OPTIMIZATION OF WATER RESOURCES MANAGEMENT AND SUSTAINABLE DEVELOPMENT OF AGRICULTURE ON THE VARAMIN PLAIN

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ABSTRACT

In this situation the water input is a valuable input which should pay to its optimal use. Planning through the optimal use of water and soil resources not only does keep them, but also does increase and improve the farmers' income and increase the rural prosperity. This study was done for improving the water resource management on Varamin plain by using the normal liner and goal optimization model. In this research for optimizing the water and prioritization of croping pattern in water use was attended by using the linear and goal planning models. In this research the impact of deficit irrigation on models of cropping patterns on irrigation and drainage networks was evaluated. The results show that the option 16 had the most financial return with 0.33 benefits on water use, and the option 22 had the least financial return with 0.2225 values. The findings of study show that the planning orientation had the most important and determinant role in management process and specializing the water resources of network.

Introduction

Proper management of water resources is one of the most exciting challenges of the 21st century (Hook, 1994; Cabelguenne et al., 1995). Because Iran is in the hot and dry zone, most plains of Iran need correct management of water resource and optimizing the water use to have the maximum utilizing from minimum water resources (Alizade, 1998). In some cases, the profitability of irrigated crops can be improved by reducing the amount of water used and optimizing the timing of application (Stockle and James, 1989; Bergez et al., 2002) and therefore increasing the efficiency of use of the allocated irrigation water (Kirda and Kanber, 1999; Pereira, 1999).

One of the basic ways in agriculture; as a great user of water resource, is the combined use of surface and underground water resources and undoubtedly executing the suitable and optimal cropping patterns can have the effective impact on water use decrease and benefit increase in an agriculture system (Asad pour *et al.*, 2005). The goal of this study is to increase and develop and apply the model for surface and underground water resources and reach the optimal cropping patterns.

The public model for linear planning and idealistic planning

These days the planning specially the linear planning (LP) is one of the improved tools of management tools which is used widely (Ghaderi et al., 2006).

The Goal programming was first presented by Charnes & Cooper in 1961. After Charnes & Cooper, Ignizio (1976) played an important role in over generalizing the goal programming and improving the models of Charnes & Cooper. Ignizio is one of those scholars who have dragged the goal programming and its applications to financial and management decisions. He presented the first software GP for solving the nonlinear models in 1962, and in 1976 he supplied the software "Integer goal programming priority". Lee (1972) dragged the application scope of these techniques to the field of applied science. Zankis & Gupta (1985) are those people who had important role in this field and presented the suitable segmentation from related resources to GP. Simultaneously Romoro (1986) supplied a long list from the goal programming resources from 1970 to 1982, and their application percent in different fields was shown (Zimmermann, 1978). Through this, in relation to math models applications in agriculture different studies have been done by Glen (1987) in crop and animal production systems, and Lowe & Preckel (2004) studied in production programming and agricultural anticipating industrials (Aouni and kettani, 2000).

The general model of Goal programming

In setting the linear model of GP, the objective function is thought as an available function which is the sum of variances of each goal. Since availability to all goals is not possible, the main problem in GP is to minimize the variable variances through the goals.

From math perspective GP can be mentioned as below (Ignizio, 1976):

$$S.T: Minimize\ \{p_1(n,p) + p_2(n,p) + \cdots + p_m(n,p)\}$$

$$f_i(x) + n_i - p_i = b_i \quad (i = 1,2,\dots,m)$$

$$g_j(x)(\geq,=,\leq)b_j \quad (j = 1,2,\dots,n)$$

$$x,n,p \geq 0$$

n,p : positive and negative variable variances

pm (n,p): linear function and normal from **m**th goal of deviations of variables which is accessed from product of two factors for normalizing and the relative importance in variable variance.

$f_i(x)$: the function of decision variable which specifies the **i**th goal structure

b_i:: the amount of goal in I goal or the right hand constant value in limited goal of i

$g_j(x)$:a function of decision variable which specifies the system limited structure which is related to j resource.

bj: the inventory of jth resource or the right hand value in limited system of j

x_j: the decision variable of j.

Material and Methods

Presenting the studying zone

Varamin plain is in the north of Iran in southern slop of Alborz and in 40 km southeast of Tehran between 33 and 51 degree to 40 and 51 degrees east longitude and 5 and 35 to 40 and 35 degrees north latitude. The area under cultivation watering is about 50 thousands ha which has agricultural potential which is the result of Jajrood river's sediments.

Varamin's irrigation network information

The extent of plain for cultivating is 130000 ha, the area of modern irrigation and drainage network is 50000 ha, the grade one agricultural lands are 80000 ha, the under modern irrigation lands are between 60 to 65 thousands ha; from 60000 ha of under irrigation network, 32 ha; that is, 53% is related to Varamin and 28 ha (47%) is related to Pakdasht. In this research, by attending to existent water, the programming and determining the model have been done for maximum 75000 ha.

In this method the hypotheses is that the product's climate needs are supplied and water, nutrition, salt, pests and diseases don't impact on the rise and potential performance of the yield (Ym). For computing the actual and maximum performance, it is necessary to use the cropping pattern of area. The common models for Varamin plain are: wheat, barley, corn, alfalfa, cotton and vegetables which are irrigated by furrow and tape methods.

Model for optimal allocation of water resources with respect to the cropping pattern

The total structure of the goal programming model of objective deficit was formulated as below:

Eff. $\left\{\frac{\sum_i N_i x_i}{\sum_i W_i x_i}, \frac{-\sum_i GW_i x_i}{\sum_i W_i x_i}\right\}$

Which in it:

I: the number of corps (i=1,2,…)

Ni: the net profit of ith product expect the cost of water

x_i: the under cultivating crop of i level in field (ha)

W_i : total use water for crop i through the cultivation season (10^2 m^3/ha)

GWi : the use underground water in the field for crop i (10^2 m^3/ha)

$\frac{\sum_i N_i x_i}{\sum_i W_i x_i}$: The rate of profit on total water (efficiency)

$\frac{\sum_i GW_i x_i}{\sum_i W_i x_i}$, The total underground water on total use water

Optimized model by GAMS

The first model is the linear programming for maximizing the profit. This model has been written by attending to the different decrease and or increase values of groundwater overdraft (Tolue, 2010). For all above mentioned options, the model LP1 was written, and the cultivation, profit and use water values levels were compared.

The second model is the linear programming (LP2) for minimizing the underground water use where according to the field's responsible, if the groundwater overdraft decrease until 25 percent, the plain water balance will be zero.

In third model the linear-goal programming was used simultaneously for maximizing the profit and minimizing the underground water which its goal is to reach to the LP1, LP2; so that each of these values have been as a goal.

Studied options: in this study 22 options were studied.

The first option is the zone's common model which includes Wheat, barley, alfalfa, maize, cotton, tomatoes, eggplant and zucchini. Total cultivation area in this zone is 52455 ha. Now, the most cultivation area is specialized for barely and then for wheat with values of 13500 and 13075 ha, respectfully. In option two to ten, different decreases of underground water were applied and the profit and the cultivation areas were compared with together. These options were mentioned for keeping and or improving the underground water levels. In these options the decrease values from 60% to 0% were thought. The total volume of Groundwater for this goal is different from 179.44 to 448.61 million cubic in a year in options 2 to 10.

In options 11 to 16, the groundwater overdraft increase of underground has been attended to specify the profit and cultivation area changes process. The groundwater overdraft increase was increased until 25%; that is, 560.76 million cubic in a year. In these options the groundwater overdraft increase of underground water causes to the much press to groundwater aquifer and options 16 to 22 were specified to the different deficit irrigation. By deficit irrigation until 40 percent and computing the value of function, the cultivating area was increased until 74165 ha. This area is 41 percent increase of the underground level.

The results of the linear programming LP1

In all options, the existent surface water of plain was used (141.92 billion cubic in a year). The most profit is related to 15 options, and that is for a position that we

 ISSN 2319-4979

remove 25 percent more than the present underground water; that is, 560.76 million cubic in a year. In this option the increments is 1.52 times more than the present position (2162 billion Rials). Applying this option is suitable when the groundwater is powered off by resources except the inner resources, on the other hand we will face the sharp drop in the water table in Varamin plain. The minimum profit is related to the second option which the groundwater overdraft from groundwater would decrease 60 percent rather than present (179.4 million cubic in a year). In this case the increment will reach to 57% (816.4 billion Rials). Executing the option is foreseen with the trend of declining water table of area in future for preventing the plain's ruin. In other options by increasing the groundwater overdraft from groundwater (options 2 to 15), the increment will be increased. This increase has more upward in options 2 to 6 than the options 7 to 15. In other options (16 to 22) the profit is decreased more while the under cultivation area increases. The results accessed from the linear model of maximizing the profit and the under cultivation areas of this model has been accessed in table (3) and figures (2), (3) and (4).

As it is mentioned in table 3, by decreasing the removal from groundwater, the under cultivation area was decreased and in minimum level in option 2, this value reached to 28635 ha. As it was expected, in this position, the crops' under cultivation areas close to the low level, and the crops' under cultivation area were decreased by using water. By applying the irrigation and water tension, until 40 percent, the under cultivation of total area reached to 88408 ha (option 22).

By exploring the options and other options, the shortage of irrigation water would be specified. Executing the option (22), by attending to the low efficiency of water in it (17%), is suggested just for cultivating the much area of plain.

As it can be seen in figure 4, the high Efficiency water is related to option 6(0.3304), option 6 is to apply the 20 percent decrease to groundwater overdraft. The minimum efficiency is related to option 22 with 17%. As it was mentioned above, the irrigation was applied about 40 percent.

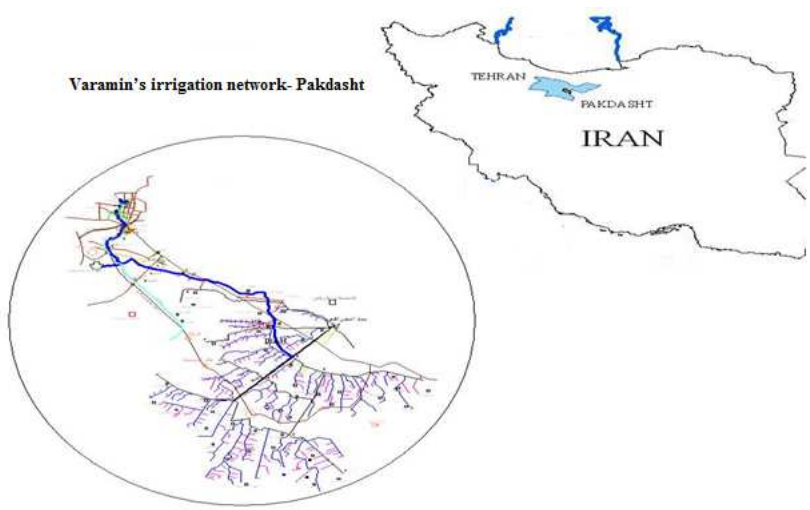

Table 1: presenting the studying options and their cultivating area

Total cultivation area under linear condition	Total cultivation area under goal condition	The amount of deficit irrigation	µ	Options
-	-	-	-	1
-	-	0	0.4	2
-	-	0	0.5	3
-	-	0	0.6	4
-	-	0	0.7	5
40904	40699	0	.80	6
40904	40699	0	0.85	7
40904	40699	0	0.9	8
40904	40699	0	0.95	9
40904	40699	0	1	10
40904	40699	0	1.05	11
40904	40699	0	1.1	12
40904	40699	0	1.15	13
40904	40699	0	1.2	14
40904	40699	0	1.25	15
41463	47578	5	1	16
41700	50437	10	1	17
41700	52927	15	1	18
41700	56655	20	1	19
41700	59394	25	1	20
41700	61163	30	1	21
41700	74165	40	1	22

For accessing the optimal area of cultivation, every option was written and solved by 3 models.

Table 2: cultivation area of studying options (ha)

cotton		Vegetables		alfalfa		maize		barley		Wheat		plant
fractional	goal	fractional	goal	fractional	goal	fractional	goal	fractional	goal	fractional	goal	**option**
2204	1999	17000	17000	1750	1750	1750	1750	9100	9100	9100	9100	**15 تا 6**
2763	3000	17000	17000	1750	1750	1750	7628	9100	9100	9100	9100	**16**
3000	3000	17000	17000	1750	1750	1750	10487	9100	9100	9100	9100	**17**
3000	3000	17000	17000	1750	3727	1750	11000	9100	9100	9100	9100	**18**
3000	3000	17000	17000	1750	4087	1750	11000	9100	9100	9100	12468	**19**
3000	3000	17000	17000	1750	6000	1750	11000	9100	9100	9100	13294	**20**
3000	3000	17000	17000	1750	6000	1750	11000	9100	9100	9100	15063	**21**
3000	3000	17000	17000	1750	6000	1750	11000	9100	9100	9100	28065	**22**

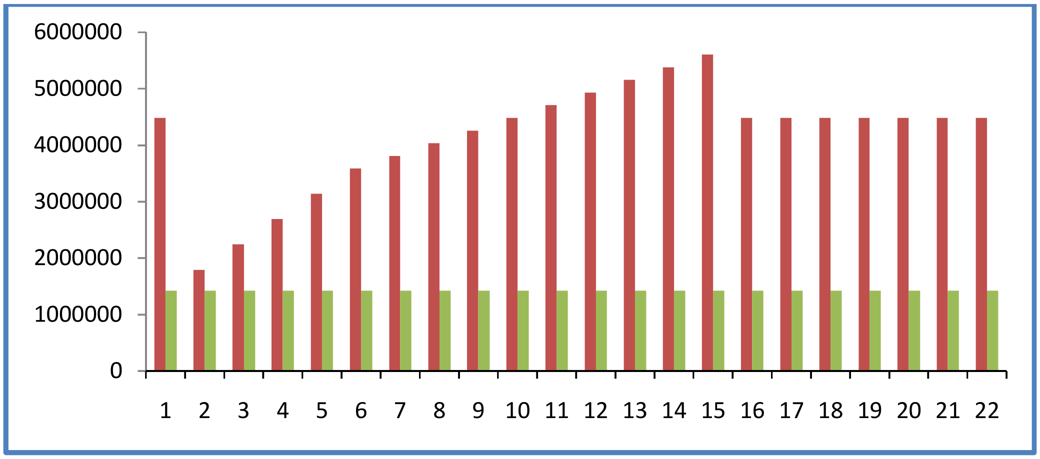

Figure (2): the value of surface and groundwater in different options LP1 (cubic in a year)

Table (3): under cultivation areas of linear programming for maximizing the profit in different options (ha)

Total	Cotton	Vegetables	Alfalfa	Maize	Barley	Wheat	Option
28635	0	6935	1750	1750	9100	9100	2
31897	0	10197	1750	1750	9100	9100	3
35158	0	13458	1750	1750	9100	9100	4
38419	0	16719	1750	1750	9100	9100	5
41270	2570	17000	1750	1750	9100	9100	6
43115	3000	17000	1750	3165	9100	9100	7
45153	3000	17000	1750	5203	9100	9100	8
47193	3000	17000	1750	7243	9100	9100	9
49232	3000	17000	1750	9282	9100	9100	10
51222	3000	17000	2022	11000	9100	9100	11
52888	3000	17000	3688	11000	9100	9100	12
54446	3000	17000	5246	11000	9100	9100	13
56365	3000	17000	6000	11000	9100	10265	14
58623	3000	17000	6000	11000	9100	12523	15
51780	3000	17000	2580	11000	9100	9100	16
54196	3000	17000	4996	11000	9100	9100	17
57543	3000	17000	6000	11000	9100	11443	18
61798	3000	17000	6000	11000	9100	15698	19
66620	3000	17000	6000	11000	9100	20520	20
72130	3000	17000	6000	11000	9100	26030	21
88408	3000	17000	6000	11000	22408	29000	22

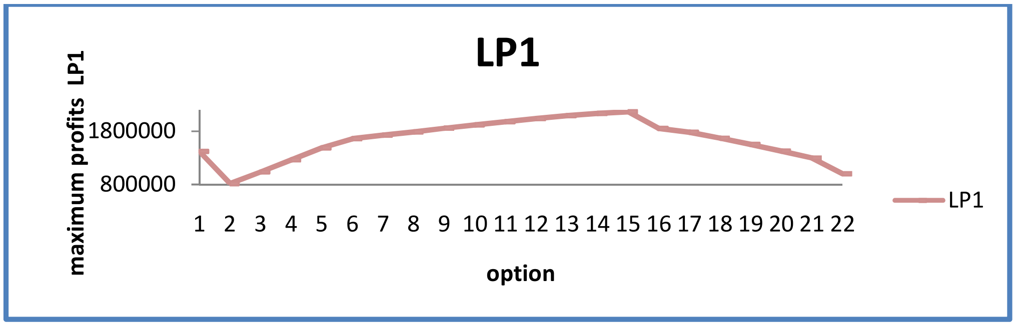

Figure (3): maximizing the profit by linear programming method (LP1) (Million Rials)

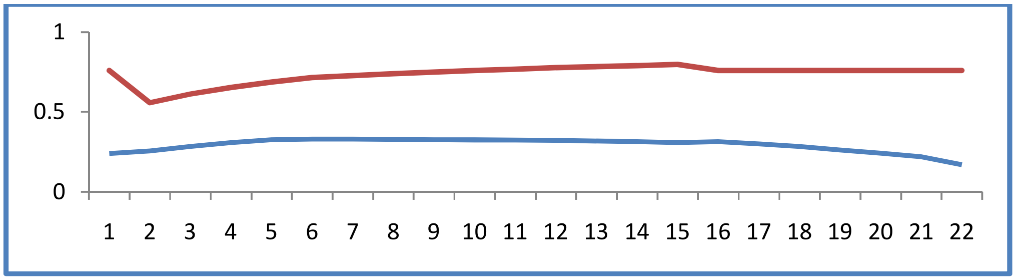

Figure 4: the productivity and groundwater levels on used water in programming deficit for maximizing the profit

The results accessed from linear programming LP2

This model is for minimizing the groundwater overdraft. According to the authorities of Varamin water, if the groundwater overdraft would be decreased about 25%, the value of groundwater overdraft and nutrition will be equal and the table will be proved. So, in all options of LP2, the amount of groundwater is proved and for groundwater is defined 326.46 million cubic (table 4). In this model, LP2 is equal for all options of 1 to 15, and in doing irrigation, the profit values, cultivation and productivity indicators and groundwater use is according to the table 4.

The results accessed from goal programming

By attending to the goal programming values accessed from above linear models (LP1, LP2), the combination and under cultivation area of crops of the zone have been written in table 5.

These values are a mean for getting maximum profit and minimum use of water. In real, it was attempted to get much profit by using minimum groundwater. Options 2 and 5 are not suitable to use for goal programming because their goal are different from each other. The values of the options 6 to 15 are prove values; so, the profit and under cultivation areas are same. In these options, the groundwater overdraft is different; that is, they are between 0.8 the present groundwater overdraft in option 2 and 1.25 times groundwater overdraft in option 15. That is, the value of groundwater overdraft reaches from 448.89 million cubic in option 6 to 560.76 million cubic in option 15. It is so important to mention that, in all above mentioned options, the surface water of network; that is, 141.92 million cubic was used. In the other options of irrigation (16 to 22), we face with high under cultivation. In these options the value of the groundwater overdraft is different from 404.12 to 372.35 million cubic in a year. In options 16 with 5 percent irrigation, the under cultivation area of corn is increased and reached from 1750 ha in last option to 7628 ha and in the next options it reached to 11000 ha. The cultivation of alfalfa reaches from 1750 ha to 6000 hevtors in options 22. As it is noticed, the value of goal is same for options 6 to 16, the different removal groundwater. In real, in these options just in one value, the value of profit is in maximum level and the use of water is minimum level. Table 6 shows the water use and profit values accessed from all options in goal programming. As it is noticed in options 15 to 20 the value of profit is much.

Computing the value of profit accessed from sailing crops in each ha

After getting the water use of the crops in the different percent of deficit irrigation tension and entering it to detour model one, the crop's application in situation that deficit irrigation tension is not applied and also in the situation that the deficit irrigation tension is applied as 5%, 10%, 15%, 20%, 25%, 30%, 40%. By attending to the results, it can be counted profits of the crops. For this, at first the resulted application of the crop (according to kilogram) multiplied to the sail cost of crop (according to *Rial*) and is reduced from the gotten value to calculate the profit of crops' sailing. The average cost of the production of one ha includes the costs of preparing the ground, cultivation, harvesting. This process was done for all crops without applying the tension on deficit irrigation and when the tension of deficit irrigation is 5 to 40%.

The mentioned results have been mentioned in Tables (7). The rate of pure profit was calculated and it will be used as an entry of other models. It can be found from the above mentioned tables that by increasing the irrigation the application of the crops was reduced and descend are different in different crops. For example in irrigation tension of 5% the less reduction is related to cotton, in this crop by applying 5% irrigation we saw 4.2% reduction; that is, the application of cotton in complete irrigation situation reaches from 4096.56 kilogram to 3922.48 kilogram in a ha in 5% irrigation tension. In 5% tension, the most reduction application is related to which shows 5.8 percent reduction and reached from 4731.62 to 4459.53 kilogram in a ha. In reality, the sensitive crop in 5% watering tension level is grain and the most resistant crop is cotton. In other crops we saw 5.2% of reduction.

Table 4: the computed values of profit, cultivation area and productivity indicators and groundwater in LP2 model

Cultivation area	Ground water/water use	Productivity (Net return/water use)	Net return	Groundwater	option
39864	7033.0	3289.0	1573260	3364575	**1 -15**
41354	7033.0	3214.0	1537320	3364575	**16**
43601	7033.0	3115.0	1490370	3364575	**17**
46287	7033.0	2977.0	1424100	3364575	**18**
49308	7033.0	2838.0	1357777	3364575	**19**
52457	7033.0	2677.0	1280570	3364575	**20**
55811	7033.0	2470.0	1181600	3364575	**21**
67089	7033.0	1931.0	923861	3364575	**22**

Table 5: the combination and level of under cultivation of crops of zone in linear goal programming (ha).

RI=40	RI=30	RI=25	RI=20	RI=15	RI=10	RI=5	μ=1.25	μ=1.2	μ=1.15	μ=1.1	μ=1.05	μ=1	μ=0.95	μ=0.9	μ=0.85	μ=0.8	current	
Option 22	Option 21	Option 20	Option 19	Option 18	Option 17	Option 16	Option 15	Option 14	Option 13	Option 12	Option 11	Option 10	Option 9	option 8	Option 7	Option 6	Option 1	Activities
28065	15063	13294	12468	9100	9100	9100	9100	9100	9100	9100	9100	9100	9100	9100	9100	9100	13075	Wheat
9100	9100	9100	9100	9100	9100	9100	9100	9100	9100	9100	9100	9100	9100	9100	9100	9100	13500	barley
11000	11000	11000	11000	11000	10487	7628	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	8500	maize
6000	6000	6000	4087	3727	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	4450	alfalfa
17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	12700	Vegetables
3000	3000	3000	3000	3000	3000	3000	1999	1999	1999	1999	1999	1999	1999	1999	1999	1999	230	cotton
74165	61163	59394	56655	52927	50437	47578	40699	40699	40699	40699	40699	40699	40699	40699	40699	40699	52455	total

Table 6: the values of profit and water use in different options in linear goal method

Net return/water use	use Water (m3)	option	Net return/water use	use Water (m3)	option
3298.0	4917089	14	2404.0	5905300	1
3298.0	4917089	15	3298.0	4917089	6
3167.0	5450442	16	3298.0	4917089	7
3062.0	5460506	17	3298.0	4917089	8
2919.0	5438283	18	3298.0	4917089	9
2723.0	5429394	19	3298.0	4917089	10
2551.0	5366968	20	3298.0	4917089	11
2374.0	5142663	21	3298.0	4917089	12
1838.0	5205468	22	3298.0	4917089	13

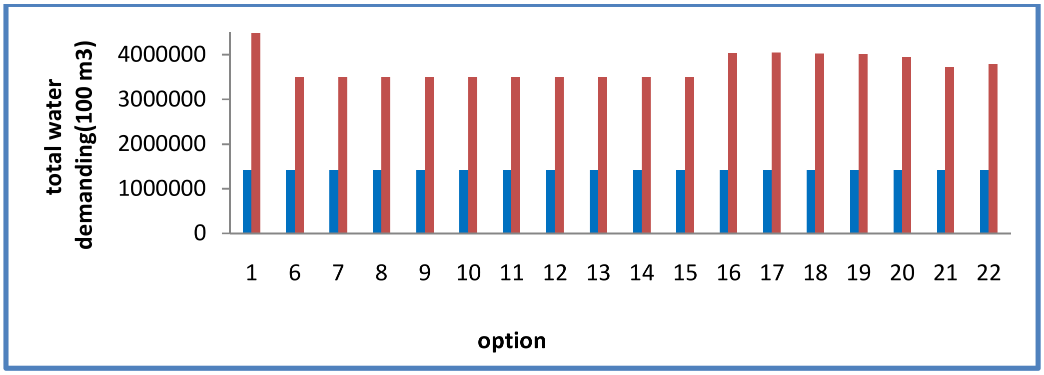

Figure 5: the values of surface and groundwater waters in studying options in linear goal programming method

Conclusion

The rate of level specialized water in all options is 141.92 million cubic in a year, and it is enough to answer the water demanding. The present overdraft rate of groundwater is 448.61 million cubic in a year.

- Comparing the options 2 to 15 of conventional irrigation which shows that by increasing the overdaraft, the level of under cultivation was increased and according to that the pure profit increased, too. So that, the maximum rate of profit in option 15 is possible to be 2162.47 billion *Rials* by removing the 25% of groundwater. In this option the level of the under cultivation was increased as 58623 ha.

- In this research the impact of deficit irrigation on crops on irrigation and drainage network was evaluated. The results showed that in executing the options 16 and 17 which were related to 5 and 10 percent irrigation, the rate of groundwater reduced from 448.61 to 338.108 and 317.634 million cubic in a year; that is, 24.63 and 29.2 percent reduction of overdraft rate. As mentioned above, by 25% reduction of overdraft rate of groundwater resources, the balance of plain was reached to zero, and in reality, the groundwater level reach to a proved rate.

Table 7: the profit resulted from crops' sailing without considering the water costs rate for one ha without applying the deficit irrigation.

Net return (10^6 Rls/ha)	Cost of production for crop per unit (10^6 Rls/ha)	Net agricultural returns per unit (10^6 Rls/ha)	Current market price of crop (10^6 Rls/ton)	Yield per unit (Kg/ha)	Percentage of deficit irrigation	Activities (main crops of region)
13.88	7	20.88	4	5219	0	wheat
12.73		19.73		4932	5	
11.58		18.58		4645	10	
10.43		17.43		4358	15	
9.29		16.29		4071	20	
8.14		15.14		3784	25	
6.99		13.99		3497	30	
4.69		11.69		2923	40	
11.03	6	17.03	3.6	4731	0	barley
10.05		16.05		4459	5	
9.07		15.07		4187	10	
8.09		14.09		3915	15	
7.12		13.11		3643	20	
6.14		12.14		3371	25	
5.16		11.16		3099	30	
3.20		9.20		2554	40	
31.30	21	52.30	1	52303	0	maize
28.95		49.95		49950	5	
26.60		47.60		47596	10	
24.24		45.24		45242	15	
21.89		42.89		42889	20	
19.53		40.53		40535	25	
17.18		38.18		38181	30	
12.47		33.47		33474	40	
34.25	18	52.25	3.4	15369	0	Alfalfa
31.38		49.39		14523	5	
28.51		46.51		13678	10	
25.63		43.63		12833	15	
22.76		40.76		11987	20	
19.88		37.88		11142	25	
17.01		35.01		10297	30	
11.26		29.26		8606	40	
68.49	26	94.49	1.5	62996	0	vegetables
63.53		89.53		59689	5	
58.57		84.57		56382	10	
53.61		79.61		53074	15	
48.65		74.65		49767	20	
43.69		69.69		46460	25	
38.73		64.73		43152	30	
28.81		54.81		36538	40	
57.87	13	70.87	17.3	4096	0	cotton
54.86		67.86		3922	5	
51.85		64.85		3748	10	
48.83		61.83		3574	15	
45.82		58.82		3400	20	
42.81		55.81		3226	25	
39.80		52.80		3052	30	
33.78		46.78		2703	40	

- Also the results show that the option 16 had the most financial efficiency with 0.33 water use, and the option 22 had the less financial efficiency. And also the option 22 with groundwater on total use-water 0.5518 and option 6 to 16 enter minimum and maximum press on ground water resources. This shows that the overdraft increase causes to increase the use of water resources, and also it causes to the reduced productivity.

- The results of research show that the planning agents (profit and productivity of water or stability in use of groundwater resources) have important role in managing process and specializing the network water resources, and it demands in different, normal situations and the disasters resulted from drought and climate changes.

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