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Optimal Utilization of the Chahnimeh Water Reservoirs in Sistan Region of Iran using Goal Programming Method

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ABSTRACT The optimal allocation of the Chahnimeh water resources among different sectors, viz. domestic, agricultural and environmental consumptions, was determined using the goal programming method in GAMS, based on the present condition in the area. Results showed an increase of 15.4, 44.5 and 230% in allocation of water to domestic, agriculture and environment sectors, respectively, in this method as compared to the present allocation. Besides, implementation of the second water transferring line to Zahedan city would result in a 66% increase in the water transferring rate to this city without any change in water supply for domestic sector in Zabol city and the surrounding villages. The scenario of 20% reduction in water per capita consumption led to about 5.9 million cubic meters saving in water supply from Chahnimeh reservoirs to the domestic sector. According to the projected population growth for 2025 in the study area, water consumption in domestic sector will increase by 15.9%. Results showed that the goal programming can be applied as a useful tool to analyze the effect of different scenarios on water demand and supply management and, hence, to allocate water for different sectors in a most appropriate way.

Keywords: *Chahnimeh water reservoirs, Goal programming, Optimal allocation, Sistan region*

1 INTRODUCTION

Water shortage, increasing demand as well as exacerbation of competition among different sectors of agriculture, domestic and industry have highlighted importance of water resources exploitation in recent decades (Mozafari *et al.*, 2009). Characterized by mean precipitation of 250 mm year^{-1}, uneven spatial-temporal distribution of rainfall and high evaporation rate, Iran is considered as an arid country (Zolfagharie and Hashemie, 2009). Optimum utilization of water resources is an integral part of water resource management (Mihankhah *et al.*, 2012). The low efficiency of water utilization projects is mainly attributed to inappropriate planning issues on water distribution to meet water demands in different sectors, which have neglected matching between supply and demand, and the resulting water loss. The use of analytical and optimization techniques can be adopted to obviate some

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Various studies on multi-objective planning for water resources utilization have been conducted in recent years, for which a wide variety of models on water allocation and management have been used. The main reasons for adopting such models include multi-objective nature of decision making issues, different decision-makers for a particular operation and the rapid development of software computer on multi-objective programming problems (Evans, 2007). Multi-objective models, including goal programming models, lend to modeling and analysis of decision-making issues as well as natural resource management, taking multiple conflicting goals into account (Fathi and Zibaei, 2012). Goal programming, as an important analytical approach devised to solve many real-world problems (Chin, 2009), sets the stage so that a decision maker is able to consider multiple goals simultaneously (Romero, 2004).

Using goal programming, Keramatzadeh *et al.* (2007) evaluated optimal allocation of water resources of Shirvan and Barzo dams among different regions and concluded that it was possible to increase water allocation to agriculture to 47 million cubic meters per year. Alam and Olsthoorn (2011) used an irrigation-economic model to evaluate the raising of a dam and its effects on long-term groundwater balance and water logging. They suggested guidelines to optimize the reservoirs by considering the farmers' action in response to government policies. The results reinforced the decision to raise the dam height, which would increase water availability by 68% in the basin. While using prioritized goal programming to manage the allocation of the Mahabad dam water to meet demands for domestic, agriculture and power plant, Nader and Sabouhi Sabouni (2012) concluded that water volume dedicated to agriculture and domestic sectors could be increased. Salimifard and Mostafaee Dolatabad (2013) adopted randomized goal programming for water resources management in a multi-criteria decision support system, the results of which revealed that the model could take multiple goals into account, simultaneously. At the same time, by defining risk parameters, the decision makers could deal with different scenarios on parameters values. A general multi-objective programming model for minimum ecological flow or water level in two representative rivers and a lake in the northern China determined a minimum ecological flow of 83 $m^3 s^{-1}$ during fish breed ingseason and 22 $m^3 s^{-1}$ for the other seasons, while a minimum regeneration flow of 393 $m^3 s^{-1}$ was determined for the midstream floodplain forest, and the minimum ecological lake level was estimated to be 191.2 m (Shang, 2015).

The present study was aimed to determine the optimal allocation of Chahnimeh water for domestic, agriculture and environment sectors in the Sistan region of Iran using the goal programming.

2 MATERIALS AND METHODS

2.1 Study area

Sistan (60° 36´ 18" to 61° 48´ 24" E and 30° 03´ 32" to 31° 22´ 50"N) is located in east of Iran and north of Sistan-Baluchestan Province (Figure 1). It is characterized byarid climate, annual precipitation of 52.3 mm, evaporation of 4700 mm and annual average temperature of 21.9 °C. The average relative humidity in the synoptic station of Zabol for a forty year period was 38% (Sistan-Baluchestan Regional Water Company, 2014).

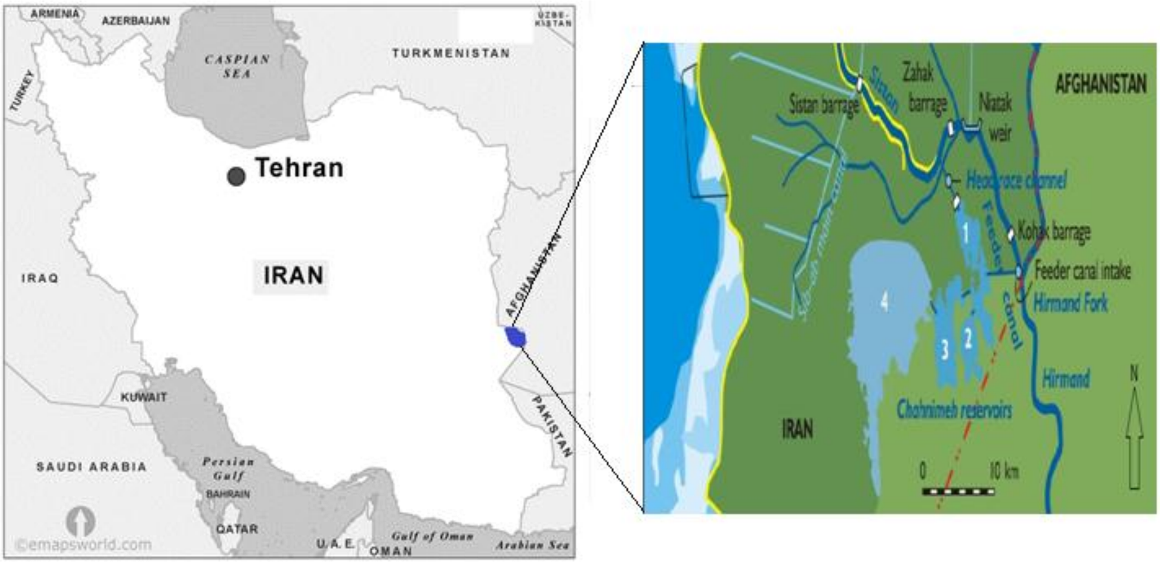

Figure1 A general view of Chanimeh reservoirs in Sistan region, Iran

The Chahnimeh reservoir was discovered in 1981 by a Japanese consulting company "Kazheh-Sanyo" near the Zahak city (Sistan-Baluchestan Regional Water Company, 2014). It is fed by the Sistan River 3km away through a constructed bypass named as Feeding Canal. It includes three naturally formed geological depressions (1, 2 and 3) with a total capacity of 760 million m^3,in which part of surplus water of the Sistan River is stored during the wet season and used for domestic and agricultural purposes. Considering the foregoing climatic conditions, these reservoirs serve as the only water source for meeting demands of the study area especially during droughts. In 2007, the fourth reservoir was constructed which has not been exploited yet. The Chahnimeh water is allocated for domestic purposes of Zabol city and its districts, Zahedan city, farming and environmental sectors.

The agricultural sector in Sistan region includes three regions of Zahak, Sistan(Shibe-Aband Poshte-Ab) and Miankangi covering 24000,48120 and 29000 hectares, respectively. Figure 2 illustrates water system in the Sistan region, according to which the Helmand River upon crossing the Iranian border (from Afghanistan) is divided into two tributaries of Sistan and Parian. The Parian River flows along the border northwardly and irrigates the Miankangi's farmlands through Shirdel, Golimir and Number One canals. The Sistan River flows towards the Hamoun-e-Hirmand at the end point and irrigates some farmlands.

2.2 Methodology

The widely used multi-objective "goal programming" method was also used in this study to optimize the allocation of Chahnimeh water among three sectors, viz. domestic, agriculture and environment. This method outperforms others programming methods as it has high degree of flexibility allowing various and contradictory goals interchanging by which managers can make better decisions on water allocation. The goal programming model consists of four parts of decision variables, system constraints, goal constraints and objective function. The decision variables and system constraints are the same constraints used in linear programming with no inflexibility and a must be met constraint.

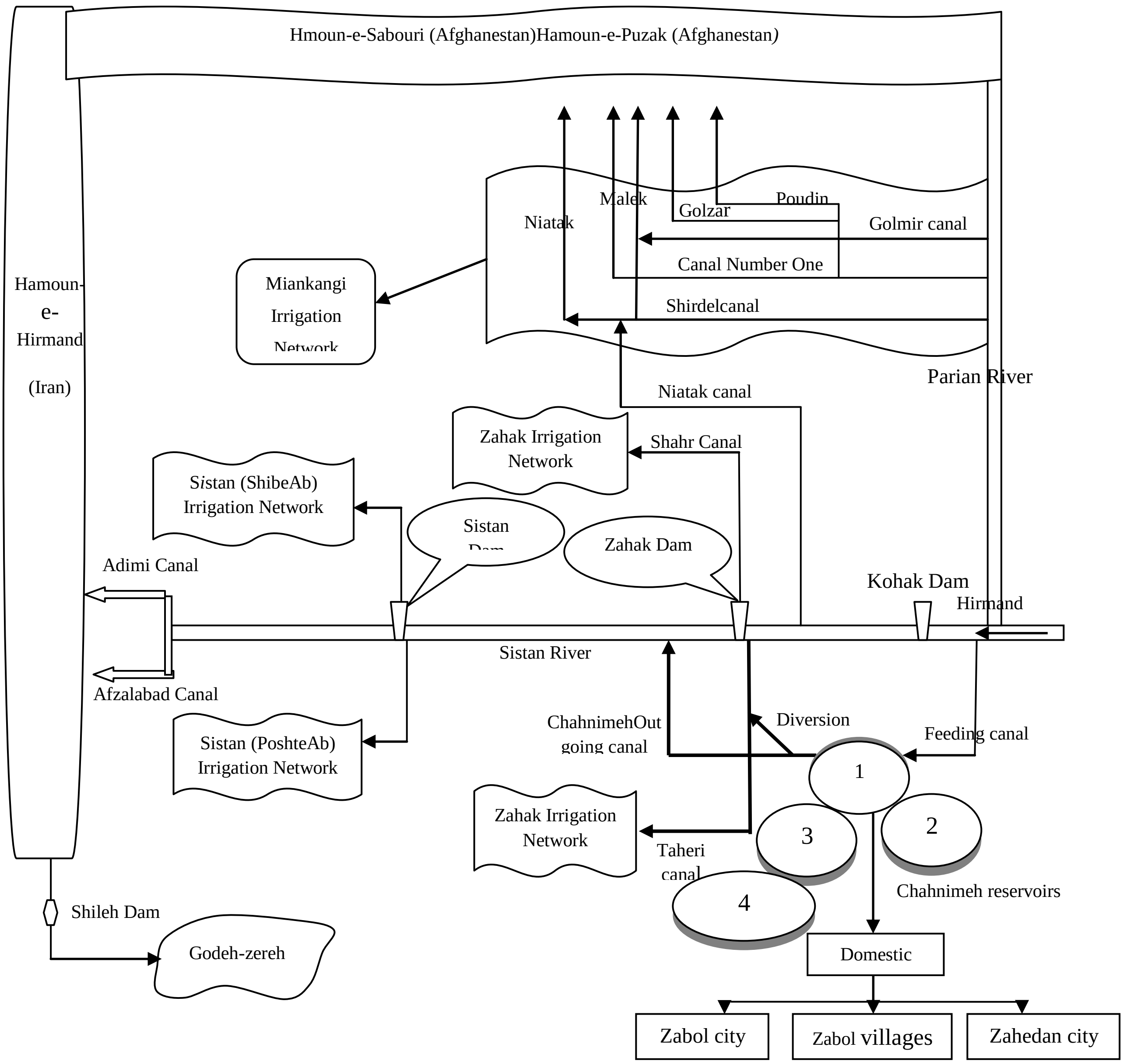

Figure 2 Conceptual model of the water system in Sistan Region, Iran

Goal constraints are characterized with positive (p) and negative (n) deviations variables so that minimizing such deviations are found to be the main goals. Flexibility of goal programming stems from such constraints (Abdolaziz, 2007).

Weighted goal programming standard pattern is based on the equations 1, 2 and 3, representing objective functions, constraints and goals, respectively (Hasan and Hasan, 2007).

$$\min \sum_{i=1}^{n} W_i \,(+ n_i - p_i) \tag{1}$$

$$g_t(x) \le b_t \tag{2}$$

$$f_i(x) \ + \ n_i - p_i = \ b_i \tag{3}$$
$$x\,, + n_i \ \ , -p_i \ge 0$$

Where, W_i represents *i*th goal weight, $qi(+ n_i - p_i)$ is deviation function from *i*th goal, $g_t(x)$ denotes *t*-thconstraint function for different activities X, $f_i(x)$ is *i*th goal function from various activities X and finally, *–n* & *+p* are negative and positive deviations from interested goals, respectively. Taking decision makers' preferences into account, goal programming simplifies goal classification. Given the experts point of view and some policies in the region, domestic sector consumption is prioritized followed by environment and agriculture sectors.

2.2.1 The variables used in the study

The main variables in the research include water transfer among three sectors, viz. domestic, agriculture and environment. Table1 presents main and interrelated variables.

2.2.2 The objective function

Objective function in the goal programming is to minimize unwanted deviations from adopted goals. Given aforementioned discussion, the objective function used in this study is as follows:

$$Z = \left(\sum_{m=1}^{12} W_{Re} \,.\, nD_{1.m}/GD_{1.m} \right) + \left(\sum_{m=1}^{12} W_{Re} \,.\, nD_{2.m}/GD_{2.m} \right) + \left(\sum_{m=1}^{12} W_{Re} \,.\, nD_{3.m}/GD_{3.m} \right) + \left(\sum_{m=1}^{12} W_{z} \,.\, nagr_{za.m}/Gagr_{za.m} \right) + \left(\sum_{m=1}^{12} W_{z} \,.\, nagr_{si.m}/Gagr_{si.m} \right) + \left(\sum_{m=1}^{12} W_{z} \,.\, nagr_{mi.m}/Gagr_{mi.m} \right) + \left(\sum_{m=1}^{12} W_{EF} \,.\, nEF_{m}/GEF_{m} \right) \tag{4}$$

Where $nD_{1.m}$, $nD_{2.m}$,$nD_{3.m}$ represent negative deviations from goal of domestic water consumption, Zabol city, Zabol villages and Zahedan, respectively; $nagr_{za.m}$, $nagr_{si.m}$, $nagr_{mi.m}$ are negative deviations from agriculture sector water consumption for regions Zahak, Sistan (ShibeAb and PoshteAb) and Miankangi, respectively and nEF_m denotes on negative deviations from environmental flow goal; $GD_{1.m}, GD_{2.m}, GD_{3.m}$ are goals of domestic water consumption in Zabol city , Zabol villages and Zahedan; $Gagr_{za.m}$, $Gagr_{si.m}, Gagr_{mi.m}$are goals of agriculture sector water consumption for regions Zahak, Sistan (Shibeab and Poshteab) and Miankangi, respectively; GEF_m is environment sector goal and finally W_{Re}, W_z, W_{EF} are found to be weights of domestic, agriculture and environment sectors, respectively. Given the goals of maximum water supply to different domestic, agriculture and environment sectors, the negative deviations from goals should be minimized as it can be seen in the objective function formula. Systemic and goal constraints should be as follow to design a goal programming for allocation of the Chahnimehes reservoirs water resources.

Table1 The variables used in the modeling process

Variable code	Variable description
$\mathbf{D_{Re.m}}$	Water transfer from Chahnimeh to domestic consumption in the region Re at month M
$\mathbf{Dagr_{z.m}}$	Water transfer from Chahnimeh for agriculture sector in the region Z at month M
$\mathbf{EF_m}$	Water transfer from Chahnimeh for environment sector in the region month M
$\mathbf{r_m}$	Water volume remained in Chahnimeh reservoirs in month M
$\mathbf{r_{m-1}}$	Water volume remained in Chahnimeh reservoirs since previous month(m-1)
$\mathbf{s_m}$	Chanimeh water level at month M
$\mathbf{nD_{Re.m}}$	Negative deviation from goal of domestic water consumption in region Re in month M
$\mathbf{nagr_{z.m}}$	Negative deviation from goal of agriculture water consumption in region Z in month M
$\mathbf{nEF_m}$	Negative deviation from goal of environmental flow consumption in month M
$\mathbf{pD_{Re.m}}$	Positive deviation from goal of domestic water consumption in region Re in month M
$\mathbf{pagr_{z.m}}$	Positive deviation from goal of agriculture water consumption in region Z in month M
$\mathbf{pEF_m}$	Positive deviation from goal of environmental flow demand in month M

2.2.3 Systemic constraints

The systemic constraints have no flexibility and should be treated as linear programming constraints (Sabouhi Sabouni, 2012). Systemic constraints for planning model of water allocation in Chahnimehes are presented as follow:

I. Constraints on transportation capacity of water pipeline for domestic consumption

Transportation capacity of water pipeline for domestic consumption for different regions can be shown in equation 5.

$$D_{Re.m} \leq WC_{Re.m} \quad (5)$$
$$m = 1, \dots, 12$$
$$\mathrm{Re} = 1, \dots, 3$$

Where $WC_{Re.m}$ represents monthly water transferred for domestic consumption in different areas and $D_{Re.m}$ is water transfer from Chahnimeh reservoirs to domestic consumption in the region Re at month M.

II. Constraints on transportation capacity of water channels for agriculture consumption

Transportation capacity of water channels for agricultural sector in various regions of Sistan is shown in equation 6.

$$Dagr_{z.m} \leq AgrC_{z.m} \quad (6)$$
$$m = 1, \dots, 12$$
$$\mathrm{z} = 1, \dots 3$$

Where $AgrC_{z.m}$ represents monthly water transferred for agricultural consumption in different parts of Sistan region and $Dagr_{z.m}$ is water transfer from Chahnimeh reservoirs for agricultural sector in the region Z at month M.

III. Constraints of maximum and minimum reservoir volume of Chahnimeh

The minimum and maximum reservoir volume of Chahnimeh are calculated by equations 7 and 8, respectively.

$$r_m \leq Smax_m \qquad m = 1, \dots, 12 \quad (7)$$
$$r_m \geq Smin_m \qquad m = 1, \dots, 12 \quad (8)$$

Where $Smax_m$ and $Smin_m$ denote the highest and lowest water volume that can be stored in the Chahnimeh reservoirs and r_m is the remaining water volume in Chahnimeh reservoirs in month M.

IV. Constraints of water supply from Chahnimeh reservoirs

Equation 9 implies to constraint of water supply from Chahnimehes into different demand sectors.

$$\sum_{Re=1}^{3} D_{Re.m} + \sum_{z=1}^{3} Dagr_{z.m} + EF_m + r_m - r_{m-1} - Iws + Eva_m = ChF_m \quad (9)$$

$m = 1, \dots, 12$

$\mathrm{Re} = 1, \dots, 3 \mathrm{z} = 1, \dots, 3$

Where $ChF_m$is water stored in Chahnimehes per month, Eva_m is monthly evaporation rate from reservoirs and Iws is initial water storage in reservoirs. Some others variables are given in Table 1.

2.2.4 Estimation of evaporation from Chahnimeh reservoirs

Due to special climatic conditions in Sistan region, including high temperatures and strong winds, estimation of evaporation of Chahnimehes is essential. To calculate evaporation, information on volume and reservoir levels is required. For this purpose, the reservoirs surface area where water is stored in is calculated and the average monthly evaporation data is used to calculate monthly evaporation from Chahnimehes as below:

$$s_m = 2460000 + .08\,(r_{m-1} + chf_m) \quad (10)$$

$$E_m = S_m . e_m \quad (11)$$

Where $S_m$is reservoir area per month inm^2, r_{m-1}volume of water remained in reservoir since previous month in m^3, ChF_m is water entered into reservoir per month M in m^3, E_m is evaporation from reservoir in month M in m^3 and finally e_m represents monthly average evaporation in meter.

2.2.5 Goal constraints

In goal programming, in addition to system constraints, goal constraint is considered as well and the right-hand side of goal constraints equations is goal levels which can be attained. Goal constraints have positive and negative deviation variables that aim to minimize the deviations from the desired goals. In this study, to provide maximum water needs of domestic consumption, agriculture and the environment, negative deviation variables were minimized.

2.2.5.1 Goal constraints on meeting domestic water consumption demand

Goal constraints on meeting domestic water consumption demand can be shown in equation 12.

$$D_{Re.m} + nD_{Re.m} - pD_{Re.m} = GD_{Re.m} \quad (12)$$

$m = 1, \dots, 12$

$\mathrm{Re} = 1, .., 3$

Where, $GD_{Re\,.m}$is desired goal of supplying domestic water demand. Other variables can be seen in Table 1.

2.2.5.2 Goal constraints on meeting agriculture water demand

Goal constraints on meeting agricultural water demand can be shown in equation 13.

$$Dagr_{z.m} + nagr_{z.m} - pagr_{z.m} = Gagr_{z.m} \quad (13)$$

$m = 1, \dots, 12$

$\mathrm{z} = 1, \dots, 3$

Here, $Gagr_{z.m}$ is goal of supplying agriculture water demand. Some other variables are given in Table 1.

2.2.5.3 Goal constraints on supplying environmental water demand

Goal constraint on supplying environmental water demand can be shown in equation 14.

$$EF_m + nEF_m - pEF_m = GEF_m \quad (14)$$
$$m = 1, \ldots, 12$$

Where GEF_m represents goal of supplying environmental water demand. Some other variables are given in Table 1.

3 RESULTS

The present study tried to shed lights on optimized Chahnimeh water allocation for domestic, agriculture and environment sectors using goal programming to help managers in decision making. Once the model was designed and programmed by using the goal programming technique in GAMS programming environment and solved for given conditions and constraints of Sistan region, optimum water allocation to different was determined for various months. Tables 2, 3, 4 and Figure 3 compare the existing allocations and optimal allocations of the Chahnimeh water to various sectors in different areas. Table 2 shows the current and optimal water allocation to domestic consumption at Zabol city, Zabol villages and Zahedan city. In addition, the present and optimized water allocation to agricultural sector at Zahak, Sistan (ShibeAb and PosheAb), and Miankangi regions is given in Table 3. Table 4 represents the present and optimal monthly allocation of water for the environment sector.

Table 2 The present and optimum allocation of the Chahnimeh water to domestic sector in different areas (million m^3)

Month	Existing water allocation			Optimal water allocation		
	Zabol city	Zabol villages	Zahedan city	Zabol city	Zabol villages	Zahedan city
Jan	0.872	1.241	2.162	0.979	1.394	2.650
Feb	o.806	1.210	1.911	0.949	1.351	2.650
Mar	0.88	1.252	1.943	1.078	1.554	2.650
Apr	1.05	1.334	2.462	1.075	1.558	2.650
May	0.822	1.361	2.543	1.081	1.562	2.650
Jun	0.895	1.443	2.461	1.084	1.566	2.650
Jul	0.981	1.372	2.62	1.087	1.57	2.650
Aug	0.981	1.420	2.443	1.092	1.574	2.650
Sep	0.763	1.144	2.411	0.969	1.38	2.650
Oct	0.773	1.162	2.382	0.972	1.383	2.650
Nov	0.806	1.113	2.355	0.974	1.387	2.650
Dec	0.861	1.081	2.292	0.977	1.39	2.650
Total	10.49	15.133	27.985	12.310	17.669	31.80

Table 3 The present and optimum allocation of the Chahnimeh water to agricultural sector in different areas (million m^3)

Month	Existing water allocation			Optimal water allocation		
	Zahak area	Sistan	Miankangi	Zahak	Sistan	Miankangi
Jan	2.22	12.98	11.13	0	10.03	18.46
Feb	1.13	0	21.41	0	0	19.97
Mar	0	0	0	0	0	0
Apr	0	0	0	0	0	0
May	0	0	0	0	0	24.10
Jun	0	0	3.72	10.69	27.28	25.92
Jul	17.30	3.53	0	1.02	9.98	0
Aug	0	0	13.99	7.45	6.99	0
Sep	5.32	21.31	3.92	15.96	14.92	0
Oct	7.21	26.42	0	25.92	24.49	0
Nov	10.90	18.21	10.91	12.46	15.93	6.36
Dec	4.73	7.13	6.12	3.27	15.51	10.20
Total	48.81	89.58	74.12	76.77	125.13	105.01

Table 4 The present and optimum allocation of the Chahnimeh water to environment sector (million m^3)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Present allocation	3.6	0	0	0	0	0	5.1	9.1	0	0	0	8.8	26.6
Optimum allocation	7.5	6.7	7.2	7.5	7.2	7.5	7.5	7.2	7.5	7.2	7.5	7.5	88

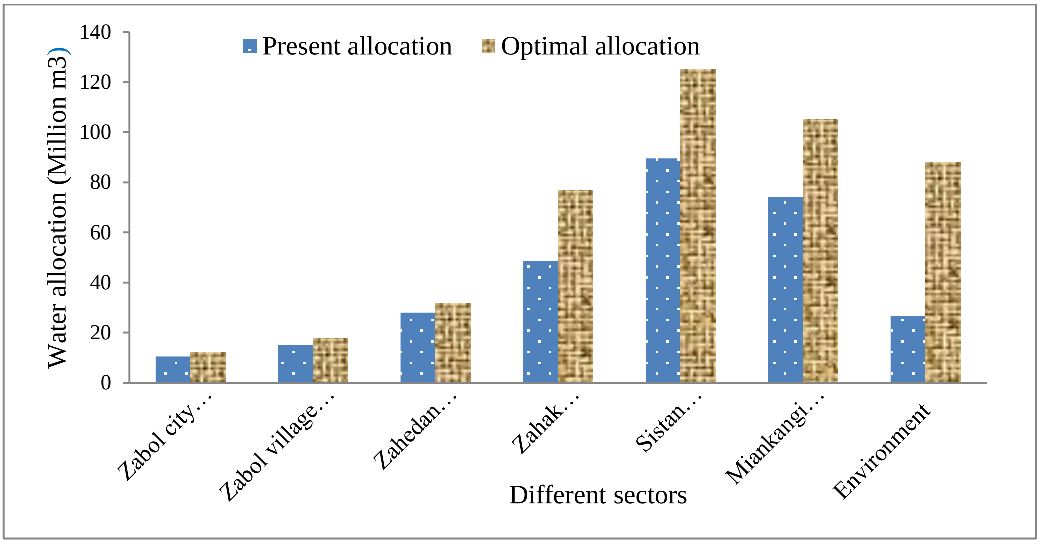

Figure 3 The present and optimal annual water allocation of the Chahnimeh reservoirs for domestic, agriculture and environment sectors

As it can be seen in Figure 3, in case of optimal utilization of the Chahnimeh reservoirs, there is a potential to supply more water to different sectors, especially agriculture and environment. Yearly allocated water to domestic use of Zabol city, Zabol villages and Zahedan city was 12.31, 17.67 and 31.8 million m^3 that could be increased by 17.3, 17.1 and 13.8 percent upon optimal water allocation, respectively. At the same time, water allocated for agricultural sector in Zahak, Sistan (Shibe-Ab and Poshte-Ab), Miankangi regions at the present conditions was found to be 76.77, 125.13 and 105.01million m^3, respectively, which could be increased by about 57.6, 39.8 and 41.7% upon optimal allocation. Furthermore, using an optimal allocation strategy will results in more water availability for the flow required by the terminal wetlands of the Sistan region, especially the Hamoun Lake. Once the model was run, based on basic scenario (the present conditions), results of optimal water allocation among competing sectors were different from the the present conditions (Tables 2, 3 and 4). In addition, this model was used to compare the effects of the construction of the second water transferring line from Chahnimeh to the Zahedan city, and reducing per capita consumption of domestic water in rural and urban areas to the national average values according (Table 5). On the other hand, the impact of predicted population growth until 2025 on the region's water demand was projected and compared with the present water allocation (Table 6).

Figure 4 shows annual water allocation to all domestic, agriculture and environment sectors under different scenarios. As it can be seen, agriculture and domestic sectors account for the highest and lowest water consumption, respectively.

Table 5 Basic model and proposed scenarios

No	**Scenario**	**Population exploiting water reservoirs (person)**	**Capacity of water transferring pipeline to Zahedan (million m^3/m)**	**Per capita water for urban area (liter/day)**		**Per capita water for villages (liter/day)**	
				first half of year	**second half of year**	**first half of year**	**second half of year**
1	Basic model	1175938	2.656	175	160	155	140
2	Increasing water transportation capacity to Zahedan city	1175938	5.195	175	160	155	140
3	Reduced per capita water consumption	1175938	2.656	140	125	125	110
4	Population increase	1595759	2.656	175	160	155	140

Table 6 Predicted annual water allocation to domestic, agriculture and environment sectors under different scenarios

No	Domestic consumption			Agriculture consumption			Environment
	Zabol city	Zabol villages	Zahedan	Zahak	Sistan	Miankangi	
1	12.230	17.464	31.80	76.77	125.13	105.01	88
2	12.230	17.464	52.80	71.77	113.10	99.74	88
3	9.756	14.075	31.80	76.77	129.33	106.67	88
4	15.492	23.981	31.80	74.76	120.18	103.60	88
Present allocation	10.490	15.133	27.985	48.81	89.58	74.12	26.60

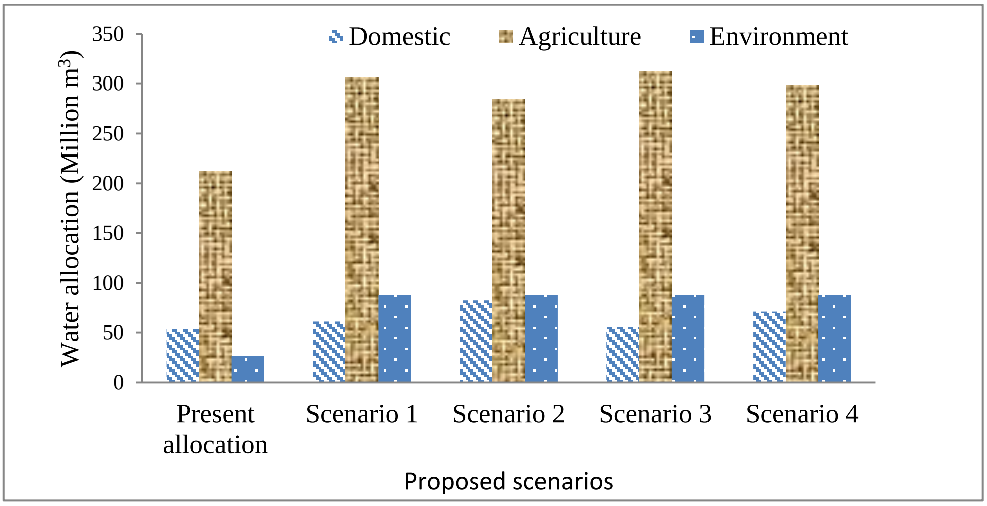

Figure 4 Annual water allocations to all domestic, agriculture and environment sectors under different scenarios

4 DISCUSSION AND CONCLUSION

In the present study, the goal programming was adopted to optimize water allocation for different competing sectors, in order to assist managers and policy makers in one of the driest regions in the world and subjected to prolonged droughts. Given the high importance of domestic uses and as per experts view points, the domestic sector was considered as the most prioritized sector followed by environment and agriculture sectors. Running the goal programming model based on the basic scenario showed that water allocated to domestic, agriculture and environment sectors could increase by 15.4, 44.5 and 230%, respectively, compared to the present water allocation system.

Given that under current water allocation strategies and decisions taken by the local authorities, water demands in domestic, agricultural and environmental sectors are not met completely, which can be assured that under optimum water allocation. There is a potential for more water allocation to various sectors and hence it is possible to meet demands of domestic and agricultural sectors completely and, meanwhile, supply more water to the environmental sector. So, under the optimal water allocation, water scarcity in different sectors will be obviated.

The findings suggested that using the goal programming could lead to increase in the amount of water allocated to different sectors via optimizing water use. Application of the goal programming model by Keramatzadeh *et al.* (2007) on the Shirvan-Barzou dam, Mozafari *et al.* (2009) on the Amir Kabir dam, Nader and Sabuhi Sabouni (2012) in the Mahabad plain have also proved that using goal programming increases water allocated to different competing sectors.

In order to study the impacts of future and ongoing policies on Sistan water resources, the management scenarios were developed and analyzed using goal programming. The principal objective of such scenarios is to analyze water management policies, plans and projects. One of the in-progress plans in the region is construction of the second water pipeline transferring water from Chahnimeh to Zahedan city which has caused some doubts and worries among the Zabol citizens and officials as well. It has been analyzed as a scenario. Evaluation of this scenario indicated that although implementing this plan would increase water transfer volume to Zahedan city by 66% and decrease water transferring to Zahak farmlands, Sistan (Shibe-Ab and Poshte-Ab) and Miankangi by 6.5, 9.6 and 5.2%, respectively, it would cause no changes in water allocation to other sectors, especially domestic sector in Zabol city and villages around. Given that at present, about half of domestic water demands of Zahedan city are met by Chahnimeh reservoirs, once the second pipeline is in function, all its domestic demand will be met, without affecting the domestic uses in Zabol city and the surrounding villages. Hence construction of this water pipeline can overcome water scarcity in Zahedan city as the provincial centre of the Sistan-Baluchestan province. Therefore the findings of this study can help the region’s policy makers, authorities and officials in informing the public about the plan and resolve worries and doubts of citizens about the impacts of the plan.

The results showed that when per capita domestic water use decreased by 20%, water allocated to domestic sector was decreased to 5.9 million m^3, which means water saving. In addition, the results showed that the transfer of water to domestic consumption would increase by 15.9% in 2025 horizon when the population would grow by 3.1%. However, the limited capacity for water pipelines to Zahedan and Zabol cities would be the main barriers for water transferring to meet the demand of population in 2025. Hence utilization of the second water pipeline and increasing transportation capacity of water to Zahedan and Zabol cities is inevitable.

It can be concluded that the goal programming can be applied as a useful tool to analyze the effect of different scenarios on water demand and supply management and hence, to allocate the water for different sectors in a most appropriate way.

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بهره‌برداری بهینه از مخازن آبی چاه نیمه‌های سیستان با استفاده از روش برنامه‌ریزی آرمانی

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چکیده هدف از تحقیق حاضر تخصیص بهینه منابع آب چاه نیمه بین بخش‌های مختلف مصارف خانگی، کشاورزی و محیط‌زیست با استفاده از روش برنامه‌ریزی آرمانی می‌باشد. پس از طراحی و برنامه‌نویسی مدل در محیط برنامه‌نویسی *GAMS* و حل آن براساس شرایط فعلی منطقه، آب تخصیصی به بخش مصارف خانگی و کشاورزی به‌ترتیب به‌میزان ۱۵/۴ و ۴۴/۵ درصد و آب تخصیصی به بخش محیط‌زیست حدود ۲۳۰ درصد نسبت به تخصیص فعلی آن افزایش یافت. نتایج نشان داد که با اجرای خط دوم لوله انتقال آب به زاهدان میزان انتقال آب ۶۶ درصد افزایش پیدا کرد، بدون این‌که در تامین مطمئن آب به مصارف خانگی شهرستان زابل و روستاهای آن تغییری ایجاد شود. سناریوی کاهش مصرف سرانه آب در حد ۲۰ درصد، باعث کاهش انتقال آب به میزان ۵/۹ میلیون مترمکعب در سال از مخازن چاه نیمه به بخش مصرف خانگی می‌شود. افزایش جمعیت تا افق سال ۱۴۰۴ نیز باعث افزایش ۱۵/۹ درصدی انتقال آب به بخش مصارف خانگی خواهد شد. نتایج نشان داد با استفاده از روش برنامه ریزی آرمانی می‌توان اثر سناریوهای مختلف بر روی مدل را اعمال و براساس آن مناسب‌ترین تخصیص آب بین بخش‌های مورد تقاضا را، براساس شرایط منطقه انجام داد.

کلمات کلیدی: سیستان، مخازن آبی چاه نیمه، تخصیص بهینه، برنامه‌ریزی آرمانی