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Groundwater Management at Varamin Plain: The Consideration of Stochastic and Environmental Effects

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ABSTRACT: Groundwater is one of the common resources in Varamin Plain, but due to over extraction it has been exposed to ruin. This phenomenon will lead to economic and environmental problems. Also, the world is expected to face with more stochastic events of water supply. Furthermore, incorporating stochastic consideration of water supply becomes more acute in designing water facilities. Therefore, the strategies should be applied to improve managing resources and increase the efficiency of irrigation system. Hence, in this study the effect of efficiency improvement of irrigation system on the exploitation of groundwater and cropping pattern is examined in deterministic and stochastic condition using Nash bargaining theory. The results showed that farmers in B scenario are more willing to cooperate and as a result of their cooperation, they lose only 3 percentages of their present value of the objective function. Therefore, the efficiency improvement of irrigation system can result in improving the cooperation between farmers and increasing the amount of reserves.

Key words: Groundwater, Stochastic and environmental effects, Cooperative and Non-cooperative Game, Varamin Plain

INTRODUCTION

One of the main resources of providing water in Varamin plain is groundwater resources. It is vital to mention that the agriculture sector consumes more than 80% of this groundwater. Unfortunately, due to over drafting of groundwater and drought, the water level has been dropped in the Varamin aquifer (IWRM, 2011). What is more, over drafting of groundwater and agricultural activity lead to environmental problems such as pollution and salinity of the groundwater (Raquel *et al*., 2007). Moreover, stochastic effects, like drought and climate change, will increase the level of uncertainty in the supply of groundwater (Dinar and Howitt, 1997). The amount of changes in salinity, water supply and water level changes at Varamin aquifer are shown below in Figs. 1 and 2. As the charts show, Extraction of water is increasing and water table is decreasing. Hence, the use of chemical fertilizers and groundwater scarcity, Leading to an increase in water salinity.

As a result of limited rainfall in arid and semi-arid, water allocation and management are considered as two important issues for researchers (Yubingfan *et al.,* 2014). Furthermore, the limitation of common natural resources is affected by the kind of exploitation system used by human (Madani and Dinar, 2013). It is worth highlighting that the Increase of irrigation efficiency will lead to a reduction in the rate of exploitation of groundwater by farmers (Pereira *et al.,* 2003).

The tragedy of the commons is usually caused when the individual preferences are valued more than the group preferences (Madani, 2010). Therefore, the management of common natural resources has always faced with challenges of exploiters since there are generally conflicts in goals among them. In this situation, deciders have to find an optimal solution in order to keep their social welfare (Raquel *et al.,* 2007).

Since 1960, after taking more complex hydrological models into consideration, researchers have used the stochastic and deterministic dynamic programming in groundwater management and modeling. These models have been used by Provencher and Burt (1994) in order to evaluate the external effects, resulting from the water extraction of resources. Additionally, Knapp and Olson (1996) and Msangi (2005) have modeled the water resources management using a recursive

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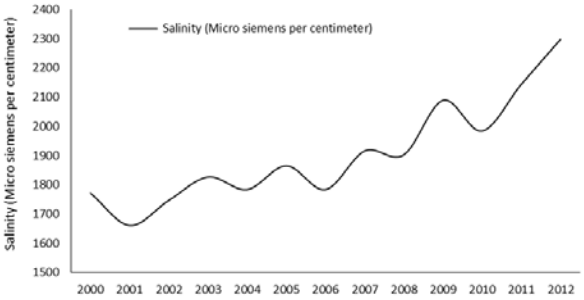

Fig. 1. The Changes in Groundwater Salinity at Varamin Aquifer

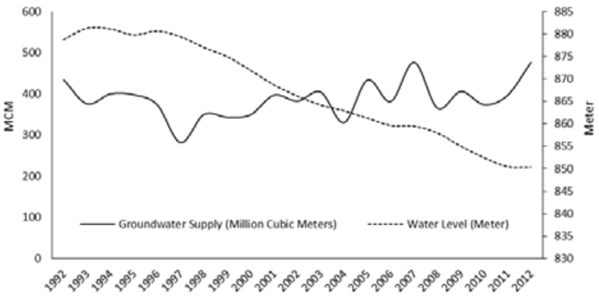

Fig. 2. The Changes in groundwater supply and groundwater level at Varamin Aquifer

utility function. Howitt *et al.,* (2002) have used the dynamic stochastic programming method in order to simulate the aquifers stochastic flows and they have obtained the optimal value of extraction of water resources. Besides, Chakravorty and Umest (2003) have evaluated the water recourses management methods by means of a spatial model as well as the dynamic programming approach. In another study, Li *et al.,* (2006) have identified the optimal value of water allocation between the various usages using the multi stages stochastic programming. Using the distance stochastic dynamic programming model, Luo *et al.,* (2007) allocated the optimum of water between different economic sectors. In order to manage and allocate the optimum of water recourses, the model of dynamic stochastic fuzzy programming was used by (Li *et al.,* 2009). A multi-stages stochastic programming model was utilized for water allocation to determine the optimal cropping pattern in uncertainty conditions (Dai and Li, 2013).

It deserves mentioning that Game theory can be used in the allocation of profits or losses resulting from the stochastic flow of water. In the water resource case, cooperative game theory can work. Dinar and Howitt (1997) attempted to address the problem of stochastic supply of water. They identified that the stability of the allocation arrangement is sensitive to the state of nature and the selected allocation scheme. Negri (1989) has used differential games in analyzing common exploitation of an aquifer and surveyed the external effects of extraction by the feedback and open-loop equilibrium. In their study, Provencher and Burt (1993), obtained the optimal rate of water extraction using a theory of dynamic games with feedback strategy. Nakao *et al.,* (2002) surveyed the management of transboundary groundwater using the game theory. Loaiciga (2004) obtained the stable and optimal rate of water extraction in terms of cooperative and non-cooperative conditions. Dinar *et al.,* (2006) have examined the comparison of outputs from game theory solution and negotiating solutions in the allocation of water. Raquel *et al*., (2007) have devoted the solution of conflicts in the withdrawal of groundwater in Mexico. Ganji *et al*., (2007) have used stochastic dynamic solution in reservoirs allocation in ZayandehRud area. Esteban and Dinar (2011) used the game theory approach to investigate the amount of cooperation in an aquifer faced with over-extraction. Madani & Dinar (2012) have studied the role of formation of non-cooperative institutions stability in the common natural resources management.

Regarding the important role of stochastic condition on groundwater supply, and environmental effect of over extraction of groundwater; this study aims at evaluating the effects of these factors. It is worth mentioning that the Improvements in irrigation efficiency have an important role in the groundwater management. Concerning the literature expressed in relation to the groundwater management and the game theory, in this study, a deterministic dynamic programming model was utilized to determine the demand on the groundwater and an optimal cropping pattern at Varamin plain in a ten-year period. In the current research, the effects of increasing the efficiency of water from 40% (B Scenario) to 70% (A scenario) on the optimal crop pattern and demand for groundwater have been investigated. Subsequently, according to the function of groundwater demand, groundwater consumer's surplus has been maximized using stochastic dynamic programming model. Then, having used stochastic Nash bargaining, the researcher obtained the optimal extraction of groundwater and optimal cropping pattern for the two scenarios. . At last, according to the environmental impacts that occur in each scenario, the optimal cropping patterns and extraction amount are determined.

Case Study and Data: Varamin plain is in the area of Iran's Central Catchment and its annual discharge amount of groundwater is equal to 414 million cubic meters. The annual drop of groundwater level is approximately 1.4 meter. One of the important realities in Varamin region is that if the exploiters do not decrease

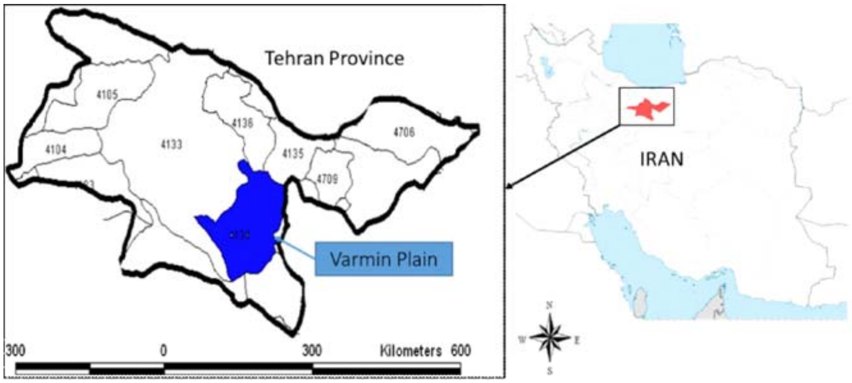

Fig. 3. Location of the study area, Varamin Plain, Northeastern Tehran, Iran.

Table 1. Main characteristics of the sampled farms and technical coefficient (10 years average) at Varamin Plain

	farmers					wells				
	age		experience	Farm size		Well depth		Water table		Debi
Characteristics	58.6 (Year)		35.3 (Year)	34.6 (Hectare)		138.6 (m)		50.23 (m)		48.9 (liter/s)
	Crops									
	WEATH	BARELY	MELON	CUCUMBER	VEG	MELONOP	MAIZE	TOMATO	WMELON	ALFALFA
Yield (Kg/Hecht)	4800	3697	26842	26115	39965	29507	48623	39458	45731	16142
Price (Dollar)	0.103	0.088	0.095	0.123	0.036	0.094	0.015	0.054	0.046	0.081
Cash (Dollar)	320	288	536	1020	536	844	300	1072	328	280
Labor (Person/day)	34.24	26.77	43.11	140.59	131.71	43.11	34.81	146.34	39.19	36.11
Nitrogen fertilizer (Kg/Hecht)	193.1	187.9	242.2	245.6	215.4	204.8	251.7	264.4	270.9	193.2
Phosphate fertilizer (Kg/Hecht)	113.9	141.3	190.0	125.9	123.3	171.2	118.8	135.7	229.9	107.4
Potash fertilizer (Kg/Hecht)	40.84	56.63	192.08	40.13	63.42	35.09	55.55	42.72	87.23	80.37
Seed (Kg/Hecht)	204.98	227.02	3.56	1.87	47.73	3.57	43.39	0.64	4.70	49.39
Pesticides type 1 (liter/Hecht)	0.92	0.87	2.72	1.97	1.52	1.75	0.85	1.14	3.49	1.48
Pesticides type 2 (liter/Hecht)	1.52	1.27	1.49	1.13	0.90	1.61	0.58	0.61	0.87	0.64
Pesticides type 3 (liter/Hecht)	1.22	1.48	1.95	1.46	1.17	1.68	0.86	1.05	0.75	1.61

Resource: Research Findings

their extraction amount of groundwater, it is likely that the entire agricultural area is ruined. Thus, cooperation must be strengthened in order to reduce the extraction and the extraction amount of each exploiter should be decreased to its stable amount (IWRM, 2011).

This plain (area of 1916 square kilometers) is located between eastern latitude of 51-28-42 to 51-49 and northern latitude of 35-2 to 35-29-25. This plain is located in flat fertile plain with semi-arid climate and loam soils. 58 percentages of total plain lands are devoted to agriculture. More than 12124 farmers have worked in this plain. Its annual precipitation is about 104 mm. total water used in agriculture is 800 million square meters in a year. Most farmers irrigate their lands by using traditional irrigated system such as furrow irrigation. The plain position in central plateau of Iran can be seen in Fig. 3.

In this study, the data required for wells and the extraction rate are obtained by collecting data using 110 questionnaires. According to these data, the amount of energy required for each cubic meter of groundwater extraction has been calculated. Data relating to technical coefficients, Input and product prices are also obtained by collecting data from 174 questionnaires for the year (2012). Technical coefficients for other 9 years, are obtained using the information of ministry of agriculture. Furthermore, prices for other 9 years are adjusted by means of a price producer index. Characteristics of the sample farmers, Technical coefficients, products prices and yield of products in Varamin plain are all shown in Table 1.

MATERIALS & METHODS

Water Efficiency: Burt *et al.*, 1997 define Irrigation efficiency (φ) as the “proportion of consumed water (also called “consumptive use”) that is beneficially used by a crop (effective water)”. The higher is the efficiency of the irrigation system, theless is the use of groundwater per unit of production. NETWAT and OPTIWAT Software have been used to calculate the amount of irrigation efficiency according to soil type, rainfall, evapotranspiration and crop type.

Varamin Deterministic Dynamic Programming Model (VDDPM): Mathematical programming has been widely used in agriculture (Hazell and Norton, 1986). In the static optimization models, only a particular period of time is chosen, but in the dynamic models, optimization is done longitudinally (Bellman, 1961). Based on Berbel and Gomez-Limon (2000), Amri and Fisher (1999) and Balali *et al*., (2011)'s researches, the following model has been designed. In this model, the objective function is the maximizing of net present value from cropping in Varamin plain for a period of 10 years:

$$Max\pi(t) = \frac{1}{(1+r)^t}\sum_{t=0}^{T}\sum_{i=1}^{I}\sum_{j=1}^{J}\left(\beta_{ijt}\,.AC_{ijt} - PW_G.AC_{ijt}.\frac{w_{ijt}}{\varphi}\right) \quad (1)$$

s.t.

$$\Delta H_t = \frac{1}{As}\left(R_t + (\alpha - 1).\left(AC_{ijt}.\frac{w_{ijt}}{\varphi}\right)\right) \quad (2)$$

$$\sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{j=1}^{J} AC_{ijt} \le AC_{Total} \quad (3)$$

$$\sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{j=1}^{J} AC_{ijt}.\frac{w_i}{\varphi} \le WATER_{Total} \quad (4)$$

$$\sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{j=1}^{J} \rho_{ijt}.AC_{ijt} \le INV_{Total} \quad (5)$$

$$H_0 = H0 \quad (6)$$

$$AC_{ijt} \ge 0 \quad (7)$$

Where i= the number of sectors (South and North, i=1,2); j= crop type, j=1,…,10); t= Time period, t=0,1, …,10; β_{ijt}= gross profit per hectare (Income minus variable cost); AC_{ijt}= crop area; PW_G= Groundwater price ($/M3); w_{ijt}=amount of water consumption in any hectare; φ = is Irrigation efficiency. The objective function consists of maximizing the present value of net returns.

The relationship 2 is the equation of hydrological relation of groundwater. This differential equation is measured in comparison with water height during time. It has to be mentioned that, in this relationship, α is backflow coefficient, A is aquifer area and S is aquifer storage coefficient and R_t is aquifer natural nutrition that has obtained from the sum of entrance underground stream to aquifer, the amount of influence from direct rainfall, the influence of surface water, the influence of agricultural water consumption, and the influence of industrial and drinking water. The relationship 3 is the indication of land constraint and the amount of land allocated to each product. This amount should not be more than the total lands existing in that area for each sort in each region. The relationship 4 is also referred to water constraint. The required water for plants in each region system must be provided during planting to harvesting seasons by surface water or groundwater. Plant water requirements have been obtained from NETWAT and OPTIWAT software.

The relationship 5 is also the constraint of machinery, labor, fertilizers, toxins, cash capital, and seeds. Here, p_{ijt} indicates technical coefficients, and also INV_{Total} shows the amount of inventory of those inputs. The relation 7 constraint is also indicative of non-negativity of the decision variable. This dynamic programing model has been solved by GAMS software.

Scenarios: Changes in the efficiency of irrigation systems (φ) are examined in the two scenarios. It is assumed that for Scenario A, the irrigation efficiency is equal to 40% and in scenario B, it is equal to 70%. It is worthy of note that in each scenarios, the different demand functions for groundwater are obtained, each of which is defined on the basis of a group of players. Each player payoff function is also equal to the area under the demand curve (Consumer Surplus). Hence, the increase in the efficiency of the irrigation system can be evaluated based on the farmers' bargaining power and decision making

Stochastic Dynamic Programming: Stochastic Dynamic Programming provides a useful tool for analyzing the two phenomena facing with stochastic and dynamic issues. In these issues, the impacts of stochastic factors on water resources inventories are actually formulated using these models type; so that their impacts on the beneficiaries' objective function and the type of their decisions are obtained (Bertsekas, 1976). One of the solution methods for such problems is approximate dynamic programming (ADP). This method utilizes simulation and approximation function in a way that it can reduce the computational volume (Bertsekas and Tsitsiklis, 1996). In this method, the value table is made by means of the set of States. Therefore, the best continuous objective function is obtained using the Computational Economic Approximation Methods (Judd, 1989). The Value Iteration Method is also used to maximize the objective function, while the Bellman equation can also be solved. The advantage of this method is in its rapid convergence as well as the fact that the control and status variables are continuous.

The polynomials Chebychev approximate has been used for obtaining the carry-over value function using the value-iteration method. Chebychev Polynomial, which belongs to a family of orthogonal polynomials, is described by Judd (1998), and implemented by Provencher and Bishop (1997) and

Msangi (2005). The terms of the Chebychev polynomial are sinusoidal in nature, which is more easily enumerated.

Non Cooperative stochastic dynamic model: In this method, the surplus demand for groundwater using the following objective function for two scenarios (A and B) is as follows. It is based on the researches done by Howitt *et al.,* (2002) and Msangi (2005).

$$MaxV_t = \left\{(CS_t(W_{Gt})) + \left(\frac{1}{(1+r)^t}\right).E_{e1}[V_{t+1}(X_{t+1})]\right\} \quad (8)$$

$$s.t.$$

$$X_{t+1} = X_t + \tilde{e}_{1t} - W_{Gt} \quad (9)$$

$$X_{min} \leq X_{t+1} \geq X_{max} \quad (10)$$

$$W_{Gt} \geq 0 \quad (11)$$

Where, V_t is the amount of objective function that should be maximized; $CS_t(W_{Gt})$ equals groundwater demand surplus and X_t is the initial inventory of water. Constraint 9 shows the dynamics of groundwater flow which is stochastic and e_{1t} shows stochastic factors. At each year, the level of a state variable is a function of its last level, the control variable, and the realized stochastic factors. Constraint 10 indicates that, in each period, the amount of storage aquifer should not exceed a certain amount. The constraint 11 is also the indication of non-negativity of groundwater extraction. The objective function is separately maximized for the two scenarios. The payoff function of each scenario is based on the surplus of demand function obtained from the area under the groundwater demand curve (Howitt *et al.,* 2012). In this condition, the optimal extraction rate has been achieved at non-cooperation statuses.

Cooperative stochastic dynamic Nash model: In this section, the weighted average of water demand surplus, in A and B scenarios, is considered as the objective function; moreover, it is assumed that the values of ω_t and ω_s equal to 0.5.The stochastic dynamic Nash bargaining was designed based on Ozyildirim (1996) and Ganji (2007)'s studies. The objective function of this equation has been maximized as follows:

$$MaxV_t = \left\{(CS_t(W_{Gt})) + \left(\frac{1}{(1+r)^t}\right).E_{e1}[V_{t+1}(X_{t+1})]\right\} \quad (12)$$

$$s.t.$$

$$X_{t+1} = X_t + \tilde{e}_{1t} - W_{Gt} \quad (13)$$

$$X_{min} \leq X_{t+1} \geq X_{max} \quad (14)$$

$$W_{Gt} \geq 0 \quad (15)$$

Here, CS_t^m is the groundwater demand surplus in B scenario and CS_t^s is the groundwater demand surplus in A scenario. This objective function actually adds the profit values of both groups initially and dispenses the gains between them subsequently. This division of gains is actually the permit the exploitation of a certain amount of water for each group.

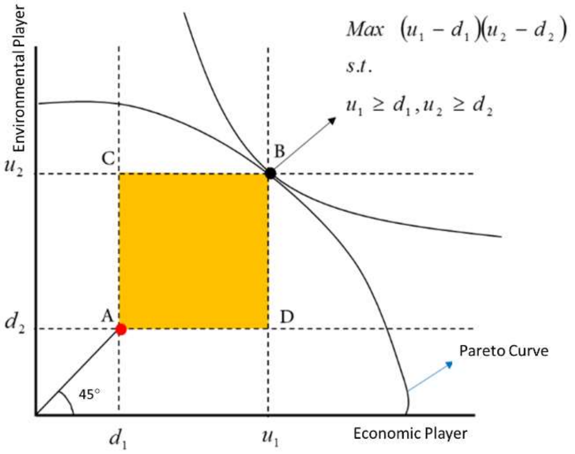

Fig. 4. Nash Bargaining Model between to Player

Symmetric Nash bargaining based on environmental considerations: One of the kinds of bargaining theories is the Nash bargaining approach that has been shown in Fig. 3 (Nash, 1950). According to Fig. 4, the utility of the two players is at point A initially and, after bargaining, it reaches the point B.

In fact, the model of bargaining maximizes the area of the square ACBD. This model uses the following programming (Nash, 1950; Raquel *et al.,* 2007):

$$Max\,(u_1 - d_1).(u_2 - d_2) \quad u_1 \geq d_1 \text{ and } u_2 \geq d_2 \quad (16)$$

Here, u_1 and u_2 are the profits of the economic and environmental players after bargaining and d_1 and $d_2$indicate the present profit of each player before bargaining.

RESULTS & DISCUSSION

First, the values of used parameters are shown in Table 2.

Table 2. Aquifer Parameters

Parameters	Description	Value (units)
r	Social discount rate	0.2
t	Time Period	10 (year)
α	Return flow coefficient	0.47
e	Energy Use for lifting per Cubic of Groundwater	0.00907 ($)
P_e	Energy Price	0.0025 ($)
Ep	Pomp Randeman	75%
Altitude	Varamin plain Altitude	918 (m)
H0	Water table natural level above sea level	867.77 (m)
A	Area of the aquifer	980 (km^2)
S	Storativity Coffecient	0.06
X_{min}	Maximum natural resource inventory	507.07 (MCM)
X_{max}	Minimum natural resource inventory	313.29 (MCM)

Resource: Database of IWIRM, 2012.

Table 3. Groundwater Demand Function in A and B scenarios

Parameters	Description	Value (units)
Slope	Groundwater Demand Function Slope in B scenaro	-11.41
Slope	Groundwater Demand Function Slope in A scenaro	-3.99
Intercept	Groundwater Demand Function Intercept in B scenaro	2951.27
Intercept	Groundwater Demand Function Intercept in A scenaro	1394.3

Resource: Research Findings

Table 4. Chebyshev Polynomial Coefficients

	1	1	3	4	5	6	7
B Scenario	2007810	1042.7	-962.8	836.3	-666	464.4	-237.3
A Scenario	1263280	11574	-7376.5	3102.8	-472.2	350	-257.2

Resource: Research Findings

Table 5. Groundwater Allocation between two groups of Farmers

		Without Coporaion	With Coporaion
Allocated Groundwater (MCM)	B	224.7	210.58
	A	349.57	272.01
Average Peresent Value per unit of groundwater ($)		2.21	2.27

Resource: Research Findings

The estimation of Groundwater Demand Function Using VDDPM: In Table 3, the values of the intercept and slope of demand functions obtained from the basic model (VDDPM) have been shown. After optimization of the deterministic dynamic programming model, the demand of groundwater in both scenarios of irrigation system was obtained. To obtain the demand functions, different prices for groundwater were considered and the changes in water consumption were calculated subsequently (Ballali *et al.,* 2011, Amir and Fisher, 1999 and Barbel and Gomes-Limon, 2000; Howitt *et al.,* 2012).

According to table 3, the slope of the demand function in B scenario is more than A. Hence, the farmers, in B scenario, are less sensitive to changes in groundwater prices. In the following, we use the values of slope and intercept of demand functions in order to obtain the welfare surplus of extraction of groundwater.

Groundwater Allocation in stochastic condition: In this case, players are farmers in A and B scenarios it is worth highlighting that the society group and the environmental impacts have not been taken into consideration. The groundwater supply (Fig. 2) were simulated by means of the approximate dynamic programming. The stochastic flows (groundwater supply in Fig. 2) ($\tilde{e}_{1t}$) are normally distributed and categorized in 6 groups and the probability of each flow has been determined. In addition, 7 sentences of Polynomial Chebychev have been considered to simulate the expected values of the objective function (Table 4). In this case, the objective function is the groundwater demand surplus expected value. Hence, after solving the equations 9 and 13, the present value of each unit of groundwater and the allocated amount of groundwater have been achieved in both cases of cooperative and non-cooperative states (Table 5).

In cooperative state, the water allocated to A Scenario is more than the B one, although in comparison with the case of non-cooperation, in A Scenario it must be reduced to 77.55 million cubic meters of groundwater extraction, while in B Scenario, only 14.12 million cubic meters of extraction are decreased. The excepted present value of each unit of water extracted in cooperative state is 0.053$ more than that in the non-cooperative state. In fact, these results indicate that any agreement could bring up more expectation value for each unit of groundwater. Because the reduction in water consumption, water productivity has increased.

Groundwater Allocation with Environmental considerations: In this case, players are society group and farmers in A and B scenarios and the environmental impacts are taken into account. In order to determine the players' Gain function, first, the amount of income for each of these two groups in different scenarios of withdrawal must be obtained. In each of these scenarios, the extraction amounts of groundwater, fertilizer consumption and toxin have been obtained. The farmers' objective function value is achieved by maximizing the VDDPM in two scenarios. The Payoff function of the society group is also achieved by the equation 17 which is resulted from different amount of groundwater extraction and fertilizer and toxin consumption:

$$WE_s = \alpha.Groundwater + \beta.Fertilizers + \vartheta.Pesticides \quad (17)$$

The above equation is an indicative of society loss function as the result of farmers' use of groundwater, fertilizers, and toxins. In this study α is equal to 0.5, and β and ϑ are also equal to 0.25. The payoff function of both groups (society and farmers) has been normalized between zero and one in order to compare the gains amounts more simply. $x_n = (x-x_{min})/(x_{max}-x_{min})$ Equation, has been used for normalizing the data. Table 5 shows the amounts of normalized payoff for each player as the result of different amount of groundwater extraction: (Table 6)

Based on Table 6, the first state is the most desirable case for farmers since the income amount of this group is equal to 1. On the other hand, the 11th state has the least loss for society and the normalized amount of this loss for this group is equal to zero (the least amount). After bargaining and maximizing equation 16, the optimal extraction of groundwater is obtained. To obtain the optimal extraction, Pareto function must be estimated. If the environmental normalized attributes are regressed on the economical normalized gains, the Pareto function is estimated. The estimation results of this equation with OLS method, are observable in Table 7.

In order to determine the optimal point on Pareto curve, first, different weights from 0 to 1 with the difference of 0.025 for each of the economic and environmental goals are given. The optimal amounts are obtained subsequently considering the maximization of Nash bargaining function (equation 16). Now, if the importance of the economic and environmental goals are considered the same (50-50 weight), the best withdrawal amount from groundwater will be 333.17 and 225.64 in B and A scenario subsequently, that is equal to 225.64 million cubic meters in a year. *Change in Cropping Pattern:* After bargaining, in stochastic condition and Environmental consideration, a certain amount of groundwater is allowed to extract by the farmers in A and B scenarios. Regarding this limited amount, the optimal cropping pattern of each scenario will be as follows with respect to the VDDPM (Table 8). As table 8 shows, the maximum of present value of objective function is occurred in stochastic condition, B scenario and without cooperation. But the minimum amount of extracted water is occurred in stochastic condition, B scenario and with cooperation. Due to the fact that in the plains of Varamin, management and conservation of water resources are more important, therefore, the best state of extraction water is cooperative method with higher water efficiency in stochastic condition.

In stochastic condition, farmers in B scenario are more motivated to cooperate, because only 3% of their

Table 6. Normalized payoff matrix for application of conflict resolution

States (Groundwater Extracting (MCM))	Farmer Economic Gains		Society Environmental Gains							
			Weighted sum of environmental attributes		Aquifer overexploitation coefficient		Pesticides in runoff and percolation		Fertilizer in runoff and percolation	
	A	B	A	B	A	B	A	B	A	B
1	1	1	0	0	0	0	0	0	0	0
2	0.87	0.89	0.05	0.07	0.02	0.13	0.09	0.002	0.02	0.01
3	0.74	0.77	0.08	0.11	0.05	0.18	0.25	0.05	0.03	0.02
4	0.62	0.66	0.23	0.34	0.17	0.45	0.46	0.32	0.14	0.12
5	0.51	0.56	0.3	0.36	0.19	0.46	0.65	0.34	0.17	0.18
6	0.41	0.46	0.38	0.41	0.35	0.48	0.68	0.37	0.25	0.38
7	0.31	0.36	0.41	0.42	0.41	0.48	0.72	0.39	0.26	0.38
8	0.23	0.26	0.47	0.44	0.5	0.48	0.75	0.41	0.32	0.46
9	0.15	0.16	0.61	0.53	0.63	0.5	0.9	0.58	0.45	0.55
10	0.07	0.08	0.64	0.68	0.65	0.56	0.95	0.84	0.48	0.78
11	0	0	1	1	1	1	1	1	1	1

Resource: Research Findings

Table 7. Pareto curve estimation in traditional and modern modes

Variable	B Scenario		A scenario	
	Coefficient	t-statistics	Coefficient	t-statistics
Intercept	1.0407	(21.08)*	0.9353	(10.43)*
Economic objective	-0.6624	(-2.87)*	0.3358	(4.54)*
Squared Economic objective	-0.3951	(-1.98)***	3.1503	(-2.15)***
DW	1.99		1.8	
R2	96%		91%	

Resource: Research Findings

*, *** is significant in 1 and 10%

Table 8. Change in cropping pattern in A and B Scenarios in different condition

Crops (Hecht)	Status Quo	Stochastic Condition				Deterministic Condition			
		Without Corporation		With Corporation		Before Bargaining		After Bargaining	
		B	A	B	A	B	A	B	A
Wheat	27709	33917	36427	36802	23260	33917	33917	34541	36802
Change (%)		22.4	31.5	32.8	-16.1	22.4	22.4	24.7	32.8
Barley	23285	12037.5	5649	8736	3270	10709	9464	3754	8736
Change (%)		-48.3	-79.6	-68.5	-88.2	-61.4	-65.8	-86.5	-68.5
Melon	334.6	0	0	0	0	0	0	0	0
Change (%)		-100	-100	-100	-100	-100	-100	-100	-100
Cucumber	1094.3	322	1892	952	2980.3	322	322	3224	952
Change (%)		-70.6	72.9	-13.0	172.3	-70.6	-70.6	194.6	-13.0
Vegetable	3297	3400	2388	3408.9	3071	3400	3400	1066	3068
Change (%)		3.1	-27.6	3.4	-6.9	3.1	3.1	-67.7	-6.9
cantaloupe	2512.3	2724	2193	2715.56	1673	3026	3026	2507	3444
Change (%)		8.4	-12.7	8.1	-33.4	20.4	20.4	-0.2	37.1
maize	9062	11977	7037	9117	0	11977	11977	5861	9117
Change (%)		32.2	-22.3	0.6	-100.0	32.2	32.2	-35.3	0.6
Tomato	3228.7	6618	4496	4631	4371	6618	6618	4584	4631
Change (%)		105.0	39.3	43.4	35.4	105.0	105.0	42.0	43.4
Watermelon	441	0	0	0	1257	0	0	0	0
Change (%)		-100	-100	-100	185.0	-100	-100	-100	-100
Alfalfa	4604.7	4461	12498	6341	22290	4461	4461	13932	6341
Change (%)		-3.1	171.4	37.7	384.1	-3.1	-3.1	202.6	37.7
Total Area	75568.6	75456.5	72580	72703.46	62172.3	74430	73185	69469	73091
Change (%)		-0.1	-4.0	-3.8	-17.7	-1.5	-3.2	-8.1	-3.3
Present Value of Objective (Million Dollar)		**2.577**	**2.164**	**2.501**	**1.565**	**1.613**	**1.835**	**1.408**	**1.781**
Average of Groundwater Using (Million Cubic Meter)		**224.7**	**349.57**	**210.58**	**272.01**	**372.3**	**235.76**	**325.56**	**225.53**

Resource: Research Findings

objective function present value will be reduced, while in the A scenario, farmers will lose about 38% of the present value of their objective function as the result of cooperation. Hence, the latter group will lose, because their power of cooperation is less. For farmers in B scenario in cooperative case in comparison with the non-cooperative one, the area under the cultivation of wheat, cucumbers, vegetables, and hay will increase however, the same area of barley, melon, corn, and tomatoes will decrease. On the other hand, In A scenario, in cooperative condition, the area under cultivation of cucumbers, vegetables, watermelons, and hay will increase while the area of wheat, barley, melons, corn and tomatoes will decrease. Changes in cropping patterns happen because the farmers have to reduce their groundwater consumption, so the cropping pattern tends to such products, which will give more earning present value to the farmers for each groundwater unit. In deterministic condition with Environmental considerations, as a result of bargaining between farmers and society for decreasing water extraction, cropping pattern is changed for that s specific region. In A scenario, the area under cultivation of wheat, cucumber, watermelon, and alfalfa crops in comparison with optimal cropping pattern is increased and the level of tomato, corn, melon, vegetables, and barley is decreased. In overall case, the amount of present value of the objective function shows a decrease of 12.7 percent. Also, the withdrawal amount of groundwater has been decreased to 12.55 percent. Considering the identical values given to each of the environmental and economic objectives, these results had not been unexpected. In B scenario, the level of wheat, cucumber, and alfalfa is increased while the level of barley, vegetables, cantaloupe, corn, and tomato is decreased. The present value of the objective function decreases 3 percent and the consumption amount of groundwater shows a decrease of 4.3 percent. In this case, farmers in B scenario are more capable of bargaining, since farmers in A scenario, considering the optimal case, have to decrease their water withdrawal to 14 percent. So that farmers in B scenario only require decreasing 4 percent of their withdrawal. Results indicate that the more the power of the environmental goals are, the less the extraction amount of water will be;. If there is a society group that is capable of bargaining on the environmental goals with farmers, it can decrease the extraction amount of groundwater in Varamin plain. In fact, , due to decrease in area level of agricultural crops and groundwater extraction, the amount of using toxins and fertilizers has been diminished and as a result, the amount of pollution and salinity of this aquifer will also be decreased.

CONCLUSIONS

In this study, firstly, we tried to determine the optimal cropping pattern through the deterministic dynamic programming method in a 10-year period. Then, according to different prices for groundwater, the groundwater demand functions were obtained. Regarding these functions, the groundwater demand functions were maximized through stochastic dynamic programming model and finally the optimal amount of extraction of groundwater in A and B scenarios in both cooperative and non-cooperative methods were achieved. Since the slope of the demand function in B scenario is more for modern beneficiaries than traditional ones, thus, the reaction of former group to the price policies of groundwater is less than the latter one. On the other hand, the cooperation solution leads to reduce 16% in the aquifer use, which increases 2.64 percent in the present value per unit of water. Now, because of the amount of extraction of groundwater in both cooperative and non-cooperative models, using VDDPM model, the cropping pattern can be obtained in each mode. In this case, farmers in B scenario, lose 3% of the present value of the objective function because of their collaboration, while the farmers in A scenario have already lost 38% of the objective function. Therefore, farmers in A scenario are more willing to participate in the cooperative coalition. It can be concluded that the increase of the efficiency of irrigation systems will lead to a reduction in the extraction of groundwater. The results of the study are implemented by Cooley *et al.*, (2009), Jury and Vaux, (2005), Johnson *et al.*, (2001) and Evans and Sadler, (2008). Additionally, an increase in the efficiency of irrigation systems, will enhance the bargaining power of farmers. Consequently, it is suggested that we should encourage the farmers to reduce the exploitation of the aquifer, upgrade the type of operating system for using groundwater and increase the efficiency of irrigation system of used water in the farms.

Another aim of this study is to design a cooperative game between farmers and society. In this region, farmers are considered with economic goals while society is regarded with environmental goals. When bargaining happens and the optimal cropping pattern and groundwater consumption change, the farmers in B have more ability in bargaining and they can meet the environmental desires of the society.

Moving of the cultivation pattern after bargaining is towards products that give more net profit to farmer per unit of groundwater consumption. The existence of institutions to control groundwater extraction can help strengthen bargaining power of the society group so that the environmental situation is also better.

Finally, the improvement of the efficiency of irrigation systems, leads to a reduction in stochastic effects on farmer's income and also improve the quality of the environment and groundwater. However, increasing the area under cultivation should not be allowed in this case.

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