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Original Article

Impact of Irrigation Groundwater Price and Quota Policies in Changing Cropping Patterns in the Province Kerman in Iran

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ABSTRACT

Objective: Water scarcity is a growing global problem and increasing population pressures, living standards and the growing demand for environmental quality have evoked all the governments to represent better solutions about water resources management. In addition, there are growing political ties for reducing water use in agriculture that follow enough environmental benefits and increase the welfare of other water consumers. **Methods:** In addition, there are growing political ties for reducing water use in agriculture that follow enough environmental benefits and increase the welfare of other water consumers. This further increases the economic analysis to check the behavior of farmers using mathematical programming techniques and has been followed the application of Positive Mathematical Programming (PMP) especially. **Results:** Applied policies include increased 5, 10, 20 and 30 percent in water irrigation prices and reduced 10, 15, 25 and 30 percent in the amount of available irrigation water policies. Farmer's response to these policies showed that increased costs and reduced available irrigation water are effective in accepting deficit irrigation.

1.INTRODUCTION

According to agriculture is the biggest consumer of water resources. Water production rate isn't responder to increasing in demand for water. Moreover, Population growth, promoting social welfare, agricultural and industrial development and protection of ecosystems is Causes by increased water demand. These factors and important role of water in sustainable development has been Caused that authorities more attention to demand management and water supply has in planning and macroeconomic policy regional and national. Kerman province with an area of 175,069 km, population of 6 / 2 million people, The elevation range of 190 meters in the Lut Desert until 4465 meters in altitude in Hezar mountain and this province is located between geographical coordinates of 54 and 59 eastern longitude and 26 and 31 north latitude. Annual rainfall in Kerman province is about 145 mm and is provided 38 / 90 percent of its groundwater from wells and 98 / 5% and 64 / 3 percent, respectively, of the aqueduct and fountain. terms of water consumption, in different sectors according to Statistics, 86/95 percent of water extracted from groundwater water resources consumption is in agriculture, 34 / 3 percent of the drinking and 8 / 0 percent in the industrial sector. Excessive withdrawals from groundwater aquifers have many complications, including decreasing water levels in the plains of the province. Therefore adopted strategies are important to optimize water use, particularly in terms of water shortages and drought. Among the policies that help to solve this problem is limiting the amount of irrigation water available and water pricing.

1.1.Background

Mirzaee and *et al*. in 1386 in a study was doing to analyze the optimal water allocation and planting patterns due to changes in expected earnings of agricultural products and increase water prices by using linear programming. Results

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showed that optimizing cropping patterns and water allocation will help to increase profits in the agricultural sector Berbel and Gomez-Limon in 2000 in an article titled the impact of water-pricing policy in Spain: an analysis of three irrigated areas that this study compares the predictive performance of several mathematical programming models. The results show that the best prediction corresponds to a model that includes expected profit and a qualitative measure of crop riskiness. The results suggest that, in order to obtain reliable predictions, the modeling of farmers' responses to policy changes must consider the risk associated with any given cropping pattern. Sabouhi and et al. in 2007 using positive mathematical programming model were examined impact of price changes and reduce the amount of water available in the private and social interests in the Khorasan province. Results showed that Farmers respond to increase water irrigation prices with changed their Planting pattern and thus with rising cost of water irrigation lead to reduce to water consumption at farm level. Nikoee and zibaee in 2009 In the study, the consequences of increasing the acreage of colza at representative farm (RF) level of Nemdan plain were analyzed using positive mathematical programming (PMP), which were improved to overcome normative character of optimization models. The main aim of PMP is to give as true a picture as possible of the situation and then simulate the behavior of farmers as parameters in which the object of agricultural policy intervention is shifted. Based on the results of this study, reduction in the acreage of wheat and bean and increase in the expected profit of RFs are the consequences of increasing acreage of colza. But, as variance of profit increases, the net impact of policy on the expected utility of RFs is not perfectly known. The results also indicated that the use of pesticide increases through introducing colza into a cropping pattern. The effect of policy on water use is different among RFs and they can't take this policy as a water demand management policy.

Cortignali and severini in 2009 Studied Irrigation water policies by positive mathematical programming model.results showed that increasing water costs do not motivate adoption of DI techniques. Rather, farmers are induced to save water by switching from full irrigation to deficit irrigation when water availability is reduced or the prices of irrigated crops are increased.

2. MATERIALS AND METHODS

2.1. PMP method

The PMP methodology, developed to calibrate agricultural supply models, assumes a profit-maximizing equilibrium in the reference period. It recovers additional information from observed activity levels in order to specify a non-linear objective function such that the resulting nonlinear model exactly reproduces the observed behavior of farmers. The Standard approach: (1) specification of a linear programming model bound to the observed activity levels by calibration constraints, in order to derive the differential marginal cost vector (m); (2) estimation of a quadratic variable cost function assumed to capture all farming conditions not modeled in an explicit way and (3) the formulation of a quadratic programming model including the variable cost function in the objective function. This model exactly reproduces the behavior observed in the base year and can be used to perform simulations on several parameters of the model, including product and factor prices, subsidies and resource availability. The variable cost function is assumed to be quadratic because this form is relatively easy to work with and has the desirable property of increasing marginal cost functions for each activity, apart from the marginal (least profitable) activity. Denoting the crops by j, the quadratic programming model can be compactly written as:

$$\max \quad z = \sum_j (r_j - Ac_j(x_j))\,x_j$$

$$s.t \qquad \sum_j a_{ij}\,x_j \le b_i$$

$$x_j \ge 0$$

where Z denotes the objective function value; x_j represents the production activity levels (hectares allocated to crop j); r_j denotes average revenue per unit of activity; $\alpha_{i,j}$ represents the scalar element of a matrix of coefficients in the resource/policy constraints (index i); b_i is the vector of available resource quantities; $AC_j(x_j)$ denotes average variable cost function per unit of activity and it has the following form:

$$Ac_j = \alpha_j + \frac{1}{2}\beta_j x_j$$

where α and β are parameters to be estimated. Multiple sets of cost function parameters satisfy the marginality conditions of the problem (1). One of the options for recovering these parameters is the following (Arfini and Paris,

1995):

$$\alpha_i = c_j \qquad , \beta_j = \frac{\mu_j}{x_j^0}$$

Where c_j are the observed accounting costs and μ_j are the dual values recovered by means of the following calibration constraints:

$$x_j \le x_j^0(1+\varepsilon_0) \qquad [\mu_j]$$

Where x^0_j are the observed variable levels and e is a small positive number (Howitt, 1995). In the Standard approach, the parameters of the cost function for each activity are recovered for each land-use activity separately from each other. In this way, different production technologies for the same crop (variants) are considered as separate activities and are not considered that a large substitution among these variants could occur in the phase simulation considering that they have similar technical-agronomic characteristics. In fact variants generally refer to different ways of producing the same crop product and differ only in terms of the amount of production factors used (e.g. amount of fertilizers and water, irrigation technologies, crop protection technologies) and yield. Therefore farmers can be expected to adjust cropping technologies more easily (i.e. switching from one variant to another) than cropping mix (i.e. switching from one crop to another). Ro¨hm and Dabbert (2003) propose a different modeling approach, given that the elasticity of substitution is expected to be higher between variants of the same crops than between different crops. Denoting the crops by j and the variants by v, the quadratic programming model can be written as (Cortignali and severini in 2009):

$$\max z = \sum_j \sum_v (r_{j,v} - Ac_{j,v}(x_{j,v}))x_{j,v}$$
$$s.t \qquad \sum_j \sum_v a_{i,j,v} x_{j,v} \le b_i$$
$$x_{j,v} \ge 0$$

Where average variable costs per unit of activity ($AC_{j,v}$) are defined as:

$$Ac_{j,v}(x_{j,v}) = \alpha_{j,v} + \frac{1}{2}\beta_{j,v}x_{j,v} + \frac{1}{2}\gamma_j \sum_v x_{j,v}$$

They introduce an additional slope parameter not included in (2) which is common to all variants of the same crop. Therefore, there are two sets of slope parameters, one for each crop ($\gamma_{i,j}$) and another for each variants of the same crop (β). As for the Standard approach, multiple sets of cost function parameters satisfy the marginality conditions. Similar to the standard method, set coefficients of cost function creates the ultimate conditions. Correction parameters are applied as follows:

$$\alpha_{j,v} = c_{j,v} \qquad , \beta_{j,v} = \frac{\mu_{j,v}}{x^0_{j,v}} \qquad , \gamma_j = \frac{\mu_j}{\sum_v x^0_{j,v}}$$

Where $c_{j,v}$ are the accounting costs and the other parameters can be recovered on the basis of the results of the original linear problem with two sets of additional calibration constraints:

$$\sum_v x_{j,v} \le \sum_v x^0_{j,v}(1+\varepsilon_1) \qquad [\mu_j]$$
$$x_{j,v} \le x^0_{j,v}(1+\varepsilon_2) \qquad [\mu_{j,v}]$$

Where ε_1 and ε_2 are small positive numbers ($\varepsilon_1 < \varepsilon_2$); μ_j are dual values associated with crops; and $\mu_{j,v}$ are dual values associated with crop variants. The method used in this study is generalized method Rohm and Dabbert. This method allows considering the activities that are not available in the reference period. Compared with equations 9 and 10, the calibration limits as follows:

$$\sum_v x_{j,v} \le \sum_v x^0_{j,v}(1+\varepsilon_0) + \varepsilon_3 \qquad [\mu_j]$$
$$x_{j,v} \le x^0_{j,v}(1+\varepsilon_{0\square}) + \varepsilon_3 \qquad [\mu_{j,v}]$$

Where ε_3 is a sufficiently small positive number ($\varepsilon_1 < \varepsilon_2 < \varepsilon_3$). In fact, considering that some variants are equal to zero, an additive small positive number (ε_3) must be specified for the variants not observed (in this case the DI techniques) in order to recover nonzero dual values in all cases. (Cortignali and severini in 2009).

$$Ac_{j,v}(x_{j,v}) = \alpha_{j,v} + \frac{1}{2}\beta_{j,v}x_{j,v} + \frac{1}{2}\gamma_j \sum_v x_{j,v} + \upsilon_{j,v}$$

$$\alpha_{j,v} = c_{j,v} \qquad ,\beta_{j,v} = \frac{\mu_{j,v}}{x^0_{j,v}} \qquad ,\gamma_j = \frac{\mu_j}{\sum_v x^0_{j,v}} \qquad ,\upsilon_{j,v} = \mu_{j,v}\left(1 - \frac{x^0_{j,v}}{\sum_v x^0_{j,v}}\right)$$

Where $\nu_{j,v}$ are linear cost parameters that consider the relative weight of the variant ν within the crop j. This method of recovering the cost parameters satisfies the marginal conditions of the considered problem. The parameter ν is relatively large when the variant is cultivated on a limited share of the whole crop j area. In the present study at %5 and %10 deficit irrigation techniques for basic products that were not seen in years and Noteworthy is the Model, the base acreage for the year into consideration. Using these models and policies to increase 5, 10, 20 and 30 percent of irrigation water and reduce the price of 10, 15, 25 and 30 percent in the amount of water available for irrigation will be discussed. To solve model was used software GAMZ.

3. RESULT

sample farmers just is included Groundwater users that were divided into three groups of small farms with less than 9 acres under cultivation, medium farms,10 to 18 hectares of farmland under cultivation and large farms more than 19 hectares. This division is done using software Spss.16. Results from the primary model using positive mathematical programming in Table 1 shows that increased acreage with increased farm size .This could be due to poor management on large farms than small and medium farms. After consideration of new activities, means activities that have been not observed in the base year, model considers an initial cultivation for their. we considered two DI techniques for each of the five crops under the assumption that the techniques reduce irrigation levels by 5% (crop 2) or 10% (crop 3) with respect to the actual levels. These reductions are applied linearly to each irrigation without altering the irrigation calendar. This simplified approach is used here given the small considered reductions (5% and 10%). However, a less simplified approach should be used in future research to explore such important aspects better.

Table1.

Results of cropping pattern using positive mathematical programming corrected

production	**small**	**medium**	**larg**
corn1	79.2	97.2	147.9
corn2	23.8	57.8	134.8
corn3			
wheat1	62.0	13.4	51.0
wheat2	3.4	13.5	3.3
wheat3	4.7		5.0
barely1	31.3	53.0	59.0
barely2	25.4		1.5
barely3			4.0
sugerbeet1	40.0	43.5	60.6
sugerbeet2	3.2	10.5	5.3
sugerbeet3	4.5		6.2
potato1	8.0	78.8	18.0
potato2	5.4	23.6	1.0
potato3	3.7	23.6	3
full irrigation	220.5	286.0	336.4
deficit irrigation	74.1	129.0	164.1
total	294.5	415.0	500.5
percent of full irrigation	74.9	68.9	67.2
percent of deficit irrigation	25.1	31.1	32.8

Source: Research Findings (crops2 and crops3 are deficit irrigation at 5% and 10%)

Results of policies to reduce the amount of water available in 5, 10, 15 and 25 percent and increase water prices to levels 5, 10, 15, 20 and 30% are shown in the attached tables. According to Table 2, farmers for crops: potatoes, sugar beet and wheat tend to be both techniques, but for corn and barley tend to be DI techniques 5%. Due to the present DI techniques and due to the reduction of water consumption of the DI techniques, this technique has been accepted by most farmers .Other groups were also similar. according to the bottom two rows of the table, After implementation of policies, in full irrigation increased acreage and DI techniques shows reduced acreage relatively, and The absolute decrease shows in both cases. Decreasing water availability policies in 5, 10, 15 and 25 percent, deficit irrigation cultivation change in small farms of 74.1 acre to 81.8, 103.2, 75.9 and 12.3 acres, in average farms of 129 farms in the thus, the 169.2, 187.3, 183.6 and 30.2 acres and in large farms from 164.1 to 183.8, 215.3, 85 and 3.1 acre. As you can see deficit irrigation cultivation in the group initially increased and then decreased and for the three groups is similar. Deficit irrigation cultivation decreased more than 15% through water availability reduction; this decrease could be due to lack of supply of minimum water requirement. Full irrigation cultivation in small farms of 220.5 to 193.8, 176.7, 125 and 37.9 acres, in farm average of 286 to 221, 185, 75.2 and 29.5 acres and in large farms 336.4 to 307.6, 270.9, 147.1 and 20.7 acres for all three groups was the same. increasing prices Policies for 5, 10, 15, 20 and 30 percent of irrigated cultivation Full irrigation changed for small farms to 197.6, 188.1, 132.6, 69.5 and 22.6 for medium farms to 254.2, 235.36, 232, 206.3 and 173.8 in large farms to 325.1, 290.6, 265.6, 236.5 and 212.2 ha that Shows a decreasing trend. Deficit irrigation cultivation increased in small farms, 48.3, 77.2, 104, 131.5 and 107.5, and in average farms to 89.1, 114.7, 141, 164.8 and 195 and for large farms to 49.8, 72.1, 82.7, 105.8 and 119.8 acres, too. Decreasing water availability scenarios, reducing Full irrigation cultivation and increased in cultivation deficit irrigation has three representative farms. For example, in decreasing water availability at 10% scenario, reducing Full irrigation cultivation from 220.5 to 176.7 acres for a small farm, a farm medium of 286 acres to 185 and in large farms, as well as 336.4 to 270.9 ha. Deficit irrigation cultivation increasing for small farms from 74.1 to 103.2 acres, the average farm of 129 to 187.3 and for large farms of 164.1 to 215.3, respectively. Decreasing water availability at 25 percent has been change in cultivation, small farms from 294.5 to 9.6 acres farms average of 415 to 15.2 acres and larger farms than 5.500 acres to 1.8 hectares. Amount of deficit irrigation cultivation decreased for small farms from 74.1 to 4 acres, in average farm of 129 to 1.1, and for large farms from 164 to zero. Increasing prices Scenarios were followed, reducing Full irrigation cultivation and increased deficit irrigation cultivation. Percent decline in cultivation farms in full irrigation in water availability Scenarios was lower than increasing price. One reason is the low price of irrigation water; increased prices of this input had little effect on the pattern of crops. Comparing the two scenarios, at 10 percent, shows that the total cultivation for farms, small, medium and large, respectively, 295.5, 415 and 500.5 ha, full irrigation cultivation for each groups, 220.5, 286 and 336.4 and deficit irrigation cultivation acreage is 74.1, 129.1 and 164.1, respectively. After than decreasing water availability scenario at 10 percent, full irrigation cultivation changed to 176.7, 185 and 270 acres respectively and deficit irrigation cultivation increased to 103.2, 187.3 and 215.3 acres. After running the increasing water prices scenario, at 10 percent, full irrigation cultivation decreased to 188.1, 235.3 and 290.6 acres and deficit irrigation cultivation increased to 116.9, 143.3 and 184.6, respectively. Thus, can say that after scenario deficit irrigation techniques cultivation increased and this increasing in decreasing water availability scenarios is greater than increased water pricing scenarios.

Table2.

Cropping patterns in the policies in small farms

production	base year	decreasing water availability %					increasing water pricing%				
			5%	10%	15%	25%	5%	10%	15%	20%	30%
corn1	79.2	60	49	43.8	24.8	64	58.7	47.5	34.8	4	63.4
corn2	23.8	25	26	33.8	4.8	26	28	34.8	14.8	4	61.6
corn3			7.2	9.6			7.2	9.6			
wheat1	62	59	57	40.6		59	57	40.6			13.5
wheat2	3.4	4.5	6.5			5.7	7.5				13.5
wheat3	4.7	5.5	7.5			6.4	8.2				
barely1	31.3	29.2	28	17.5	10	30.2	28.7	20.4	14.6	7	12.0
barely2	25.4	20.9	19	15.5	7.5	20.9	29	19.5	11.5	7	
barely3			6	7.5			6	7.5			
sugerbeet1	40	38	36	18.1		38.8	37	17.1	12	6	13.9
sugerbeet2	3.2	5.5	7.5			5.5	7.5	9	12	13	18.2
sugerbeet3	4.5	7.5	8			7.5	8	9.3			

potato1	8	7.6	6.7	5	3.1	5.6	6.7	7	8.1	5.6	71.0
potato2	5.4	7.3	8.5			7.3	8.5	9	14.6	5.7	27.5
potato3	3.7	5.7	7.2	9.6		5.7	7.2	9.6			27.5
full irrigation	220.5	193.8	176.7	125	37.9	197.6	188.1	132.6	69.5	22.6	173.8
deficit irrigation	74.1	81.8	103.2	75.9	12.3	85	116.9	108.2	52.9	29.7	148.3
total	294.5	275.6	279.9	200.9	50.2	282.6	305	240.8	122.4	52.3	322.0
percent of full irrigation	74.9	70.3	63.1	62.2	75.5	69.9	61.7	55.1	56.8	43.2	54.0
percent of deficit irrigation	25.1	29.7	36.9	37.8	24.5	30.1	38.3	44.9	43.2	56.8	46.0

Source: Research Findings

Table3.

Cropping patterns in the policies in medium farms

production	base year	decreasing water availability %				increasing water pricing%				
		5%	10%	15%	25%	5%	10%	15%	20%	30%
corn1	97.2	64.9	53.8	38.4	14.0	66.5	66.1	65.2	64.3	63.4
corn2	57.8	60.1	61.2	45.3	18.6	58.5	58.9	59.8	60.7	61.6
corn3		12.8	17.5							
wheat1	13.4	13.5	13.5			13.5	13.5	13.5	13.5	13.5
wheat2	13.5	13.5	13.5			13.5	13.5	13.5	13.5	13.5
wheat3										
barely1	53.0	50.1	41.4	23.0	11.1	52.0	42.4	44.3	31.0	12.0
barely2							4.0	6.0	12.0	
barely3		13.0	17.9	23.7			3.0	5.0	7.0	
sugerbeet1	43.5	23.1	13.5	5.6		44.5	36.6	33.7	24.1	13.9
sugerbeet2	10.5	13.2	14.0			13.5	14.6	16.4	17.1	18.2
sugerbeet3										
potato1	78.8	69.4	62.8	8.2	4.3	77.7	76.8	75.3	73.5	71.0
potato2	23.6	28.3	31.6	57.3	5.8	24.1	24.6	25.3	26.3	27.5
potato3	23.6	28.3	31.6	57.3	5.8	24.1	24.6	25.3	26.3	27.5
full irrigation	286.0	221.0	185.0	75.2	29.5	254.2	235.3	232.0	206.3	173.8
deficit irrigation	129.0	169.2	187.3	183.6	30.2	133.8	143.3	151.4	162.9	148.3
total	415.0	390.2	372.3	258.8	59.7	388.0	378.6	383.4	369.2	322.0
percent of full irrigation	68.9	56.6	49.7	29.1	49.4	65.5	62.2	60.5	55.9	54.0
percent of deficit irrigation	31.1	43.4	50.3	70.9	50.6	34.5	37.8	39.5	44.1	46.0

Source: Research Findings

Table4.

Cropping patterns in the policies in large farms

production	base year	decreasing water availability %				increasing water pricing%				
		5%	10%	15%	25 %	5%	10%	15%	20%	30%
corn1	147.9	143.7	142.2	69.1	3.1	144.4	143.2	144.2	147.7	154.6
corn2	134.8	139.0	140.5	68.3	3.1	139.3	134.5	138.5	135.0	128.1
corn3		5.0	8.0							
wheat1	51.0	48.0	43.0	17.2		50.0	48.0	43.0	23.0	14.0
wheat2	3.3	5.0	6.0	2.0		4.7	7.0	8.6	9.5	11.0
wheat3	5.0	7.0	12.0	6.6		6.0	7.4	8.7	12.0	
barely1	59.0	54.0	40.0	32.0		66.0	54.0	42.0	36.0	21.0
barely2	1.5	3.0	6.5			4.0	7.0	10.0	11.0	13.0
barely3	4.0	8.0	13.0			5.0	7.0	8.0	9.0	11.0
sugerbeet1	60.6	46.0	30.7	14.1	5.7	46.6	33.4	26.5	20.8	16.6
sugerbeet2	5.3	6.1	7.5	4.1		5.3	6.3	8.2	10.4	12.2
sugerbeet3	6.2	7.4	9.8	4.1		2.3	5.4	7.3	8.1	10.2
potato1	18.0	16.0	15.0	14.8	11.9	18.0	12.0	10.0	9.0	6.0
potato2	1.0	1.2	6.5				3.0	4.7	5.6	8.8
potato3	3	2.1	5.5			4.7	7.0	9.1	11.0	12.4
full irrigation	336.4	307.6	270.9	147.1	20.7	325.1	290.6	265.6	236.5	212.2
deficit irrigation	164.1	183.8	215.3	85.0	3.1	171.2	184.6	203.0	211.6	206.7
total	500.5	491.4	486.2	232.1	23.8	496.3	475.2	468.7	448.1	418.9
percent of full irrigation	67.2	62.6	55.7	63.4	86.9	65.5	61.2	56.7	52.8	50.7
percent of deficit irrigation	32.8	37.4	44.3	36.6	13.1	34.5	38.8	43.3	47.2	49.3

Source: Research Findings

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