbitrary component wise no decreasing norm to aggregate deviations with respect to targets. In order to have a better allocation of production resources like water, land, labour force and so on among various farming activities. We used the GP model that can take different objectives of managers based on their importance and priority in agricultural units. In this paper using true information about production resources and existing cultivation pattern in Dasht-e Naz Sari, this site is located in eastern north of Sari in Mazandaran province, Iran. Findings based on analyzing model outcomes, show that changing cultivation pattern based on model suggestion we can increase gross income as much as 336100 per hectare considering the manager's opinion. Also model show that regarding the limited water and land resources in optimal cultivated pattern, making a suggestion to increase the cultivation area of the spring crops, summer crop yield drops and fall crop yield increases, like wheat and canola.

Key words: Goal programming . multi-objective decision making . cultivating pattern . Dasht-e Naz

INTRODUCTION

Evidences and study results show that today most of the producers are more concerned about their own sense than the economical issues. So the outcomes are of low certainty and by chance. The crop intended to be produced is mostly selected regardless to the market status [1]. Regarding the objectives of the fourth development plan, aiming agricultural crop production increasing and making large productive units efficient, it is necessary to design a true crop cultivation pattern to make the most of production resources and achieve the most production capacity and increase the agricultural units' income [2].

It is important to design the cultivation pattern as a determination of the cultivation area and should be done in a way that in addition to make the most of existing and available capacities, it is possible to cover parts of national and regional needs. Such a design is a complicated process and like a multi variable function which makes the designer gather as much information as possible, hence the procedure selection, analyzing and combining of the information, considering the managers' proposed criteria is crucial and play an important role [3].

In empirical method, designing is based on the designer's experience and qualifications. In this way, designing is mainly done based on the designers ideas and no matter how much information has been gathered only a little of that might be applied because it is difficult for man's brain to process and combine lots of information at the same time and the personal ideas and tastes have a great impact on the design. Another problem arose is that even if the designer can optimize the conditions of the project; he is not able to anticipate unexpected and fast economical changes. If he applies a mathematical model in order to obtain a proper combination for his units production plan, he can put the change in the procedure just as the happen and with the least cost. So to have a combination of potentials, restrictions and need, based on technical, political and socioeconomic considerations, there is a necessity political and socioeconomic consideration; there is a necessity to apply a more efficient method to design so that there is a possibility to make the most of existing resources. Here by programming methods and modeling and also computers as fast and accurate devices are introduced as a great help to the cropping pattern designers [4].

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So it is necessary for all the agricultural managers to do their best to make as much effort as possible to increase agricultural products [4-10].

It is obvious that one of the ways is to apply mathematical programming model to determine crop cultivation pattern and also to make the most of existing production resources and factors which should be more and more considered [1].

Since economical plans are a key in management, applying fundamental programming methods is inevitable [3]. This paper is introducing the application of a multi-objective programming model to determine optimal cultivation pattern in large cultivation and industrial units. the program is to achieve several objectives which sometimes might be in contrast, is more applicable than the other economical ones [2] hopefully through the program, proposed achievements can be obtained and it can attract more and more programmers and executive managers.

MATERIALS AND METHODS

General structure of the model: Sometimes there might be contrasts between the objectives and the methods through which these objectives are going to be achieved also such contrasts might appear between production factors and the objectives. Therefore total value of the objectives, policies and the means to achieve is not necessarily equal to the sum of the components' value. So the combination should be defined to get to the best point. So the optimum combination of production regarding an optimum combination of objectives in time intervals and objective priority is important.

As mentioned in introduction, to analyze the information gathered from Dasht-e Naz station in Sari a multi-objective model is applied. This program was first introduced by Charnes and Cooper [3]. They introduced three different alternatives of multi-objective issues in their book called" Aristotle objective programming, Chi Bi Chef objective programming and prioritizing objective programming. In this paper the latter alternative has been applied. The third alternative is specific because it can give the managers the possibility to prioritize the objectives [11-12]. A prioritizing multi-objective program for optimal cultivation pattern has been applied gathering related statistical information from Dasht-e Naz agricultural production station. Therefore the crops in the region are categorized in three following categories:

- Spring crop including sprig soy bean, seed corn, grain corn and rice
- Fall crops including canola and wheat
- Summer crops including sorghum and soy bean

According to these making-decision variables, restrictions and model coefficients in order to design optimal cultivation pattern are determined as follow:

Acs = allocated land for cultivation crop c during season s.
C = 1,2,….,c Crop and s = 1,2,3,…S Season.
Total available land in season s in hectare = Ls.
Estimated available water in season s in cubic meter = EWS.
Estimated available labor force during a year in man-workday = EMD.
Estimated available cash for expenditures production stages during a year in Rials =ETC.
Required labor force per area unit to cultivate crop c in season s in man-workday = MDCS.
Estimated required water per area unit to cultivate crop c in season s in cubic meter = WCS.
Average production cost per area unit to cultivate crop c in season s in Rials = AVCCS.
Estimated production per area unit to cultivate crop c in season s in Kilograms = EPCS.
Optimum proposed production area (optimum objective) for crop c = ATPC.
Market price for crop c in harvest season s in Rials/Kg =MPCS.
Estimated gross income per area unit for crop c in season s in Rials / hectare =PRCS.
Optimum manager's proposed area for gross income for crop c in season s in Rials = PRTCS.
d_i^+ = Positive deviation from optimum objective (ideal).
d_i^- = Negative deviation from optimum objective (ideal).

General objective description in model structure: The most important manager's proposed objectives in the farm unit with following general structure in the model are considered [5].

Land application objectives: The most important manager's question is the area of the land on which the proposed objective could be achieved for different crops so the equation for land limitation enters the model:

$$\sum_{c=1}^{C} A_{cs} + d_i^- - d_i^+ = L_s, \quad s = 1, 2, 3 \quad i = 1,2, ...,n$$

Where n is the number of land limitation.

Production objectives: The equation of production limitation regarding distribution of different crop cultivation during the year has been put into the model as follow:

Table 1: A summary of the gathered information through questionnaires

Description	Corn (A_{73})	Wheat (A_{62})	Canola (A_{52})	Rice (A_{41})	Grain corn (A_{31})	Seed corn (A_{21})	Spring soybean (A_{11})	Sorghum (A_{82})
Production (Kg/Ha)	30000	2800	2500	5000	6000	1800	2700	2000
Price (Rials/Kg)	80	460	1050	1300	590	2600	1100	1100
Circulating capitol (1000 Rials/Kg)	1027	724.2	647.6	2251.5	1105	1725	857.4	822.4
Labor force (man-workday/ha)	19	15	15	39	24	22	20	20
Water requirement (cubic meter/ha)	3000	-	-	15000	4000	3000	2500	2500
Gross income (1000 Rials/ha)	1392.9	129.03	2054.1	2343.6	1448	2606.6	1999.2	1244.4

Total available labor force (man-workday during the year) = 116800; Total available turnover capitol = (1000 rails); Total value of proposed optimum gross income (1000 Rails); Total available water; Sum of available water in spring = 8664960; Sum of available water in summer = 5776640

$$\sum_{s=1}^{S} A_{cs}.EP_{cs} + d_i^- - d_i^+ = ATP_c,\ c = 1, 2, ..., C$$

Water consumption objectives: The equation of water consumption objectives for different areas of different seasonal crops has been put into the model as follow:

$$\sum_{c=1}^{C} A_{cs}.\ W_{cs} + d_i^- - d_i^+ = EW_s \qquad s = 1,2\ ,3$$

Labor force getting to work objectives: The equations of labor force getting to work in crop-production procedure during one Farming year have been put into the model as follow:

$$\sum_{c=1}^{C}\sum_{s=1}^{3} A_{cs}.\ MD_{cs} + d_i^- - d_i^+ = EMD$$

Cash investment objective: It includes needed cash capitol for preparation stages, planting, maintenance and harvesting of different crops. The equation has been put into the model as follow:

$$\sum_{c=1}^{C}\sum_{s=1}^{3} A_{cs}.\ AVC_{cs} + d_i^- - d_i^+ = ETC$$

Achieving optimum gross income objective: Planning to cultivate the crop aiming to achieve optimal gross income

$$\sum_{c=1}^{C}\sum_{s=1}^{3} PR_{cs}.\ A_{cs} + d_i^- + d_i^+ = PRT_{cs}$$

After designing the structure of the model using the information gathered through questionnaires and regarding priorities offered by the managers in Dasht-e Naz station the model was solved by LINGO software package .

Structures of prioritizing objectives: In this structure the following objectives are put in to the objective function respectively and the model is solved stage by stage so that we could get the proposed result [12-15].

- Minimizing deviation in positive direction to utilize the land during different season of the year(regulate the model to utilize the existing land and not more than that).
- Minimizing deviation in negative direction of optimum production objective (the objectives are defined by the managers of Dasht-e Naz station shown on the right side of the production equations).
- Minimizing deviation in positive direction to utilize water and labor force (regulate the model to utilize the existing water resources and labor force and not more than that).

Minimizing deviation in positive direction to utilize available circulating cash capitol and minimizing deviation in negative direction of optimum gross income objective based on these and using technical coefficients in (Table 1) triple procedure models are designed as follow:

Model of stage 1 of the first prioritize structure:

$$\text{Minimize}\ \ (d_1^+ + d_2^+ + d_3^+)$$

S.T.:

$$A_{11} + A_{21} + A_{31} + A_{41} + d_1^- - d_1^+ = 2000$$
$$A_{52} + A_{62} \qquad + d_2^- - d_2^+ = 3024$$
$$A_{73} + A_{83} \qquad + d_3^- - d_3^+ = 1662$$
$$A_{cs} \geq 0, \qquad d_i^+.d_i^- = 0$$

Model of stage 2 of the first prioritize structure:

$$\text{Minimize}\ \ (d_4^- + d_5^- + 1.5d_6^- + 2d_7^- + 1.5d_8^- + d_9^- + d_{10}^-)$$

S.T.:

$$A_{11} + A_{21} + A_{31} + A_{41} + d_1^- = 2000$$
$$A_{52} + A_{62} \qquad + d_2^- = 3024$$
$$A_{73} + A_{83} \qquad + d_3^- = 1662$$

Table 2: Analyzing the sensitivity of different prioritizing structures' outcomes (hectare)

S.N	Objective priority structure	Soybean	Spring corn	Seed corn	Grain Rice	Canola	Wheat	Corn	Summer soybean
1	$P1(d_1^+ + d_2^+ + d_3^+)$ $P2(d_4^- + d_5^- + 1.5d_6^-$ $+2d_7^- + 1.5d_8^- + d_9^- + d_{10}^-)$ $P3(d_{11}^+ + 2d_{12}^+ + 1.5d_{13}^+)$ $P4(d_{14}^+ + 2d_{15}^-)$	749.26	702.78	289.33	172.2	106.8	2316.43	453	0
2	$P1(d_1^+ + d_2^+ + d_3^+)$ $P2(d_{11}^+ + 2d_{12}^+ + 1.5d_{13}^+)$ $P3(d_{14}^+ + 2d_{15}^-)$ $P4((d_4^- + d_5^- + 1.5d_6^-$ $+2d_7^- + 1.5d_8^- + d_9^- + d_{10}^-)$	968.45	64.47	289.33	172.2	707.57	2316.43	453	0
3	$P1(d_1^+ + d_2^+ + d_3^+)$ $p2(d_{11}^+ + 2d_{12}^+ + 1.5d_{13}^+)$ $P3(d_4^- + d_5^- + 1.5d_6^-$ $2d_7^- + 1.5d_8^- + d_9^- + d_{10}^-)$ $P4(d_{14}^+ + 2d_{15}^-)$	749.26	702.78	289.33	172.2	106.8	2316.43	453	0

$$
\begin{aligned}
&2.7A_{11} + 2A_{83} && + d_4^- - d_4^+ = 2023\\
&6A_{31} && + d_5^- - d_5^+ = 1736\\
&1.8A_{21} && + d_6^- - d_6^+ = 1265\\
&5A_{41} && + d_7^- - d_7^+ = 861\\
&2.5A_{52} && + d_8^- - d_8^+ = 267\\
&30A_{73} && + d_9^- - d_9^+ = 13590\\
&2.8A_{62} && + d_{10}^- - d_{10}^+ = 6486\\
&A_{cs} \geq 0, && d_i^+.d_i^- = 0
\end{aligned}
$$

Model of stage3 of the first prioritize structure:

$$\text{Minimize} \quad (d_{11}^+ + 2d_{12}^+ + 1.5d_{13}^+)$$

S.T.:

$$
\begin{aligned}
&A_{11} + A_{21} + A_{31} + A_{41} && + d_1^- = 2000\\
&A_{52} + A_{62} && + d_2^- = 3024\\
&A_{73} + A_{83} && + d_3^- = 1662\\
&2.7A_{11} + 2A_{83} && - d_4^+ = 2023\\
&6A_{31} && - d_5^+ = 1736\\
&1.8A_{21} && - d_6^+ = 1265\\
&5A_{41} && - d_7^+ = 861\\
&2.5A_{52} && - d_8^+ = 267\\
&30A_{73} && - d_9^+ = 13590\\
&2.8A_{62} && - d_{10}^+ = 6486\\
&2.5A_{11} + 3A_{21} + 4A_{31} + 1.5A_{41} && + d_{11}^- - d_{11}^+ = 8664.96\\
&3A_{73} + 2.5A_{83} && + d_{12}^- - d_{12}^+ = 5776.64\\
&20A_{11} + 22A_{21} + 24A_{31} + 39A_{41} &&\\
&+15A_{52} + 15A_{62} + 19A_{73} + 20A_{83} + d_{13}^- - d_{13}^+ = 116800 &&\\
&A_{cs} \geq 0, \quad d_i^+.d_i^- = 0 &&
\end{aligned}
$$

Model of stage 4 of the first prioritize structure:

$$\text{Minimize} \quad (d_{14}^+ + 2d_{15}^-)$$

S.T.:

$$
\begin{aligned}
&A_{11} + A_{21} + A_{31} + A_{41} && + d_1^- = 2000\\
&A_{52} + A_{62} && + d_2^- = 3024\\
&A_{73} + A_{83} && + d_3^- = 1662\\
&2.7A_{11} + 2A_{83} && - d_4^+ = 2023\\
&6A_{31} && - d_5^+ = 1736\\
&1.8A_{21} && - d_6^+ = 1265\\
&5A_{41} && - d_7^+ = 861\\
&2.5A_{52} && - d_8^+ = 267\\
&30A_{73} && - d_9^+ = 13590\\
&2.8A_{62} && - d_{10}^+ = 6486\\
&2.5A_{11} + 3A_{21} + 4A_{31} + 1.5A_{41} && + d_{11}^- = 8664.96\\
&3A_{73} + 2.5A_{83} && + d_{12}^- = 5776.64\\
&20A_{11} + 22A_{21} + 24A_{31} + 39A_{41} &&\\
&+15A_{52} + 15A_{62} + 19A_{73} + 20A_{83} && + d_{13}^- = 116800\\
&857.4A_{11} + 1725A_{21} + 1105A31 &&\\
&+2251.5A_{41} + 647.6A_{52} + 724A_{62} &&\\
&+1027A_{73} + 822.4A_{83} && + d_{14}^- - d_{14}^+ = 4250000\\
&1.9992A_{11} + 2.6066A_{21} + 1.448A_{31} &&\\
&+2.3436A_{41} + 2.0541A_{52} + 1.2903A_{62} &&\\
&+1.3929A_{73} + 1.2444A_{83} && + d_{15}^- - d_{15}^+ = 8000\\
&A_{cs} \geq 0, \quad d_i^+.d_i^- = 0 &&
\end{aligned}
$$

The unsaid point in the model is the coefficients for deviations in the objective function [7].

The coefficients show the importance of each deviation. The importance is considered as a value determined by the manager showing the opportunity value of each deviation compared with the others. For example the coefficient 2 for d_7^- and the coefficient 1.5 for d_6^- and d_8^- show the importance of these deviations compared with the others at the same level of priority [8].

Next stage is selecting the best prioritizing structure from among the different structures. As it can be seen in Table 2 the model is solved with three different prioritizing structures with different objective prioritization level.

Selection of the best prioritizing structure: In order to select the best prioritizing structure from among the ones offered by the managers of Dasht-e Naz station Euclidean distance function has been used. The basis of the selection is to maximize the land surface allocated to each crop using different prioritizing methods for the objectives. In fact the function determines a kind of variance of the best outcome for the manager at the level of the first objective in all the prioritizations. Since the land is considered as the most important production factor by the manager, it is put on the top of priority list. (Table 2) to determine the best prioritize structure, the allocated land for each crop in different season during the year, is used. To do so, the optimum surface of the allocated land for crop c during the cultivation season s, (Acs) is determined from different structures. Then Euclidean distance function is used to make the best decisions about the cultivation pattern [6].

IfA^t_{CS}, the allocated land for crop c during the cultivation season s, is based on prioritize structure t in Table 2, a series of answers for land allocation among different crop during season s is obtained from solving different models with different prioritize structure (A_{CS})

If the maximum allocated land for each crop during the cultivation season s is selected from among the different prioritize structures and shown as A^*_{CS}, using Euclidean distance function, from among t = 1, 2,…,p priorities, the best prioritize structure is selected then; so that it has the least deviation from the optimum acceptable answer.

Euclidean distance function for the tth answer for A_{CS} can be defined as follow:

$$D^{(t)} = [\sum_{c=1}^{C}\sum_{s=1}^{S}(A^*_{cs} - A^t_{cs})^2]^{1/2}$$

Table 3: Comparison between existing cultivation pattern and the optimal one

Crop	Existing cultivated area (hectare)	Optimal cultivated area (hectare)
Spring soybean A11	516	968
Seed corn A21	506	64
Grain corn A31	217	289
Rice A41	123	172
Canola A52	89	708
Wheat A62	1081	2316
Corn A73	302	453
Summer soybean A83	190	0

where D^t is the related deviation to the answer of tth prioritizing structure. Now to approach the optimum answer (the least variance from the best answer from different prioritizing structure) the minimum deviation obtained from the optimum answer for the decision maker, is calculated as follow:

$$\text{Minimum } \{D^{(t)}\} = D^p \qquad t=1,2,...,p$$

CONCLUSIONS AND DISCUSSION

Studies on Dasht_e Naz cultivation and industrial company in sari, as one of the large agricultural production units, show rather high deficient outcomes due to lack of proper programming for developing optimum cultivation patterns.in fact the existing cultivation patterns are not aiming towards what managers have in mind. In order to show the problem we consider the outcomes from the existing programming and cultivation patterns. as mentioned before the managers have had so many different goals in mind that achieving them were in contrast with the others. Here by a pattern is introduced for the managers through which they can achieve their goals as much as possible. The model also gives a report on shortages and excesses of the resources. As it can be seen in Table 3 there is a lot of differences between allocated land for different crops in existing system and that in the system where the model is applied. According to obtained optimum answers from the different prioritizing structures for objectives; the allocation of resources for different crops is not based on optimization regulations in order to achieve the advanced goals. In other words the existing cultivation pattern in the area is not an optimum one. There is a large difference between the real income and that of the optimal model.

The income from production resources is very low due to lack of an optimal pattern; in fact the resources are being wasted in the area. (Table 4).

Table 4: Compare gross margin income and percentage variation (Figures in 1000 Rials)

Net income	Spring soybean (1)	Grain corn (2)	Seed corn (3)	Corn (4)	Wheat (5)	Canola (6)	Summer soybean (7)	Rice (8)
Existing	1031587	314216	1318939	420656	1394814	182815	236436	288263
Optimal	1936120	418949	168047	630983	2988889	1453419	0	403568
Variation percentage	87	33	-87	49	114	695	100	40

Total existing gross income = 5187726000 Rials; Total optimal gross income = 8000000000 Rials; Common (overhead) and personnel expenses have not taken in to account to obtain gross income from optimal pattern; Personnel expenses = 427187200; Common expenses = 727372800; the sum of the two expenses is equal to 1154560000 Rials. Subtracting it from optimal gross income, it is equal to 6845440000 Rials, which has a considerable increase

One of the managers' most important goals in both governmental and private sector is to achieve a reasonable logical and economical income level So that the final economical evaluation for economical units is based on this criterion.

Hereby we make a comparison between existing cultivation pattern and the optimum one based on multi-objective programming model.

Table 4 shows the gross income from the existing cultivation pattern and the optimal one and the variation percentage.

Therefore

- The multi-objective programming model is a good base, on which decision makers can apply the priorities to achieve the goals which are in contrast at an ideal level. It is realistically difficult and in some cases impossible to achieve all the advanced goals. But based on this model one can get the best from among the different objective prioritizing structures.
- In designing the optimal cultivation pattern in Dasht-e Naz in Sari there are different environmental restrictions which are not easily controllable, like rainfall in fall which can be a real concern and is not taken in to account? Anyway the multi-objective programming model opens a new horizon for decision makers to apply the priorities to design an optimal cultivation pattern in large cultivation and industrial units, aiming several different objectives.
- Outcomes from running the model and analyzing it show that from among all the production resources, water plays the most important role which is to be taken more care of, during spring and summer i.e. using the storing systems in the area we can store water from rainfall in fall and winter to compensate the shortage in summer.
- Outcomes from the model show that capitol is another productive resource which in this unit is low. Investment level based on the capitol attraction capacity is another concern which is determined in this model for the unit. This level is programmable and determinable; the outcomes show that the manager needs more money as much as 392860 Rials per hectare to achieve the designed goals, which should be provided in one way or the other.
- Another productive in-demand factor is labor force. The outcomes of the model show that the manager needs to hire as many as 27738 man-workdays more, during a year to achieve the goals completely.
- It is obvious that the manager can earn more gross income as much as 3361000 per hectare if he make changes in these resources(water, capitol and labor force)
- Outcomes of the model show that regarding the limited water and land resources in optimal cultivated pattern, making a suggestion to increase the cultivation area of the spring crops, summer crop yield drops and fall crop yield increases, like wheat and canola.

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