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Research Article

APPLICATION OF MULTI OBJECTIVE FUZZY COMPROMISE MATHEMATICAL PROGRAMMING IN DETERMINING THE OPTIMUM CROPPING PATTERN BASED ON THE CRITERIA OF SUSTAINABLE AGRICULTURE (CASE STUDY: CITY OF ISFAHAN)

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ABSTRACT
Agricultural activities are one of the major development parameters in countries like Iran, and this indicates the need for more attention to this sector. Increase of resource utilization efficiency by optimizing cropping patterns is a good strategy for the development of agricultural sector. In this study, optimal cropping pattern was determined by examining the Isfahan's current cropping pattern, using the gathered data relating to 2006, 2007 and 2012 with the objectives of maximizing production, maximizing food security, minimizing water consumption, maximizing gross margin, and minimizing the use of fertilizers. To achieve these objectives, compromised Multi Objective Fuzzy Compromise Non-Linear Programming (MOFCNLP) was used. In this method, with the aim of maximizing the weighted sums of fuzzy goals values, the area under cultivation are optimized in such a way to be Able to meet the mentioned objectives in the range of tolerance defined for them. Although, in many cases full realization of these goals in multi-objective model have less possibility compared to the single-objective models, But considering the outcome of the results and the assigning of weight to each of the objectives by the decision maker, which appears in the form of a composite distance goal function, it has Shown that a multi-objective model is superior to the current model and also to single objective models, compromising between multiple patterns. The implementation of this pattern in the study area, in addition to reducing the consumption of water and fertilizers, increases the gross margin. Moreover, this pattern results in stability in the current state of production and food security. Therefore, replacing the current pattern with Multi Objective crops pattern can cause desirable economic and environmental outcomes for the city of Isfahan.

***Keywords**: Cropping Pattern, Optimization, Multi Objective Fuzzy Compromise Nonlinear Programming*

INTRODUCTION
Agriculture is one of the most important sections of the economy and because of direct association with feeding Humans, follows several goals at the macro level, including achieving food security, achieving self-sufficiency and maximizing social profitability. On the other hand, at the micro level, farmers seek to maximize their profits. These goals at micro and macro levels may not be fully compatible (Jolayi and Jeiran, 2006). One of the major problems and the main characteristics of developing countries, including Iran is low efficiency in different economic sectors which is caused by lack of optimal allocation of production factors. Studies show that currently most of the producers pay less attention to economic issues and their production decisions is based on their feeling, which will lead to cultivating various crops resulting in random and unsecure incomes (Hoseinzade *et al.*, 2014). One of the main strategies to increase efficiency in agriculture is the correction cropping patterns according to economic criteria in different areas and also taking into account technical constraints and factors of production. Today's advances of humans, gives them the ability to make better use of these strategies. The advantage of modern methods to traditional methods is the optimal allocation of production factors to achieve maximum efficiency from their use (Mohammadi *et al.*, 2013).

Therefore optimization of cropping patterns and to make them operational is inevitable, not only to deal with drought and water shortages, but also to eliminate limiting factors and optimal utilization of existing resources (Amini *et al*., 2009).
In fact, optimization of cropping pattern, leads to greater efficiency, and many countries can solve the mentioned problems in the field of agriculture and horticulture, by designing and implementing optimum patterns through a specific program, In order to optimize the crops composition management, considering the regional and climatic challenges and opportunities, available resources and foundations, economic, social and cultural factors, modern technology and indigenous knowledge of farmers. Therefore it seems that with the cropping pattern optimization, we can move toward increased production and income, creation of jobs and reduction of poverty in the rural areas (Baniasadi and Zare, 2011).
Due to the reduced rainfall in recent years in Isfahan province, and increase of area under agriculture cultivation that has intensified the use of underground water resources, presenting a cropping Pattern to optimize water use and reduce the environmental impacts by reducing the use chemical fertilizers, is necessary (Erfanifar *et al.*, 2014).
In This study in addition to the above objectives, improving cropping patterns gross margin and proper attention to production of crops which have a greater role in providing the society's required energy (food security), are considered. It should be noted that the issue of decision making in the real world has two main features. Firstly, the issue is facing with the various and often Conflicting goals and secondly, describing the decision parameters is accompanied with uncertainty and ambiguity (Arikan and Gungor, 2007).
Obviously, one way to dealing with this problem is mathematical programming, which had optimal changes throughout the course of its development whenever the need has been felt. Due to the Multi Objective nature of this study, the conventional linear programming which is a single-objective optimization method cannot be used for Multi Objective decision making. In this context, goal programming is one of the leading tools for analyzing multi-objective decision making. Unlike linear programming models, fuzzy goal programming method allocates resources better by creating flexible goals (Asadpur, 2006).
In studies of cropping patterns of different areas conducted by Doppler et al. in 2002 and Rastegari and PurSabuhi (2010) realizing the objective of increased efficiency by providing the highest crops gross yield, were considered (Doppler *et al*., 2002) (Rastegari and PurSabuhi, 2010). On the other hand, the sustainable use of scarce water resources is a target for researchers and planners of water resources (MohamadReza *et al*., 2009) (Alimohamadi and Hoseinzade, 2010).
This goal, in addition to providing the highest gross yield and optimal use of water in cropping patterns optimization, has been one of the specific objectives of many studies, including (Bender and Simonovic, 2000), (Berbel and Gomez-Limon, 2000), (Bartolini *et al*., 2007), (Erfanifar *et al*., 2014), (Nikoue *et al*., 2011), (Pakdaman and Najafi, 2010), (Mohammadi *et al*., 2013) and (Taheri *et al*., 2009).
In this study considering the importance of determining the cropping pattern that provides multiple objectives of decision makers, It has been tried to use mathematical programming and fuzzy logic, to find the compromise between providing program objectives to improve efficiency, productivity and food security, with the goals of reducing water consumption and reducing the use of chemical fertilizers. To accomplish this goal, and considering that the city of Isfahan as an important hub of the country's agricultural production, this case study was conducted in this city.

MATERIALS AND METHODS

Introduction and Features of the Study Area

City of Isfahan, with an area of 853 square kilometers and semi-arid climate with relatively cold winters is located almost in the center of Isfahan province and is located At 51 degrees and 38 minutes eastern longitudes and 32 degrees and 39 minutes northern latitude. City's total area of cultivable land is 95,979 hectares of which 53,233 hectares is under irrigated cultivation (55%), and the remaining 42,746 hectares in the city, is the area of fallow.

Designing and Modeling of Decision-making Process

Mathematical planning is one of the methods of decision-making procedures that are used in the field of agricultural issues (Hazell and Norton, 1986).

Fuzzy logic goal process method includes three main stages, first making the data input fuzzy, second the fuzzy process and third the conversion of fuzzy to non-fuzzy (Zadeh, 1965).

In this study, according to the fuzzy state of the study goals and efforts to achieve a general goal based on maximizing the value of their mixed distance goal function, the structure of the decision making was designed as a fuzzy compromised nonlinear programming model (FCNLP), which has the ability to optimize multiple objectives simultaneously, with condition of resources limitation (Bender and Simonovic, 2000).

Pattern intended for the current study were designed, based on minimizing the mentioned goals' composite fuzzy distance, of the ideal limit of each individual goal. The following equations show the general form of chosen model (Barnes and Jones, 2000).

$$\sum_{j=1}^{M} \mathcal{W}\text{j} \times \lambda\text{j} \quad (1)$$

Subject to:

$$\lambda_j\left(Z_j^{max} - Z_j^{min}\right) + Z_j(x) \ll Z_j^{max} \;\; when\; Z_j^{min} \;\; is\; best \quad (2)$$

$$Z_j(X^*) - \lambda_j\left(Z_j^{max} - Z_j^{min}\right) \gg Z_j^{min} \;\; when\; Z_j^{max} \;\; is\; best \quad (3)$$

$$\sum_h \sum_i \sum_t A_{hit} X_{it} \ll B_h \quad (4)$$

$$xi \gg 0 \quad (5)$$

$$0 \ll \lambda \ll 1 \quad (6)$$

In the above equations, (X_{it}) is the area under cultivation of crop (i) in the year of (t), (λ_j) is the ideal value of (j)-th goal of decision pattern variables, that must be the optimal after the solution is obtained. The intended years are, the wet years, the normal years and the Drought years.

Equation (1) is the pattern objective function where λ is the weighted (composite) sum of the goals ideals in the current study. In this Equation ω_j is the weight the goal (j).

Equations (2) and (3) show the membership functions of the mentioned goals of studied pattern.

In These Equations, Z_j^{max}, Z_j^{min}, $Z_j(x^*)$ are the maximum, minimum and optimum value of j-th goal and x* is the optimal solution. Difference between Z_j^{max}, Z_j^{min} is defined as the tolerance limit (Nikuyi *et al*., 2011), (Erfanifar *et al*., 2014).

Equation (2) is intended as the membership of the goals which ideals are being maximized (production, food security and Program efficiency) While equation (3) is used for those goals which the ideals should be minimum (water and fertilizer consumption).

Therefore optimum values determined by the pattern should not be lower (for the maximizing ideals) or greater (for the minimizing ideals) than this critical limit.

Thus, ideal value of each of the goals should be obtained based on a single-objective optimization process.

Equations (1) to (3) summary subject to the technical limitations can be considered in the form of equation (4).

In this equation A_{hit} is the technical coefficient for (i)-th product, and (h)-th limit (production resources) and for (t)-th year, and B_h is balance of (h)-th limit (production resources) in the pattern (Bender and Simonovic, 2000).

In This study, the competing goals include Maximizing production in order to increase social benefits, maximizing food security in course of sustainable development, Minimizing water consumption in order to move towards sustainable development, maximizing gross margin in order to increase economic prosperity, And Minimizing use of chemical fertilizers to protect the environment.

Thus, this model's structure is a hierarchical one which the final decision is on top of that structure. This decision should establish a balance between the mentioned goals. Summation of these goals is available within the limitations of decision making space.

In order to form the membership functions of five Individual goals, initially the optimal or ideal values for each individual goal were determined. By using the term optimal value, maximum production (Z1), maximum food security (Z2), minimum water consumption (Z3), the maximum gross margin (Z4) and minimal use of chemical fertilizers (Z5) is intended. These values are determined in the single-objective programming model subjected to current limitations (eq. 4 and 5) and the objective functions (eq. 7 to 11).

Max Crop Production $CP = \sum_{i=1}^{10} \sum_{t=1}^{n3} X_{it} \times Y_{it}$ (7)

Max Calories Food Security $FS = \sum_{i=1}^{10} \sum_{t=1}^{n3} X_{it} \times FOS_i \times Y_{it}$ (8)

Min Apply Water Consumption $AW = \sum_{i=1}^{10} \sum_{t=1}^{3} WOC_i \times X_{it}$ (9)

Max Net Benefit $NB = \sum_{i=1}^{10} \sum_{t=1}^{3} P_{it} \times Y_{it} \times X_{it} - \sum_{i=1}^{10} \sum_{t=1}^{3} IC_{it} \times X_{it}$ (10)

Min Fertilizer Consumption $FC = \sum_{i=1}^{10} \sum_{t=1}^{3} NPK_{it} \times X_{it}$ (11)

In these Equations Y is the crop yield, FOS is the product's calorie, X is the area under cultivation, WOC is the product's net water consumption, P is the price of the product, IC is variable costs of production and NPK is the consumption of fertilizers. Indices (i) and (t) represent the product type and crop year.

Weight Distribution of Goals and Balance of the Factors

In fuzzy goal programming problems, Decision-makers usually have difficulty in distributing weight to goals, because there is a conflict in goals to achieve an appropriate level. In the first stage, the manager must determine the limits and criteria of decision-making to achieve the specific goals in each choice. Generally, this is a mental process that is not clearly defined and documented and is dependent on the needs and priorities of decision-maker (Barnes and Jones, 2000).

In the current study, to consider the needs and preferences of decision maker, weights was given to the competing goals in proportion to their importance, which was judged by exchange of ideas with other decision makers. Method of work included a pair wise comparison of the goals with each other, in the terms of needs and priorities of decision-making, and using a time spectrum, to give the preference of one goal to another which is a qualitative evaluation, a quantity or value. This information was gathered through questionnaires and interviews of several experts in the field. Then relative weight of each of the goals was determined of using Analytical Hierarchy Process (AHP) techniques. The sum of these weights is equal to one unit and the value of each is between zero and one. The balance Factor of the current study was considered as one unit which allows the highest substitution between different goals of model. Goals enter the objective function in order of the prioritization structure and model is solved step by step until final result is achieved.

$V(f_z) = \sum_{j=1}^{j} \mathcal{W}_j V(f_j)$ (12)

$\sum_{J=1}^{J} \mathcal{W}_J = 1$ (13)

Equation (14) represents the ultimate goal function obtained by giving weight to each of the objective functions (Ceriolli and Zani, 1990).

$V = \mathcal{W}_1 \times \mathcal{V}_1(f_1) + \mathcal{W}_2 \times \mathcal{V}_2(f_2) + \mathcal{W}_3 \times \mathcal{V}_3(f_3) + \mathcal{W}_4 \times \mathcal{V}_4(f_4) + \mathcal{W}_5 \times \mathcal{V}_5(f_5)$ (14)

$\text{Objective functions} = \mathcal{V}_1(f_1), \mathcal{V}_2(f_2) \ldots \mathcal{V}_5(f_5)$ (15)

$\text{Objective functions weight} = \mathcal{W}_1, \mathcal{W}_2, \ldots \ldots \mathcal{W}_5$ (16)

Goals weight values should be between the minimum and maximum. This measure takes into account the interaction between the objectives (Chiappero, 1996).

Table 1: Objectives weight in the planning

Objectives	**Relative weight**
Maximum Gross Margin	0/35
Minimum Water Consumption	0/20
Maximum Food Security	0/20
Minimum Fertilizer Consumption	0/10
Maximum Production	0/15

Method of Data Collection

Much of the information used in this study is based on existing documents' data. The basis of this information include Data of Agriculture Organization of Isfahan province, Isfahan Regional Water Company and Iran Statistical Center. In order to gather information, interviews will be conducted with some of the province farmers and experts, and an Average cost and revenue for each of the major products will be obtained, and through modeling, the feasibility of changes in products and changes the in cropping patterns to move toward oil seed production, will be calculated. The studied crops are major crops grown in the province, including wheat, barley, maize, sugar beet, cotton, beans and oilseeds such as canola, safflower, sesame and sunflower. The data used in this study were collected from various sources. Data related to existing cropping patterns, price, performance and cost of production various crops were obtained from Isfahan agriculture organization and data related to the irrigation water of various products was obtained from the Iran's water national document. Price, cost and calculated program efficiency and other information relating to various products, is related to 3 durations, normal year (2006-2007), wet year (2007-2008), and drought year (2012-2013), As a result Factor of time will be effective in the calculations.

RESULTS AND DISCUSSION

The Result of the Optimal Cropping Patterns in the City of Isfahan

Table (2) shows the studied crops' area of cultivation in the different patterns. In the pattern with the goal of maximizing the efficiency of program crops, the area under wheat cultivation has increased from 42600 hectares in 2006 to 48,135 hectares.

This value has increased in 2007 to 43,889 hectares and has decreased to 2,800 hectares in 2012. In the optimization of cropping pattern, having a minimum gross margin equivalent to the current pattern, has entered the model as a limitation.

Barley production under a compromised pattern has decreased 4100 hectares and 4949 hectares in 2006 and 2007 respectively, and is present in the optimal model having the same cultivation area of the current pattern in the 2012.

Cultivation area of maize has changed from 2058 hectares in 2006 to 1,046 hectares in the production maximization pattern while in the other models it has decreased to 500 hectares.

In 2012 the corn cultivation area has increased from 30 hectares in the current pattern to 10,792 hectares in compromised pattern, and this value for sugar beet has increased from 1500 and 1409 hectares in 2006 and 2007 years to 1529 hectares and 7651 hectares. In case of cotton and sunflower crops, area under cultivation has decreased compared to current pattern. Area under cultivation of Sesame and canola oil products has increased in compromised pattern.

Area under cultivation of Sesame crop in 2012 has increased from 25 hectares in the current pattern to 1379, 1616, 2287, 22015, 20661 and 2287 hectares under production maximization, maximizing food security, minimizing water consumption, maximizing the gross margin, minimization of fertilizer use, and compromise pattern, which indicates the plant's resistance to dehydration and also plant's adaptation to drought conditions.

In water consumption minimization pattern, area under cultivation of maize, beans, sunflower and canola is similar gross margin maximization pattern.

In fertilizer use minimization pattern, cropping composition of beans, sunflower and canola is similar to water consumption and gross margin maximization patterns. In minimal fertilizer use pattern, safflower entered the model with cultivation area of 2229 hectares in 2006 which was a normal year in terms of water, and finally has increased to 1278 hectares in compromised pattern.

The value for canola production has increased compared to the current situation.

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Table 2: Comparison between current and optimum crops pattern parameters for normal, wet and dry year (hectare) in the city of Isfahan

Crops Type	Cropp-ing seasons	Existing Cultivated area (ha)	Optimal Cultivated (ha) According to Optimization Goal					
			Crop Production	Food Security	Water Consumption	Gross Margin	Fertilizer Consumption	Fuzzy Compromise
Wheat	2006-2007	42600	43009	48388	49883	48135	47401	48135
	2007-2008	41500	34176	47107	51180	43889	38153	43889
	2011-2012	28000	2800	2800	2800	2800	2800	2800
Barley	2006-2007	8100	9203	5668	4000	4000	4000	4000
	2007-2008	7021	6031	10172	702	2072	7987	2072
	2011-2012	6300	6300	6300	6300	6300	6300	6300
corn	2006-2007	2058	1046	500	500	500	500	500
	2007-2008	1900	3145	772	190	190	190	190
	2011-2012	30	3411	19864	10792	190	190	10792
Sugar beet	2006-2007	1500	1488	1406	1470	1529	1655	1529
	2007-2008	1409	8788	853	1484	7651	7551	7651
	2011-2012	303	11955	70	647	1270	1351	647
Bean	2006-2007	25	70	70	70	70	70	70
	2007-2008	34	10	10	10	10	10	10
	2011-2012	0	20	20	20	20	20	20

Source: Research Findings

Continued Table 2: Comparison between current and optimum crops pattern parameters for normal, wet and dry year (hectare) in the city of Isfahan

Crops Type	Cropping seasons	Existing Cultivated area (ha)	Optimal Cultivated (ha) According to Optimization Goal					
			Crop Production	Food Security	Water Consumption	Gross Margin	Fertilizer Consumption	Fuzzy Compromise
Cotton	2006-2007	3000	2878	500	500	2535	1888	2535
	2007-2008	3715	370	370	1695	370	370	370
	2011-2012	1600	500	500	500	370	500	500
Sunflower	2006-2007	210	200	200	200	200	200	200
	2007-2008	250	100	100	100	100	100	100
	2011-2012	15	100	100	100	100	100	100
Sesame	2006-2007	30	100	100	100	100	100	100
	2007-2008	22	100	100	100	100	100	100
	2011-2012	25	1379	1616	2287	22015	20661	2287
Safflower	2006-2007	933	500	2127	500	1278	2229	1278
	2007-2008	1786	500	500	500	500	500	500
	2011-2012	1100	500	500	500	500	500	500
Canola	2006-2007	276	500	500	500	500	500	500
	2007-2008	200	500	500	500	500	500	500
	2011-2012	0	500	500	500	500	500	500

Source: Research Findings

The Effect of Cropping Patters with Different Goals on Various Indices of the City of Isfahan

Table (3) shows the indices of production, food security, water use, gross margin and the use of fertilizers, from each cropping pattern obtained from the optimization of the six goals (five solo goals and one compromised goal), and also from the current cropping pattern. Mentioned Indices values are considered the critical values for the current cropping pattern and ideal values for cropping patterns obtained from optimization of solo goals.

Table 3: The effect of cropping patters with different goals on various indices of the city of Isfahan

Variable description	Cropping seasons	Existing Cultivated	Optimal Cultivated (ha) According to Optimization Goal					
			Crop Production	Food Security	Water Consumption	Gross Margin	Fertilizer Consumption	Fuzzy Compromise
Production (kg)	2006-2007	379224100	379224100	379224100	379224100	379224100	379224100	379224100
	2007-2008	351492900	604877100	351492900	351492900	566873300	561940800	566873300
	2011-2012	177216400	697214900	224865000	177216400	177216400	177216400	177216400
Food Security (kcal)	2006-2007	1096650000	1096650000	1142144000	1120168000	1096650000	1096650000	1096650000
	2007-2008	1004626000	1004626000	1106915000	1004626000	1004626000	1004626000	1004626000
	2011-2012	551767200	551767200	817963400	551767200	573866100	551767200	551767200
Water Consumption (1000m^3)	2006-2007	292686	292686	292686	280691	292686	292686	292686
	2007-2008	291307	291307	291307	277090	291307	291307	291307
	2011-2012	181690	181690	181690	136471	181690	175315	136471
Gross Margin (1000 RLS)	2006-2007	6345973000	6345973000	6345973000	6345973000	6464222000	6345973000	6464222000
	2007-2008	5864631000	5864631000	5864631000	5864631000	6045996000	5864631000	6045996000
	2011-2012	14549180000	14549180000	14549180000	1454918000	7590547000	7155430000	14549180000
Fertilizer Consumption (kg)	2006-2007	40937420	40937420	40937420	40694860	40937420	40421650	40937420
	2007-2008	38725020	38725020	38679110	38725020	38725020	37011220	38725020
	2011-2012	23590990	16712160	23449640	15926420	11741210	11463290	15926420

Source: Research Findings

According to Table 3, the lowest water consumption is in the water use minimization pattern and then in compromised pattern and then in the minimized fertilizers pattern. Food security Indices In all patterns except the food security pattern and gross margin pattern (2012) has no change from current status which is critical.

Distance of each of these Indices values from critical values are entitled "distance to the crisis" and their distance from ideal values are entitled "distance to the ideal", which is shown In Tables 4 and 5 for the current status of cropping pattern as well as each of the studied goals. In 2006, in pattern maximizing gross margin pattern, gross margin Indices was fully realized, but fertilizer and water use was as same as the current situation which was critical. Failure to fulfill the goals of minimization water consumption and fertilizer in maximizing gross margin pattern is repeated in year 2007. Under this pattern in 2012, the goal of reducing the amount of fertilizer use to the 11,849,780 kilograms has been met. In gross margin maximization pattern, indices of food security and agriculture have been achieved in 2007 and 2012 respectively and show improvement compared to current status.

Table 4: Distance to the ideal levels for any of the indices

Variable description	**Cropping seasons**	**Existing Cultivated**	**Distance to the ideal levels**					
			Crop Production	**Food Security**	**Water Consumption**	**Gross Margin**	**Fertilizer Consumption**	**Fuzzy Compromise**
Production (kg)	2006-2007	0	0	0	0	0	0	0
	2007-2008	-253384200	0	-253384200	-253384200	-38003800	42936300	-38003800
	2011-2012	-519998500	0	-472349900	-519998500	-519998500	-519998500	-519998500
Food Security (kcal)	2006-2007	-45494000	-45494000	0	-21976000	-45494000	-45494000	-45494000
	2007-2008	-102289000	-102289000	0	-102289000	-102289000	-102289000	-102289000
	2011-2012	-266196200	-266196200	0	-266196200	-244097300	-266196200	-266196200
Water Consumption (1000m^3)	2006-2007	11995	11995	11995	0	11995	11995	11995
	2007-2008	14217	14217	14217	0	14217	14217	14217
	2011-2012	45219	45219	45219	0	45219	38844	0
Gross Margin (1000 RLS)	2006-2007	-118249000	-118249000	-118249000	-118249000	0	-118249000	0
	2007-2008	-181365000	-181365000	-181365000	-181365000	0	-181365000	0
	2011-2012	-6135629000	-6135629000	-6135629000	-6135629000	0	-6135629000	0
Fertilizer Consumption (kg)	2006-2007	515770	515770	515770	273210	515770	0	515770
	2007-2008	1713800	1713800	1667890	1713800	1713800	0	1713800
	2011-2012	12127700	5248870	11986350	4463130	277920	0	4463130

Source: Research Findings

But in two other years, these objectives have not met and their values show no change compared to current status. Indices of water and fertilizer use in the minimizing water consumption pattern are the ideal range, and fertilizer use has decreased to 242,560 and 7,664,570 kilograms in 2006 and 2012. Water consumption in this pattern has decreased in the amount of 45,219 thousand cubic meters compared to current pattern in 2012. Due to the considerable decrease in fertilizer consumption in water consumption minimization pattern, it can be concluded that there is a complementary relationship between the inputs of water and fertilizers in region crops, So that by changing the cropping pattern toward the products which require less water, fertilizer consumption also declined. Under the water consumption minimization pattern, goal of programs efficiency and production are in the crisis and have no change to the current status. In this pattern production and program efficiency Indices are in critical condition. In the fertilizer use minimization pattern, fertilizer use has decreased and met the ideal minimum amount of 12,127,700 kilograms in 2012. In the same year, water consumption has decreased 6,375 thousand cubic meters compared to the current pattern, but in other two years it is in critical condition. Under this pattern, the

Program efficiency and production indices have not been achieved. In food security maximizing pattern, food security Indices are in the ideal range, and fertilizers Use Indices in are unchanged in 2006 and 2007 compared to current situation. Water consumption And program efficiency under this pattern are in critical situation.

According to Table 4, in compromised goal pattern, Distance to the ideal for any of the indices is not zero except in water consumption (2012), Production (2006) and gross margin (all three years). In other words, Apart from the above, none of the goals have been fully realized, but At the same time Indices of gross margin, production (2007), fertilizer use (2012), and water consumption (2012) have made a distance from their critical points and have improved compared to current situation. Food security Indices remains as same as the current pattern. These distances have caused the compromised pattern of the goals to fulfill maximum ideal composite distance which put it in a more favorable position compared to other studied patterns.

Table 5: Distance to the crisis levels for any of the indices

Variable description	**Cropping seasons**	**Existing Cultivated**	**Distance to crisis levels**					
			Crop Production	**Food Security**	**Water Consumption**	**Gross Margin**	**Fertilizer Consumption**	**Fuzzy Compromise**
Production (kg)	2006-2007	0	0	0	0	0	0	0
	2007-2008	0	253384200	0	0	215380400	210447900	215380400
	2011-2012	0	519998500	47648600	0	0	0	0
Food Security (kcal)	2006-2007	0	0	45494000	23518000	0	0	0
	2007-2008	0	0	102289000	0	0	0	0
	2011-2012	0	0	266196200	0	22098900	0	0
Water Consumption (1000m³)	2006-2007	0	0	0	-11995	0	0	0
	2007-2008	0	0	0	-14217	0	0	0
	2011-2012	0	0	0	-45219	0	-6375	-45219
Gross Margin (1000 RLS)	2006-2007	0	0	0	0	118249000	0	118249000
	2007-2008	0	0	0	0	181365000	0	181365000
	2011-2012	0	0	0	0	6135629000	0	6135629000
Fertilizer Consumption (kg)	2006-2007	0	0	0	-242560	0	-515770	0
	2007-2008	0	0	-45910	0	0	-1713800	0
	2011-2012	0	-6878830	-141350	-7664570	-11849780	-12127700	-7664570

Source: Research Findings

Change Percentage of the Studied Indices in Different Cropping Patterns Compared to Current Pattern

Tables 6, 7 and 8 show change percentage of the studied indices in different cropping patterns compared to current pattern in the years 2006, 2007 and 2012. According to Table 6, maximizing gross margin pattern has been able to improve the gross margin of the current pattern by 2%. This pattern does not

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make a change in fertilizer and water consumption. By implementing the cropping pattern which minimizes consumption of water, food security, production and fertilizer consumption of the current pattern would be the same and there would be 5% decrease in water consumption. This indicates that the goal of minimizing water consumption and maximizing the food security of the population are in conflict with each other. With the implementation of the compromised goal pattern, program efficiency gave increased by 2%. Also the implementation of this pattern won't change the consumption of water and fertilizers compared to current situation.

Table 6: Change percentage of the studied indices in different cropping patterns compared to current pattern in the year 2006

Objective	Crop Production (kg)	Food Security (kcal)	Water Consumption ($1000m^3$)	Gross Margin (1000RLS)	Fertilizer Consumption (kg)
Existing Cultivated	379224100	1096650000	292686	6345973000	40937420
Crop Production	379224100	1096650000	292686	6345973000	40937420
Food Security	379224100	1142144000	292686	6345973000	40937420
Water Consumption	379224100	1120168000	280691	6345973000	40694860
Gross Margin	379224100	1096650000	292686	6464222000	40937420
Fertilizer Consumption	379224100	1096650000	292686	6345973000	40421650
Fuzzy Compromise	379224100	1096650000	292686	6464222000	40937420
The changes compared to the current situation					
Crop Production	0	0	0	0	0
Food Security	0	4	0	0	0
Water Consumption	0	2	-5	0	-1
Gross Margin	0	0	0	2	0
Fertilizer Consumption	0	0	0	0	-2
Fuzzy Compromise	0	0	0	2	0

Source: Research Findings

Table 7: Change percentage of the studied indices in different cropping patterns compared to current pattern in the year 2007

Objective	Crop Production (kg)	Food Security (kcal)	Water Consumption ($1000m^3$)	Gross Margin (1000RLS)	Fertilizer Consumption (kg)
Existing Cultivated	391492900	1004626000	291307	5864631000	38725020
Crop Production	604877100	1004626000	291307	5864631000	38725020
Food Security	351492900	1106915000	291307	5864631000	38679110
Water Consumption	351492900	1004626000	277090	5864631000	38725020
Gross Margin	566873300	1004626000	291307	6045996000	38725020
Fertilizer Consumption	561940800	1004626000	291307	5864631000	37011220
Fuzzy Compromise	566873300	1004626000	291307	6045996000	38725020
The changes compared to the current situation					
Crop Production	72	0	0	0	0
Food Security	0	10	0	0	-5
Water Consumption	0	0	-5	0	0
Gross Margin	61	0	0	3	0
Fertilizer Consumption	59	0	0	0	-5
Fuzzy Compromise	61	0	0	3	0

Source: Research Findings

According to Table 7, maximizing gross margin pattern has been able to improve the gross margin of the current pattern by 3%. The implementation of cropping pattern which minimizes the consumption of water would cause 5% decrease in consumption of water. With the implementation of the compromised goal pattern, there would be 61% increase in production and 3% increase in gross margin compared to current situation. Calories production, fertilizer and water consumption do not make a change compared to the current pattern.
According to Table 8, in the 2012-2013, with the implementation of compromised goal pattern, water and fertilizer consumption decreased by 25% and 33% compared to the current situation, and other goals' values have not changed compared to current situation.

Table 8: Change percentage of the studied indices in different cropping patterns compared to current pattern in the year 2012

Objective	Crop Production (kg)	Food Security (kcal)	Water Consumption ($1000m^3$)	Gross Margin (1000RLS)	Fertilizer Consumption (kg)
Existing Cultivated	177216400	551767200	181690	1454918000	23590990
Crop Production	697214900	551767200	181690	1454918000	16712160
Food Security	224865000	817963400	181690	1454918000	23449640
Water Consumption	177216400	551767200	136471	1454918000	15926420
Gross Margin	177216400	573866100	181690	7590547000	11741210
Fertilizer Consumption	177216400	551767200	175315	7155430000	15926420
Fuzzy Compromise	177216400	551767200	136471	1454918000	15926420
The changes compared to the current situation					
Crop Production	293	0	0	0	-30
Food Security	26	48	0	0	-1
Water Consumption	0	0	-25	0	-33
Gross Margin	0	4	0	421	-51
Fertilizer Consumption	0	0	-4	391	-52
Fuzzy Compromise	0	0	-25	0	-33

Source: Research Findings

According to Table 8, the maximizing food security pattern has been able to improve the gross margin by 4% of food security by 48%, compared to the current pattern. This pattern does not change fertilizer and water consumption. With implementation of the cropping pattern which minimizes the consumption of water, food security, productivity and efficiency has been as same as the current pattern, there would be 4% and 25% decrease in water and fertilizer consumption respectively.

Conclusion

Altogether, most patterns showed improvement in environmental goals while it was only possible to improve one of the two farmers' goals. But what is clear is that there could be improvement in the farmers' current pattern which would include both the environmental goals and the farmers' goals. Based on the criteria used in the selection of patterns it can be said that those Patterns are recommended which would reduce the consumption of water, fertilizer or gross efficiency variance compared to the current situation. The results showed that although the economic interests of the compromised goal pattern remain as same as the current pattern which is critical, But it is more interesting because it contains the decision maker's other goals. Therefore it can be concluded that with the change of crops' cultivation area, the maximum level of ideal outcome for intended goals can to be achieved. So it is recommended to test the results of this model as an instrument for decision making in the city of Isfahan.
It should be noted that in the fuzzy planning it is possible for decision-makers to involve of inexact data on the parameters of the model, and in cropping pattern optimization problems, due to high risk of the

presence of inexact data, this methods are more applicable and flexible, and the obtained results are more reliable Compared to classical mathematical programming models. The above study is a new approach to determine the optimum cropping pattern, using the fuzzy environment in the presence of diverse and conflicting objectives.

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