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Application of Fuzzy Multi-objective Decision Making Model for Adapted Cropping Pattern to climate change:A Case Study of Pishin River Basin of Iran

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Abstract

Water management denotes one of the most critical problems that face the national interests in the current and near future, especially in the middle east, where, according to UNESCO, the main interstate conflicts over water occur/will occur in that region. Given that agricultural irrigation water accounts for 80% consumption of the world's water resources, better agricultural systems management can play a critical role in the peaceful resolution of such crisis. Agricultural sector of Iran on the basis of special climate and geographic position poses many challenges and problems. Among these challenges, crop selection and water management are very important. That is, to decide on the proper set of crops to be cultivated and a proper irrigation scheme. So farmers must balance conflicting objectives when planning production. Conflicts may embrace economic, environmental, cultural, social, technical, and aesthetic objectives. Selecting the best combination of management uses from numerous objectives is difficult. Fuzzy Multi-Objective Decision making (FMCD) Models provides a systematic technique for selecting alternatives that best satisfy the farmer's objectives when objectives or restrictions are not clear. Fuzzy multiple criteria decision making models generally rely on the aggregation of the objectives to form a decision function and it allows trade-off among the objectives, and has been shown to be suitable to model decision making behavior. Such decisions are made to realize a certain objectives that typically include the maximization of net profit and the minimization of required investment, minimization of water consumption. So in this research an adapted crop pattern was determined by using Fuzzy Multi-Objective decision making model.

Keywords: FMCD Model, Pishin River Basin, Crop Area Planning

Introduction:

Farmers must allocate fields to different crops and choose crop management options. Far from being obvious, these decisions are critical because they modify farm productivity and profitability in the short and long run. Also, the recent population growth and resultant urban expansion have caused heavy demand for food and agricultural products. However, water demand has increased dramatically as well. Given the limited water resources, water demands pertaining to domestic, industrial, and agricultural use put an extreme burden on the existing water supply systems. In this taxing situation, the water quantity of reservoir must be managed. Ideal water resource management involves many different components, including balancing water distribution, ensuring efficient integrated management, minimizing costs, and protecting the ecosystem.(Chen, C. F. Chen, Y. C., and Yang, J. L. 2008, p. 4)

The task of reservoir operation and planning remains incomplete without ensuring the beneficial use of obtained releases for irrigation. It requires that cropping pattern must be readjusted with respect to possible releases available. Therefore, the second step, following reservoir management, is the problem of irrigation water management. Essentially, three decisions are required in irrigation water management, namely optimal crop selection, optimal land allocation under different selected crops, and optimal amount of water to be allocated to each crop. Optimization techniques provide a powerful tool for analysis of problems that are formulated with single, quantifiable objectives.(Gupta, A. P., Harboe, R., 2000, p. 1)

To support farmers and optimally allocate scarce resources, decision support models are developed. Decision support models are including mainly large band of consequences of cropping plan decisions at the farm and higher levels, the valuation or designing of cropping plans that based on the concepts of the cropping pattern. The assessment and designing of cropping plans using models are driven by many different motivations.

Cropping plan selection models are typically used to support farmers, policy maker and other shareholders in defining strategies to allocate scarce and competing resources more efficiently. Cropping plan selection models are used in research project aiming at different outcomes and are differently used within these projects. (Matthews, 2011, p. 3)

In 1998, Aubry et al. state that Cropping plan decisions are the main land-use decisions in farming systems and it have strong impacts on resource use efficiency and on environmental processes at both farm and landscape scales. These decisions mostly occur at the farm level and are consequently part of the global technical management of farm production.

The modeling of cropping plan selection has been treated using a variety of approaches based on different objectives and they are often selected based on a single monetary criterion, i.e. profit maximization (Audsley, 1993; Itoh et al., 2003; Leroy and Jacquin, 1991). Single criterion models mainly differ from multi-criteria ones in the way in which the cropping plan decision problem is formalized (annual or rotational) and in the set of constraints that are considered for restricting profit maximization.

Although it is commonly acknowledged that cropping systems must generate incomes for farmers, some researchers (Bartolini et al., 2007; Foltz et al., 1995; Gupta, et.al., 2000; Piech and Rehman, 1993; Stone et al., 1992) point out the restrictions of an approach that focuses completely on return maximization. They argue that decision making problems like crop area planning contain consideration of multiple, conflicting and non-commensurable criteria. Objectives that influence the selection of a cropping plan have to reflect the different goals, perspectives and values of the decision-makers. These are called and formulated in multiple-criteria decision making models (MCDM. Besides, growing environmental concerns have led researchers to explicitly target objectives other than profitability (DeVoilet al., 2006; Dogliotti et al., 2005; Foltz et al., 1995; Rehman and Romero, 1993). Further, in order to meet various requirements, multiple criteria are inevitably required in programming, leading to multiple criteria decision making (MCD). However, the criteria always conflict with each other. For example, minimizing investment levels while also maximization the net benefits or

maximization of labor employment associated with maximize irrigation of cultivated lands is a classic example of conflicting objectives in water management.
Multiple optimization programming is aimed at achieving a compromised optimum among objectives but will not yield an absolute decision. While pursuing adequate management, some nuisance characteristics often exist, such as variability, uncertainty, and nonlinear characteristics; thereby hindering the complete development of a system. To overcome these difficulties, systematic and reliable programming is required (C.F. Chen, et al., 2008).
In 1992, Stone et al., and Nevo et al., 1994 have argued that using quantitative and deterministic methods alone is not enough to achieve satisfactory cropping plans due to the nature of the information that is required, as such information is often incomplete, qualitative and uncertain.
However, uncertainty due to the random character of natural processes of the real-world decision making problems to result in it can not to be defined precisely in mathematical terms (because of fuzziness). Further, it can not be dealt with quantitatively by various developed techniques and tools provided by probability, decision, control and information theories.
These rules are based on expert knowledge and are "quantified" using fuzzy logic techniques for logical conclusion or Bayesian theory to deal with uncertain processes.
Klir and Yuan, (1995) state that the fuzziness behavior of a decision making problem is characterized by a system of IF-THEN rules which can be considered as a set fuzzy. While associating fuzzy function with logical implication rule, there appear two problems (i) how this function can be represented, and (ii) how it can be used in calculations. Since a fuzzy function is a fuzzy relation, therefore, it is a common practice to represent a system of fuzzy IF-THEN rules as a fuzzy relation so that the required calculations can be performed using the compositional rule of inference.
In other developmental study (Bergez et al., 2010), designed crop management system by simulation. They followed four-step loop (GSEC): (i) generation; (ii) simulation; (iii) evolution; (iv) comparison and choice. In 2009, Sharma and Jana used fuzzy goal programming based GA approach to nutrient management for rice crop planning. They present a tolerance based fuzzy goal programming (FGP) and a FGP based GA model for nutrient management decision making for rice crop planning in India. They included fuzzy goals such as fertilizer cost and rice yield in the decision-making process

Bellman and Zadeh (1970) argued that water resources management takes place in an environment in which the basic input information, goals, constraints, and consequences of possible actions are not known precisely. Therefore, water resource managers and modelers are bound to deal with imprecision mostly due to insufficient data and imperfect knowledge which should not be equated with randomness and the consequent uncertainty. Hence, it is more realistic to consider imprecise model constraint and goals. Fuzzy goals and/or fuzzy constraints are regarded as fuzzy criteria.

Fuzzy set theory:
The fuzzy set theory was introduced by Zadeh (1965), to deal with fuzziness issues in many control systems applications. Recently, several studies (Campose & Verdegay, 1989; Mahmoud & Abo-Sinna, 2004; Negoita, 1970; Takashi, 2001; Takeshi et al., 1991; Zimmermann, 1978) has been focused on.

It was oriented to the rationality of uncertainty due to imprecision or vagueness. Its ability in representing vague data is considered as the major contribution of fuzzy set theory to science and technology.

Multiple criteria decision making was introduced as a promising and important field of study in the early 1970'es. Since then the number of contributions to theories and models, which could be used as a basis for more systematic and rational decision making with multiple criteria, has continued to grow at a steady rate.

Fuzzy optimization programming is a powerful technique to solve multi-objective decision making problems. An application of fuzzy optimization techniques to linear programming problems with multiple objectives has been presented by Bellman and Zadeh, and a few years later Zimmermann, (1978). Indeed introduction of fuzzy sets into the multi objective problems field cleared the way for a new attentions to deal with problems which had been inaccessible to and unsolvable with standard MCDM techniques.

Several researchers (Buckley, 1985: Chiou, et al., 2005) state that fuzzy set theory has given a significant contribution by accepting uncertainty and inconsistent judgment as a nature of human decision making in the area of MCDM.

Traditional AHP[1] is assumed that there is no interaction between any two criteria within the same hierarchy. However, a criterion is inevitably correlated to another one with the degrees in reality. In 1965, Zadeh introduced the concept of fuzzy measure and fuzzy integral, generalizing the usual definition of a measure by replacing the usual additive property with a weak requirement, i.e. the monotonic property with respect to set inclusion. In this section, we give a brief to some notions from the theory of fuzzy measure and MCDM.

In this paper following to Gupta et al., (2000) applied Fuzzy Multi-Criteria Decision Model for planning of Crop pattern in Pishin river basin of Iran.

It is clearly that there is no a single objective that satisfies all adversities, all interests, and all socio -economic viewpoints. Hence, five objectives have been recognized to illustrate the potential methodology are: (i)benefit maximization, (ii)investment minimization, (iii)maximization of calories, (iv) labor employment and (v) maximize crop area.

Therefore the considered objectives functions are:

1-Maximization of net benefit: considering the economic objective of net benefit maximization is commonly in the planning area problems and farmers often prefer cropping patterns which can provide more benefits. So mathematically it can formulate as:

$$\boldsymbol{Max\, Z_1 = \sum_i N_i \times A_i\, , \forall i.} \qquad (1)$$

2-Minimization of investment:

The objective like minimum investment is usually aspired to decision makers because it can plays significant role in agriculture of developing countries such as Iran; commonly farmers have financial problems and they prefer a cropping pattern which needs less investment so investment minimization can involved in the planning process. Hence:

$$\boldsymbol{Max\, Z_2 = \sum_i I_i \times A_i, \forall i.} \qquad (2)$$

3- Minimization of Water: Considering the government's policy of providing a water intensive cropping pattern to reduce water consumption in agriculture sector. Hence, it can be written as mathematically:

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[1]Analytic Hierarchy Process

$$\boldsymbol{min\ Z_3 = \sum_i W_i \times A_i, \forall i.} \qquad (3)$$

Model Constraints:
The model subjected to the seven constraints as follow:

1- Water requirement

Considering the restriction of water requirement is commonly in the planning area problems and irrigation water demand of all the crops in any month is utmost equal to the total water available:

$$\boldsymbol{\sum_i W_i^j \times A_i \leq SW^j + GW^j, \forall j.} \qquad (6)$$

2- Annual groundwater extraction constraint:

As a common environmental policy, total groundwater use should not exceed the annual allowable groundwater extraction:

$$\boldsymbol{\sum_j GW^j \leq TAGW.} \qquad (7)$$

3- Cultivable land constraint: in a cropping plan, land allocated to different crops in any month should not exceed the total cultivable area:

$$\boldsymbol{\sum_i \beta_i^j A_i \leq A, \forall j.} \qquad (8)$$

4- Non-negativity constrain: This restriction states that all decision variables of model should be non-negative.:

$$\boldsymbol{A_i \geq 0 \quad and \quad GW^j \geq 0} \qquad (12)$$

Fuzzy programming is a powerful technique to solve multi-criteria decision making problems. The essentials of the approach are usually converting the multi-objective problem into a single objective problem. Generally for each objective function $Z_t(x)$ exist a determined efficient optimal solution x_t so that:

$$\boldsymbol{\overset{\forall}{_{x \in X}} Z_t(x) \leq Z_t(x_t^*) = Z_t^*} \qquad (13)$$

Also it can define Z_t^m as:

$$\boldsymbol{Z_t^m = min(Z_t\ (X_1^*), \ldots, Z_t\ (X_{t-1}^*), Z_t\ (X_{t+1}^*), \ldots, Z_t\ (X_k^*)} \qquad (14)$$

Such that:

$$\boldsymbol{d_t^* = Z_t^* - Z_t^m} > 0 \ \text{ for t} = 1, \ldots, \text{k} \qquad (15)$$

Generalized fuzzy linear programming model

The central idea behind fuzzy linear programming is that ill-defined problems are first formulated as fuzzy decision models. Crisp models can then be designed which are equivalent to the fuzzy models and could be solved by using existing standard algorithms. This approach is particularly suitable for decision problems which have the structure of linear programming.(Gupta, et.al. 2000)

Zimmermann (1978) introduced fuzzy programming approach to solve multi- objective linear programming problems and some researchers including Sakawa and Yano (1985), beside Leberling and Hannan (1981) have developed it to fuzzy multi-objective linear programming.

Zadeh, beside Mandami and Assilian, have expanded fuzzy logic and showed a concept of approximate estimations. They showed that logically ambiguous statements provide an algorithm, which could use ambiguous μ(x) data for the conclusion from ambiguous deductions (Benitez et al., 2007). Fuzzy numbers are the natural extension of cardinal numbers (Azar and Farajee, 2007). A fuzzy number is a concave set which has been specified by an interval of cardinal numbers with membership degree between 0 and 1 (Hsu et al., 2009; Wang and Triantaphyllou, 2008) and according to the type of the function and the possibility contribution, we could define infinite fuzzy numbers (Khademizare and Abarghouee, 2008).
In μ of this theory, the membership of the members of the set is being determined by function, which x is the representative of a known member and is a fuzzy function, that determines the membership degree of x in the relevant set and its quantity is between zero and one.
Indeed the fuzzy objective function is characterized by its membership function, and membership function plays as substitute characterization of preference in determining the preferred outcome for each of the objectives. Membership function for the tth objective denoted by μZ(x) and should be have the following conditions:

$$\mu Z(x)=\begin{cases} 1 & \text{if} \quad Z_t(x) \geq Z_t^* \\ 0 \leq \mu Z(x) \leq 1 & \text{if} \quad Z_t^m \leq Z_t(x) \leq Z_t^* \\ 0 & \text{if} \quad (x) \leq Z_t^m \end{cases} \quad (16)$$

A point $x *\in X$ is said to be an optimal solution to the FLPP if $Z^*(x) \geq Z(x)$ for all $x \in X$.
The relationship between constraints and objective functions in a fuzzy environment is therefore fully symmetric, i.e. there is no longer a difference between the former and latter (Bellman and Zadeh, 1970). The fuzzy maximization problem can be defined as follows (Zimmermann, 1978; Leberling, 1981):

$$fi(xj)=\text{Max } Z = \sum_{j=1}^{n} C_j X_j \quad (17)$$

Subject to

$$\sum_{j=1}^{n} A_{ij} X_j \leq b$$

Where at least one Xj≥0.

Consider a multiple objective optimization problem with k fuzzy goals f1 ,f2, …, fk represented by fuzzy sets $\check{F}$i that all objective functions are characterized by corresponding membership functions.
By generalizing the analogy from the single objective function, the resulting fuzzy decision is given as;

$$F_1^{\sim} \cap F_2^{\sim} \ldots \cap F_k^{\sim}$$

In terms of corresponding membership values for the fuzzy goals that introduced Zadeh(1965), the resulting decision is; μ$\check{D}$(x)= min (μZ1(x)… μZk(x)). Then all objectives should be satisfied simultaneously via its membership functions. Briefly for aggregate function can be defined as follow:
μD(x) = μD ((μD Z1(x)… μD Zk(x)) and the general optimization problem will be changed to maximization of μD(x).

An optimum solution X* is one at which the membership function of the resulting decision $\breve{D}$ is maximum, that is, $\mu\breve{D}(X^*) = \max \mu\breve{D}(X)$

Multi objective fuzzy linear programming model for crop area planning:
In general, multi objective linear programming problem (MOLPP) refers to those FLP problems of systems in which multiple objectives to be controlled. For above FLPP, the multi objective fuzzy linear programming problem for crop area allocation can be formulated as follow:
So this is exact to real-world, as marginal utilization of the decision maker decreases as the level of utilization (grade of membership) with respect to attainment of objective increases.
Therefore, member function selection with hyperbolic nature is reasonable and chosen membership function for fuzzy goals of the decision maker presented as follow:

$$\mu_t^H Z_t(x) = \frac{(\tan h\left((Z_t(x) - b_t)\alpha_t\right) + 1}{2} \qquad (18)$$

Where b_t, α_t are value of Zt(x)* and a shape parameter, respectively, such that $\mu_t^H Z_t(x) = 0.5$.
Z^*_t and Z_{tm} are best and worst value of tth objective function, $b_t = \frac{Z_t^* + Z_t^m}{2}$.
Generally fuzzy objectives of the decision maker together with using the hyperbolic membership function can be presented as follow:

Max $\mu\breve{D}(x)$ = Max λ

Subject to:

$\lambda \le \mu_t^H Z_t(x)$ (19)

$\sum_{j=1}^{n} A_{ij} X_j \le b$
Where at least one Xj≥0 and $\lambda \ge 0$.

Leberling (1981) showed that $\lambda = \frac{(\tanh^{-1}(x_{n+1})+1}{2}$ and tan h(x) is a strictly monotone increasing function with respect to x, then the maximization of λ is equivalent to the maximization of xn+1. Hence, fuzzy vector valued multi-objective optimization problem can be transformed to the following crisp model:

Maximize (x_{n+1})
Subject to:
$\propto_t Z_t(x) - (x_{n+1}) \ge \propto_t b_t$, t=1,…,k (20)
$\sum_{j=1}^{n} A_{ij} X_j \le b$
Where at least one Xj≥0 and $(x_{n+1}) \ge 0$.

The shape of the membership functions such as a linear, concave, or convex function, for various objectives and constraints, can affect the optimum solution significantly. Marginal utilization of the decision maker decreases as the level of utilization (grade of membership) with respect to attainment of objective increases. So, member function selection with hyperbolic nature seems correct.
$(x^*_{(n+1,),}, x^*)$ are said to be an optimal solution to the original problem if :

$(\lambda, x^*) = (\frac{\tanh^{-1}(x_{n+1})+1}{2}, x^*)$ (21)

So, the area allocation model with hyperbolic membership function can be written as follows:
Max An+1
Subject to:
1) All original constrains for Multi- objective area allocation model
2) One Hyperbolic Membership Constraint for each considered objective as follow:
- Maximization of net benefit:
$-\propto_1 \sum_{i=1}^{n} N_i A_i + A_{n+1} \leq -\frac{\propto_1 (Z_1^m + Z_1^*)}{2}$ (22)
-Investment minimization:

$$-\propto_2 \sum_{i=1}^{n} I_i A_i + A_{n+1} \leq -\frac{\propto_2 \, (Z_2^m + Z_2^*)}{2}$$

- Maximization of total area under irrigation:

$$-\propto_3 \sum_{i=1}^{n} A_i + A_{n+1} \leq -\frac{\propto_3 \, (Z_3^m + Z_3^*)}{2}$$

3) Non negative constrains:

$$A_{n+1} \geq 0.$$

Result and discussion:
Agricultural sector pose many challenges that can be formulated as optimization problems such as crop selection and irrigation planning. Such decisions are made to achieve a certain objectives that typically include the maximization of net profit and/or the minimization of required investment. The problem is complicated by the existence of conflicted multi-objectives. Water management represents one of the most critical problems that face the national interests in the current and near future, especially in Iran. Given that agricultural irrigation water accounts for 80% consumption of the water resources, better agricultural systems management can play a critical role to solution of water crisis.
Pishin reservoir is one of the major reservoirs in the Sarbaz river basin in west south of Pishin city and confluence place of Pishin and Sarbaz rivers with 175 million cubic meters.

Climate change scenarios of future temperature and rainfall levels under the socio-economic and ecological aspects have been produced for the Pishin river basin were selected from an ensemble of climate model (CGCM3T63) that simulates with respect to different trajectories of population growth, economic development and technological growth as A2, B1 and A1B emissions scenarios of the IPCC FAR (2007) that it will affect the level of future climate change and, simultaneously. Table (1).
Simulations of changes in temperature and rainfall precipitation were introduced into a rainfall-runoff model to produce upstream flow projections. The combination of flow projections with different scenarios was used in a Fuzzy - linear programming model to produce water optimum allocation to competition sectors in the Pishin river basin.

Table (1).Climate change simulation under three scenario

scenario Variable	A1B	B1	A2
Max Temperature	+1.99	+1.06	+1.9

Mean Temperature	+1.82	+1.17	+1.77
Min Temperature	+1.64	+1.27	+1.69
Rain fall	-12.8%	+5.5%	-10.5%

Source: Finding Research

An economic model of agricultural water use is constructed using data available from crop cost and returns and land use observations for the area. The model aims are maximizing the profit and minimizing of investment and minimizing of water consumption.

This model is used to explore the effect of temperature and rainfall variations on crop selection and cultivated area in study region. Furthermore, considering of climate changes effect on agricultural products yield is important. Any increasing temperatures or/and decrease in water availability lead to decreasing of potential yield for most crops probably. Although the actual impact of climate change on potential yields depends on the specific crop, ecological zone, and the farmer reaction. Changes in cropping patterns in terms of yield variations are also estimated within the model. It is also assumed that the region is a price-taker in agricultural markets; hence prices are assumed to be exogenous in the model.

When climate projections for a climate zone are robust and climate data largely available, calibrated yield functions can be used to estimate the impact of climate change on yield. For instance, Nazari et al. (2013) in their study on the impact of climate change on the agricultural sector in different agro-ecological region of Iran uses weather data of the last 30 years to develop yield functions that relate historical yields to climatic conditions. These yield functions are then used to project how climate change impacts on future yields.

In the case of Pishin River basin, result of the projection of climate change impact on major crops of Nazari et al. (2013) study was useful and applied.(Appendix A)

Table (2). Optimal Cropping Pattern in Different models and climate Scenarios

Area (ha)	Base period	(FMCD)	FMCD under climate Change Scenario			Profit Max.	Profit Maximization under climate Change Scenario			Invest.min.	under climate Change Scenario			W. cons. Min.	under climate Change Scenario		
Crops			A2	B1	A1B		A2	B1	A1B		A2	B1	A1B		A2	B1	A1B
Wheat	62	31	31	18	30.9	31	31	33	31	31	37	34	31	31	31	30	31
Barley	76	38	38	214.3	223.9	38	38	41	38	38	46	38	43	38	38	38	38
Rice	1757	2620.7	2176	3025.7	3180.4	1941.8	1844.8	1934	1790	878.5	1843	1925	1784	87	600	803	759

														8.5			
Water Melon	210	1837.7	2102	176.15	179	474.3	626.67	495	575.7	105	627	490	573	1105	78	81	91
Bean	623	961.8	884.4	301.4	293.4	594.56	617.18	624	574	311.5	621	624	586.3	311.5	289	292	287
Onion	135	67.50	67.5	104.7	116.3	67.5	67.5	71.4	56.7	67.5	67.5	72	62.5	67.5	73	71	73
Tomato	125	526.45	541.7	632.4	609.8	212.1	236.765	225.8	198.5	62.5	541	226	521.5	62.5	71	65.5	63
alfalfa	897	448.5	448.5	389.23	367.4	550.5	448.5	570.7	523.6	448.5	448	568	548	448.5	521	451.3	476
clover	1061	823.6	530.5	986.51	275.3	958.5	828.75	1108.5	786.4	530.5	530	987.6	814.5	530.5	637	711	648
Total	4946	7355.3	6819.6	5848.4	5276.4	4868.3	4739.2	5103.4	4573.9	2473	4760.5	4964.6	4963.8	2473	2338	2542.8	2466
Variation (%)		48.7	37.9	18.25	6.7	-1.6	-4.18	3.18	-7.5	-50	-3.7	0.38	0.36	-50	-52.73	-48.59	-50.14

Resource: Finding Research

As shown in Table (2), the various optimized cropping patterns compared versus the base year cropping pattern and exhibited under three climatic scenarios and different economic-environmental aspects. The allocated cropping area was different in the base year, the cropping pattern giving the priority to Rice, Clover, alfalfa, and Water Melon with a proximity allocated area equivalent to about 87.7% of the total cropping area whereas in FMCD model in A2, B1 and A1B climatic scenarios, optimized cropping patterns was given the priorities to Rice, Water melon, Bean and in B1 scenario Rice, bean, clover; A1B scenario Water melon, Rice, clover respectively. The greatest allocated area variations versus cultivated area in base period were about -50 percent in minimum consumption model under A1B climate change scenario and smallest variation quantity was about 0.36 % in A1B Scenario under investment minimization objective.

Furthermore a considerable improvement was observed in cultivated area under A2 and B1 climate change scenarios in Fuzzy multi-Objective Decision (FMCD) about 38 and 18.5% whereas it extremely decreased in minimization of water consumption model under A2, B1 and A1B scenarios to 52, 48 and 50 % respectively. Table (2)

So cropping pattern optimization of the considered crops in Pishin river basin of Iran in under the economical and environmental aspects and accordant to different objectives showed the great potential of Pishin River Basin to restructure its cropping pattern in accordance with its climate changes to generate a different net annual return in different climatic scenario.

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Appendix A:

Table (A-1). Monthly Optimum Allocation of Water in Pishin River Basin Under Three Ecological Scenario of water allocation.

Scenario (%)	Sectors	JAN	FEB	MAR	APR	May	Jun	July	AUG	SEP	DEC	OCT	NOV
25	Agriculture	2390.760	4771.498	4650.780	5071.986	6178.735	6193.227	4511.046	3438.121	2660.933	2376.516	2822.566	3686.004
	Drinking sector	160.000	160.000	160.000	240.000	240	240	120	120	120	110	110	110
	Ecology	637.690	1232.874	1202.695	1327.996	1604.684	1608.307	1157.762	889.530	695.233	621.629	733.141	949.001
50	Agriculture	2390.760	4771.498	4650.780	5071.986	6178.735	6193.227	4511.046	3438.121	2660.933	2376.516	2822.566	3686.004
	Drinking sector	160.000	160.000	160.000	240.000	240	240	120	120	120	110	110	110
	Ecology	1275.380	2465.749	2405.390	2655.993	3209.368	3216.613	2315.523	1779.061	1390.467	1243.258	1466.283	1898.002
75	Agriculture	2390.760	4771.498	4650.780	5071.986	6178.735	6193.227	4511.046	3438.121	2660.933	2376.516	2822.566	3686.004
	Drinking sector	160.000	160.000	160.000	240.000	240	240	120	120	120	110	110	110
	Ecology	1913.070	3698.623	3608.085	3983.989	4814.051	4824.920	3473.285	2668.591	2085.700	1864.887	2199.424	2847.003

Table (2-A). Climate Change Effect on Water Optimum Allocation between Competition Sectors

Sector	Scenario	without climate change effect	Scenario A2	Scenario B1	Scenario A1B
Ag.	β=0.25	4062.68	3732.722	3732.722	4225.18824
Drinking sector		157.5	118.125	118.125	123.7
Ecology		1055.04	962.71	2888.13	2090.54
Ag	β=0.5	4062.68	3732.722	4225.19	3734.72
		157.5	118.125	163.8	118.2
Ecology		2110.09	1925.42	2194.49	2888.2
	β=0.75	4062.68	3732.72	4025.189	3732.722
		157.5	118. 25	153.8	123.74
Ecology		3165.13	2888.13	3291.75	3099.56