ECOPERSIA

2016, 4(4), 1555-1567

Optimal Cropping Pattern for Water Resources Management in Sistan Region of Iran using Goal Programming Method

Mohammad Reza Dahmardeh Ghaleno[1*], Vahedberdi Sheikh[2], Amir Sadoddin[2] and Mahmood Sabouhi Sabouni[3]

[1] Former Ph.D. Student, Department of Watershed Management, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran. At present: Assistant Professor, Department of Watershed and Rangeland Management, University of Zabol, Zabol, Iran

[2] Associate Professor, Department of Watershed Management, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran

[3] Professor, Department of Agricultural Economics, Ferdowsi University of Mashhad, Mashhad, Iran

Received: 14 June 2016 / Accepted: 4 August 2016 / Published Online: 9 December 2016

ABSTRACT The optimal cropping pattern for Sistan water resources management was determined through a goal programming technique within the GAMS programming environment. Results showed that the optimum cultivation area and net profit of the agricultural sector in the Sistan region could increase up to 18.1 and 39.8%, respectively, compared to the current status. An increase in the farm irrigation efficiency from the current 35 to 55% would increase the net profit of the agricultural sector by 49.7% despite 6.4% reduction in water consumption. At the same time, 20% increase in the efficiency of water delivery system to farmlands would lead to 8.2 and 17.2% increases in the cultivation area and net profit, respectively. The results of combining these two management scenarios indicated that farming net profit would increase by 64.3%, while total water consumption in agricultural sector would decrease by 2.3%. Under wet condition, cultivated area and net profit would respectively increase about 32 and 44%. However, upon drought years, the cultivated area and net profit would experience 86.9 and 87.3% loss, respectively.

Key words: *Agricultural management, Goal programming, Optimal cropping pattern, Sistan*

1 INTRODUCTION

Depletion in water resources as well as increasing demand and competition among different sectors have highlighted the importance of water resources exploitation in recent years (Mozaffari *et al.*, 2009). The increasing population and demand for food, construction and other requirements have made the optimal use of water resources inevitable (Nader *et al.*, 2014). Therefore, optimum exploitation of water resources is an important socio-economic objective. Agriculture sector is the largest consumer of water and has a special role in the planning and policy making for water resources management. To this end, making fundamental and comprehensive change in agriculture infrastructure is of particular importance. Therefore, designing an optimal cropping pattern and determining the cultivable area is necessary in order to prevent loss of water resources (Bakhshoudeh and Baghestani, 2009). On the other hand,

---

Corresponding author: Department of Watershed Management, Gorgan University of Agricultural Sciences and Natural Resources and Faculty member, University of Zabol. Zabol, Iran. Tel: +98 9151903169, E-mail: mr.dahmardeh@yahoo.com

inefficient use of water resources, but supplied at a high cost, has resulted in considerable loss of water resources. Low efficiencies in the existing irrigation practices and water delivery through traditional channel systems are the main causes for loss of huge amount of water per annum (Bagherian *et al.,* 2008). As solving many issues, including water management, requires simultaneous optimization of several goals, application of multi-objective methods, including goal programming, is of particular importance (Fathi and Zibaei, 2012).

Goal programming (GP) is an important analytical approach to solve many real-world problems (Chin, 2009); it sets the stage so that a decision maker is able to consider multiple goals simultaneously (Romero, 2004). GP was evaluated for environmental policies in a model that analyzed a combination of economic, energy and environmental interactions. It provided valuable insights for policy-makers to evaluate various objectives required for sustainable development. GP has also been effectively applied in water management in Iran, including optimal water allocation from various resources (Kramatzadeh *et al.*, 2007; Salimifard and Mostafaee, 2013). It was also effectively applied in optimization of cropping pattern (Asadpour *et al.*, 2007; Mousavi and Akbari, 2014).

Considering the advantages of GP on water resources management and the issues of water resource scarcity in the Sistan region as well as cultivation of crops characterized with high water demand and low farming profitability in the region, the present research aims to determine optimal cropping pattern in the Sistan region so that available scarce water can be utilized in a more appropriate manner and the profitability. Despite the arid conditions and water resources scarcity, agriculture is the main source of livelihood for many families, particularly in rural areas. However, about half of arable lands in the Sistan region are abandoned and there is no enough water for present cropping pattern.

2 MATERIALS AND METHODS

2.1 The study area

Sistan region is nested in north of Sistan-Baluchestan Province in southeast of Iran and spans across coordinates of 60° 36´ 18" to 61° 48´ 24" E and 30° 03´ 32" to 31° 22´ 50"N. It is characterized with arid climate, annual precipitation of 52.3 mm, potential evaporation of 4700 mm and average temperature of 21.9 ^{0}C. Given the arid climate, average relative humidity in the synoptic station of Zabol during 40 years period was calculated 38 percent. (Sistan and Baluchestan Regional Water Company, 2014). Figure (1) shows location of the study area.

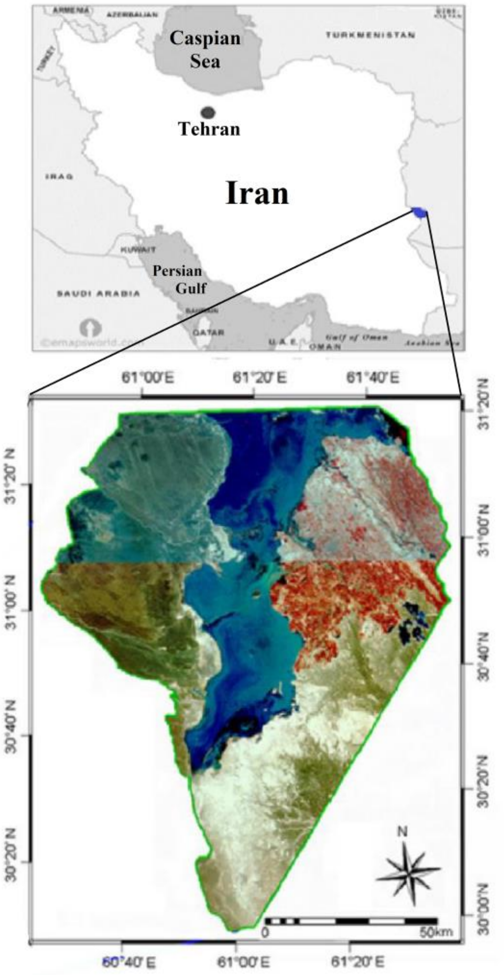

Figure1 A general view of Sistan Region, East Iran

The agriculture sector in Sistan is divided into three zones of Zahak, Sistan (Shibe-Ab and Poshte-Ab) and Miankangi regions covering about 24000, 48120 and 29000 hectares, respectively. At present, about half of these lands are under irrigation. Due to the paucity of annual precipitation (less than 50 mm), there is no opportunity for rainfed farming in the region. The Helmand River, originating from Afghanistan, supplies water for the Sistan plain. This river upon reaching the border is divided into two tributaries of Sistan and Parian Rivers. The Parian River flows northwardly along the border and irrigates the Miankangi farmlands through several canals (Figure 2). The Sistan River flows towards the Hamoun Lake and irrigates some farmlands on its way. The Chahnimeh water reservoirs, located 3 km away from the Sistan River, include three naturally formed geological depressions with a total capacity of 760 million m^3 that store part of surplus water of the Sistan River during the wet season and used during dry seasons for domestic and agricultural sectors. In light of the foregoing climatic conditions, the Chanimeh reservoirs serve as the mere source for meeting water demands of the study area, especially during droughts.

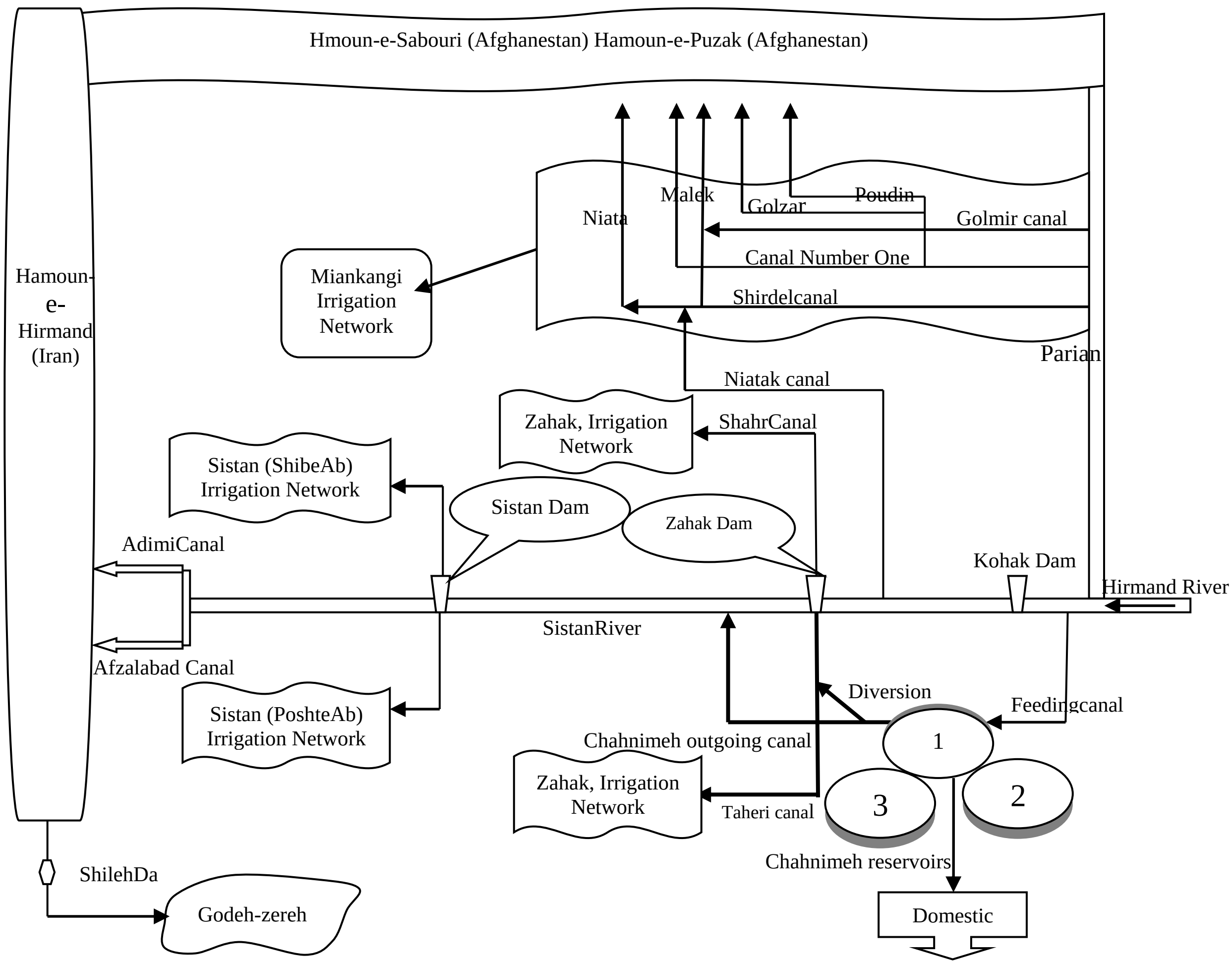

Figure 2 Conceptual model of the water system in Sistan Region, Iran

The goal programming method was adopted to specify cropping pattern for optimum utilization of water resources in agricultural sector. Given the limited water resources and related policies in the Sistan region, priority of water resources utilization is in domestic, environmental and agriculture sectors, respectively. Therefore, to determine optimal cropping pattern, the amount of water dedicated to the agricultural sector should be calculated after calculating and setting aside enough water supply for domestic and environment sectors. The water demand for agricultural sector in Sistan is supplied from the Chahnimeh reservoirs, Sistan River and Parian River. Therefore, to determine optimal cropping pattern in Sistan, first the supplied water through the Sistan and Parian Rivers to the agriculture sector was determined and then optimal water release from Chahnimeh reservoirs to farmlands was calculated. To determine the optimal water allocation and the optimum cropping pattern, the goal programming (GP) method was used, which had been found to be a multi-objective planning method with a high flexibility that allows trading-off between multiple objectives.

The GP model consists of four parts, including decision variables, system limitations, goal limitations, and objective function. The decision variables and system limitations are the same limitations used in linear programming with no flexibility and a must be met limitation. Goal limitations are characterized with positive (p) and negative (n) deviations variables, so that the minimization of such deviations is found to be the main goals. Flexibility of GP stems from such limitations. GP standard pattern, according to relations 1, 2 and 3, represent objective, limitation and goal functions, 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 ith goal weight, w_i $(+n_i - p_i)$ is deviation function from ith goal, $g_t(x)$ denotes t-*th* limitation function for different activities X, $f_i(x)$ is ith goal function from different activities X and finally -n, +p are negative and positive deviations from interested goals, respectively.

2.2 The variables used

Table 1 shows the variables used to goal programming.

Table 1 The variables used in modeling

Variable	*Description*
$x_{c.z}$	*Cultivation area for crop c in farmland z*
$Dagr_{z.m}$	*water transfer from Chahnimeh for agriculture sector in the region Z at month M*
$D_{Re.m}$	*water transfer from Chahnimeh to domestic consumption in the region Re at month M*
EF_m	*water transfer from Chahnimeh for environment sector in the region month M*
r_m	*Water volume remained in Chahnimeh reservoirs in month M*
r_{m-1}	*Water volume remained in Chahnimeh reservoirs since previous month(m-1)*
$nagr_{z.m}$	*Negative deviation from goal of agriculture water consumption in region Z in month M*

Table 1 Continued

Variable	*Description*
nbe_z	*Negative deviation from f agricultural profit goal in the region z*
$nD_{Re.m}$	*Negative deviation from goal of domestic water consumption in region Re in month M*
nEF_m	*Negative deviation from goal of environmental flow consumption in month M*
$pagr_{za.m}$	*Positive deviation from goal of agriculture water consumption in region Z in month M*
pbe_z	*Positive deviation from f agricultural profit goal in the region z*
$pD_{Re.m}$	*Positive deviation from goal of domestic water consumption in region Re in month M*
pEF_m	*Positive deviation from goal of environmental flow demand in month M*

2.3 The research objective function

Objective function in the GP was to minimize unwanted deviations from the adopted goals. Given aforementioned discussion, the research objective function is as follows:

$$\mathrm{Min}\,z = \sum_{z=1}^{3}\sum_{m=1}^{12} nagr_{z.m} + \sum_{z=1}^{3} nbe_z + \sum_{\mathrm{Re}=1}^{3}\sum_{m=1}^{12} nD_{\mathrm{Re}.m} + \sum_{m=1}^{12} nEF_m \qquad (4)$$

where $nagr_{z.m}$ represent negative deviation from goal of agriculture water consumption in region Z in month M, nbe_z represent negative deviation from agricultural profit goal in the region z, $nD_{Re.m}$ is negative deviation from goal of domestic water consumption in region Rein month M and nEF_m denotes on negative deviations from environmental flow goal.

2.4 Systemic limitations

The systemic limitations have no flexibility and should be treated as linear programming limitations (Sabouhi, 2012). Systemic limitations for planning model are presented as follow.

2.4.1 Limitation of water supply for agriculture sector in Zahak and Sistan regions(Shibe-ab and Poshte -ab)

As the agricultural lands in Zahak and Sistan (Shibe-Ab and Poshte-Ab) receive needed water from Chahnimeh and Sistan Rivers, limitation of water supply in these areas are as equation 5:

$$\sum_{c=1}^{n} a_{c.m} x_{c.z} - Dagr_{z.m} \le F_{z.m} \quad m = 1,\ldots,12 \qquad (5)$$

Z = Zahak, Sistan, Miankangi

where $a_{c.m}$ crop water demand in month m, $F_{z.m}$ is Sistan water flow to area z in month m, n is number of cultivated crops, and other variables introduced in Table 1.

2.4.2 Limitation of water supply for agriculture sector in Miankangi region

As Miankangi region receives needed water from Chahnimeh and Parian Rivers, limitation of water supply in this area is as equation 6:

$$\sum_{c=1}^{n} a_{c.m} x_{c.mi} - Dagr_{mi.m} \le P_m \quad m = 1,\ldots,12 \qquad (6)$$

$X_{c.mi}$ is cultivated area for crop c in Miankangi region, n is number of cultivated crops,$a_{c.m}$ is crop c water demand in month m, $Dagr_{mi.m}$, water demand for agriculture in the above area from Chahnimeh in month m, p_m is river and discharge of Parian River to Miankangi region.

2.4.3 Limitation of water supply from Chahnimeh reservoir

Equation 7 implies limitation of water supply from Chahnimeh into different demand sectors.

$$\sum_{\mathrm{Re}=1}^{3} D_{\mathrm{Re}.m} + \sum_{Z=1}^{12} Dagr_{z.m} + EF_m + r_m - IWS + Eva_m = ChF_m \quad m = 1,\ldots,12 \qquad (7)$$

Re = Zabol, Zabol villages, Zahedan Z = Zahak, Sistan, Miankangi

where $\mathrm{ChF_m}$ water stored in Chahnimehes per month, $\mathrm{Eva_m}$ is monthly evaporation rate from reservoir and Iws is initial water storage in reservoir. Others variables are shown in Table 1.

2.4.4 Limitation on transportation capacity of water channels for agriculture consumption

Transportation capacity of water channels for agriculture sector in different regions of Sistan is shown in equation 8.

$$Dagr_{z.m} \le AagrC_{z.m} \quad m = 1,\ldots,12 \qquad (8)$$

Z = Zahak, Sistan, Miankangi

where $\mathrm{AgrC_{z.m}}$ represents monthly water transferred for agriculture consumption in different parts of Sistanregion and $\mathrm{Dagr_{z.m}}$ is water transfer from Chahnimeh reservoirs for agriculture sector in the region Z at month M.

2.4.5 Limitation 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 9.

$$D_{\mathrm{Re}.m} \le WC_{\mathrm{Re}.m} \quad m = 1,\ldots,12 \qquad (9)$$

Re = Zabol, Zabol villages, Zahedan

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

2.4.6 Limitation of maximum and minimum reservoir volume of Chahnimeh

The minimum and maximum reservoir volume of Chahnimeh are calculated by equations 10 and 11, respectively.

$$r_m \le S\max_m \quad m = 1,\ldots,12 \qquad (10)$$

$$r_m \ge S\min_m \quad m = 1,\ldots,12 \qquad (11)$$

where $\mathrm{Smax_m}$ and $\mathrm{Smin_m}$ denote maximumand minimum water volume that can be stored in the Chahnimeh reservoirs and $\mathrm{r_m}$ is water volume remained in Chahnimeh reservoirs in month M.

$\mathrm{Smax_m} =$ 760 million cubic meters and $\mathrm{Smin_m} =$ 220 million cubic meters.

2.5 Goal limitations

Goal limitations have positive and negative deviation variables that aim to minimize the deviations from the desired goals.

2.5.1 Goal limitations on meeting agriculture water demand

Goal limitations on meeting agriculture water demand can be shown in equation 12.

$$Dagr_{z.m} + nagr_{z.m} - pagr_{z.m} = Gagr_{z.m} \quad m = 1,\ldots,12 \qquad (12)$$

Z = Zahak, Sistan, Miankangi

Here, $\mathrm{Gagr_{z.m}}$ is goal of supplying agriculture water demand.

2.5.2 Profitability goal for agricultural sector

Equation 13 shows profitability goal for agricultural sector. Dominant crops in the region are wheat, barley, sorghum, oat, alfalfa, watermelons, melons and grapes.

$$\sum_{c=1}^{n} b_c x_{c.z} + nbe_z - pbe_z = GD_z \qquad (13)$$

where GD_z is agriculture profit goal, b_c is net profit for crop c and other variables are introduced in Table 1.

2.5.3 Goal limitations on meeting domestic water consumption demand

Goal limitations on meeting domestic water consumption demand can be shown in equation 14. Domestic water demand is determined based on population number and per capita water consumption rate.

$$D_{\mathrm{Re}.m} + nD_{\mathrm{Re}.m} - pD_{\mathrm{Re}.m} = GD_{\mathrm{Re}.m} \quad m = 1,\ldots,12 \qquad (14)$$

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

2.5.4 Goal limitations on supplying environment water demand

Goal limitation on supplying environment water demand can be shown in equation 15.

$$EF_m + nEF_m - pEF_m = GEF_m \quad m = 1,\ldots,12 \qquad (15)$$

where GEF_m represents goal of supplying environment water demand.

3 RESULTS

Running the goal programming (GP) model, optimal water release from Chahnimeh to agricultural sector was calculated (Table 2). When the total water allocated to agricultural sector was specified, including the optimum water released from Chahnimeh, Sistan River and Praian River, the crop cultivated area was determined using goal programming to maximize agricultural net profit and water optimal utilization. Table 3 shows optimal cropping pattern based on the current situation and present cropping pattern. Currently, irrigation water efficiency is 35% and efficiency of water transfer from Chahnimeh to agricultural sector in the Zehak, Shibe-Ab and Poshte-Ab and Miankangi regions is 72, 65 and 65%, respectively.

After allocation of optimum water from Chahnimeh, it was found that there were 57.4, 39.9 and 41.7% increase in agricultural water availability from Chahnimeh to the Zahak, Shibe-Ab and Poshte-Ab and Miankangi regions, respectively.

Table 2 Present and optimum allocation of Chahnimeh water resource to agricultural sector in different areas (million m^3)

Agriculture sector	Zahak area	Sistan area	Miankangi area	Total
Optimal allocation	76.56	125.25	105.01	306.91
Present allocation	48.7	89.5	74.1	212.3

Table 3 Present and optimum cultivated area for crops in different areas of Sistan (ha)

Crop	Current cultivated area			Optimal cultivated area		
	Zahak area	Sistan area	Miankangi area	Zahak area	Sistan area	Miankangi area
wheat	6560	10420	7320	7062	12979	9368
barley	1225	1981	1725	1247	660	575
sorghum	210	470	694	258	340	1822
oat	904	1747	980	4075	4389	2677
alfalfa	423	755	702	211	377	351
watermelon	760	1089	1010	253	363	336

Table 3 Continued

Crop	Current cultivated area			Optimal cultivated area		
	Zahak area	**Sistan area**	**Miankangi area**	**Zahak area**	**Sistan area**	**Miankangi area**
melon	305	570	550	102	190	164
grape	115	270	180	115	270	181
Total	10502	17302	13116	13323	19568	15474
Net profit (million Toman)	23840	40663	30222	40047	54556	43885
Water requirement (mm^3)	184.6	310.75	257.16	180.15	276.35	254.65

After running the model, based on the baseline conditions, the effects of various policies and future scenarios in the region on model result was evaluated. The primary policies and plans that local authorities are going to take are increasing irrigation efficiency on farms to about 55 percent and increasing efficiency of water delivery system to farmlands from Chahnimeh to about 90 percent through implementing water transmission pipes. Scenarios are presented in Table 4 and the model was run based on these scenarios and results are presented in Tables 5, 6 and 7.

Table 4 Basic model and proposed scenarios

Scenario number	Scenario	Irrigation efficiency in farm (%)	Water transmission efficiency to Zehak region (%)	Water transmission efficiency to Zehak and Sistan region (%)
1	Basic model	35	72	65
2	Increases in irrigation efficiency in farm	55	72	65
3	Increasing water transmission efficiency	35	90	90
4	Increases in irrigation efficiency and transmission in farm	55	90	90
5	Wet years	35	72	65
6	Drought years	35	72	65

Table 5 Cultivated area for crops in Zehak region under different scenarios

Crop	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
wheat	7062	7652	7062	8511	7813	835
barley	1247	2209	1247	3731	1249	29
sorghum	258	821	258	244	1073	184
oat	4075	5576	5146	6876	5085	267
alfalfa	211	211	211	211	211	0
watermelon	253	253	253	253	253	0
melon	102	102	102	102	102	0
grape	115	232	115	232	115	0
total	13323	17915	14394	20160	15901	1315
Net profit (million toman)	40047	55096	45767	61422	50400	3892
Water requirement (mm^3)	180.15	165.07	191.75	171.64	225.53	18.31

Table 6 Cultivated area for crops in Sistan region under different scenarios

Crop	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
wheat	12979	12979	11837	13171	13163	1388
barley	660	5466	660	4168	1458	432
sorghum	340	8612	340	941	2911	414
oat	4389	8521	7711	10758	8165	246
alfalfa	377	377	377	377	377	0
watermelon	363	363	363	363	363	0
melon	190	455	190	405	190	0
grape	270	270	270	270	270	0
total	19568	28510	21748	30453	26897	2480
Net profit (million Toman)	54556	84749	70046	96225	86960	6339
Water requirement (mm^3)	276.35	258.25	299.66	272.41	409.11	35.36

Table 7 Cultivated area for crops in Miankangi region under different scenarios

Crop	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
wheat	9368	9968	9568	10168	11646	932
barley	575	2845	575	2493	971	270
sorghum	1822	3404	2398	4158	3590	524
oat	2677	4961	2643	4962	3711	420
alfalfa	351	351	351	351	422	0
watermelon	336	336	336	336	355	0
melon	164	164	164	164	164	0
grape	181	326	181	181	181	180
total	15474	22351	16216	22813	21040	2275
Net profit (Million Toman)	43885	67496	46554	69950	62080	7314
Water requirement (mm^3)	254.65	242.02	274.95	250.61	357.28	42.47

Figures 3 and 4 illustrate the net profit and cultivated area in three agricultural region of Sistan under different scenarios and current condition. As it can be seen, Shibe-Ab and Poshte-Ab account for the highest net profit and cultivated area, while the lowest is related to Zahak region. At the same time, it can be noted that the highest net profit and cultivated area is associated with the fourth scenario or combining the two scenarios of increased irrigation and water transmission efficiencies. The lowest cultivated area and net profit is for current drought conditions and cropping patterns.

4 DISCUSSION

Based on the baseline scenario, the results of the model running showed that the net profit under optimal cropping pattern in the agricultural sector in the Zahak, Shibe-Ab and Poshte-Ab and Miankangi regions had respectively increased about 68%, 34.1% and 45.2% compared to the current cropping pattern.

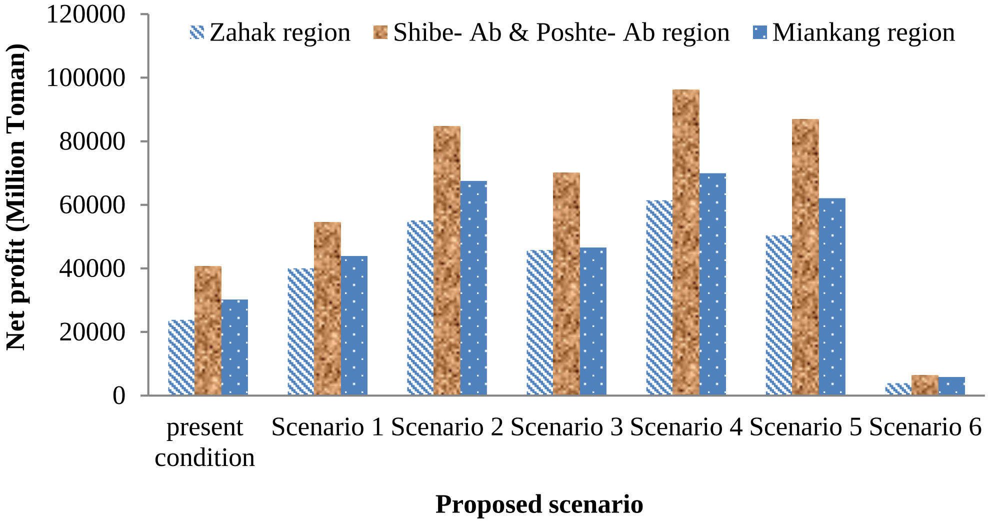

Figure 3 Net profit of agriculture sector in three regions under different scenarios and present situation

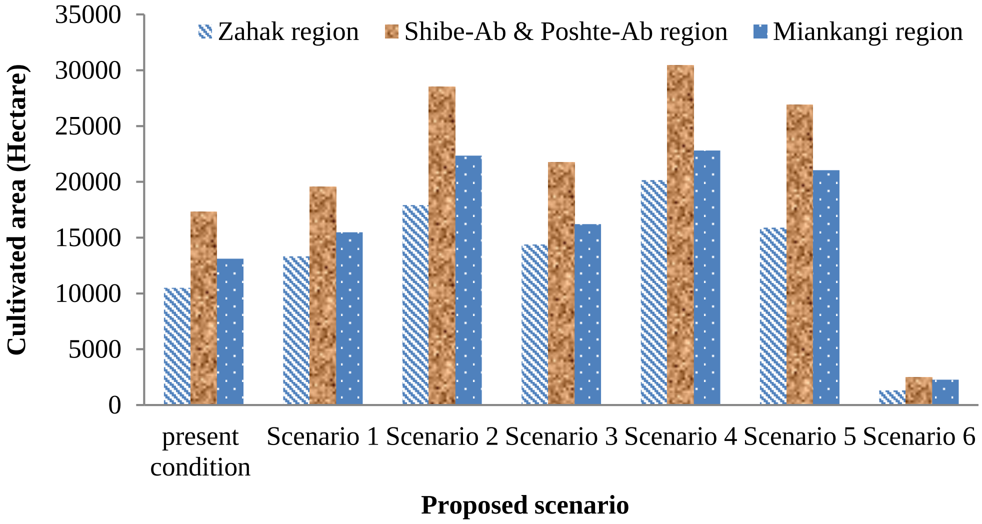

Figure 4 Cultivated areain three regions under different scenarios and present situation

At the same time, the amount of increase in the cultivated area in these regions was 24.9, 13.1 and 17.9%, respectively. So, in light of the above discussion it can be noted that by determining the optimum cropping pattern using goal programming, net gain in the total agricultural profit and area of the Sistan region can be boosted. The studies on water allocation by Asadpour *et al.* (2008) in Dasht-e Naz city of Sari, Keramatzadeh *et al.* (2007) on Barzoo Shirvan dam and Nader et al. (2014) on Mahabad dam showed that goal programming could be used to improve water resources management in order to give a boost to the agricultural net profit and cultivation area.

After running the model, based on the baseline conditions, the effects of various policies and future scenarios in the region on the model result was evaluated. The primary policies and plans that local authorities are going to take are increasing irrigation efficiency on farms to about 55 percent and increasing efficiency of water delivery system to farmlands from Chahnimeh to about 90 percent through implementing water transmission pipes.

The results of scenario analyses showed that as farm irrigation efficiency increased from 35 to 55 percent, net profit of the agricultural sector also increased about 49.7 percent, while water consumption in the agriculture sector declined 6.4 percent. Mozaffari *et al* (2009) in a study on water allocation from the Amir Kabir dam proved that by increasing the irrigation efficiency from 40 to 60 percent, the cultivated area and profitability of the agricultural sector would significantly increase. So, it can be concluded that increasing irrigation efficiency on the farm increases agricultural sector profit while saving water consumption in the sector. Increasing water transmission efficiency from Chahnimeh to the agricultural land in Sistan is another plan the local authorities are going to take into account. This plan aims to increase the current efficiency of water delivery to farmland by 20%, which will result into 8.2 and 17.2 percent increases in the cultivation area and net profit of the agricultural sector, respectively. The results of combining the two scenarios (increasing the efficiencies of irrigation and water transmission from the Chahnemeh to farmlands) indicated that he net profit of agriculture sector would increase by 64.3%, while saving about 2.3% water consumption in this sector. It can be concluded that upon simultaneously implementing both scenario, plans will lead to much more net profit and area under cultivation. Under wet years condition, cultivated area and net profit will respectively increase by 32 and 44%, respectively. However, upon drought years, the cultivated area and net profit will experience 86.9 and 87.3% loss, respectively. The results of crop pattern optimization using goal programming showed that in drought conditions some crops characterized with high water requirements would not be recommended for the Sistan region and should be eliminated from cropping pattern (viz. alfalfa, watermelons, melons and grapes). Increasing the profitability and decreasing the water consumption are management alternatives for current cropping pattern in the Sistan region and there is an urgent need to optimize policy-makings to increase agricultural water efficiency in the farm level and transmission capacity to optimize utilization of available water resources.

5 CONCLUSION

The optimal cropping pattern based on using goal programming method will result to low water consumption and increased net profitability of agricultural land throughout the Sistan. Low efficiencies in the existing irrigation and water transferring practices are the main causes of huge water waste. Generally speaking, the goal programming is a promising technique for implementation and evaluation of the effect of various scenarios and selection of most appropriate cropping patterns according to the area conditions.

6 REFERENCES

Asadpoor, H., Hasanimoghaddam, M., and Ahmadi, Gh. Designing a multi–objective decision making model for determination about optimum cropping pattern in Dasht-e-Naz Sari. Agr. Econ., 2008; 3:1-17. (In Persian)

Bagherian, A., Saleh, I., and Paykani, Gh. Farming optimization and derivation of normative demand function of water (Case study: Kazeroun region). 6th National Conference of Agricultural Economics, Mashhad. Iran., 2008; 25-41. (In Persian)

Bakhshoudeh, M., and Baghestani, M. A Study on the Optimal Cropping Pattern in Iran Using Nonlinear-Fractional Programming. The Econ. J., 2009; 4: 57-70. (In Persian)

Chin, N. L. Formulating the multi-segment goal programming. Comput. Ind. Eng., 2009; 56: 138-141.

Cristobal, J.R.A goal programming model for environmental policy analysis (Application to Spain). J. Energ. Pol., 2012; 43: 303-308.

Fathi, F., and Zibaei, M. Water Resources Sustainability using Goal Programming Approach in optimizing Crop Pattern, Strategy and Irrigation Method. Iran-Water.Resour. Res., 2012; 1: 10-19. (In Persian)

Hasan, B., and Hasan, H. A goal programming approach to weight dispersion in data envelopment analysis. G.U. J. Science., 2007; 20: 117-125.

Keramatzadeh, A., Chizari, A. H., Yousefi, A., and Balali, H. Optimal Allocation of Water and Priority of Different Region in its Usage (Case Study of Shirvan Barzo Dam). J. Agr. Econ., 2007; 1: 11-29. (In Persian)

Mousavi, S. N., Saleh, I., and Akbari, S. M. The Optimal cropping pattern and its impact on water resources management (Case study: Mrvdsht- Karbala region).Water Eng., 2015; 7: 101-110. (In Persian)

Mozafari, M., Sabuhi, M., and Keykha, A. Decision Support Model for Optimizing Allocation of Amir-kabirn Water Dam between Various Consumptions. Agr. Econ., 2009; 4: 157-176. (In Persian)

Nader, H., Sabouhi Sabouni, M., and Mahammadpour, O. Water Allocation of Mahabad Multipurpose Dam using Integrated Fuzzy Analytic Hierarchy Process and Goal Programming Models. Water Soil Sci., 2014; 3: 215- 229. (In Persian)

Romero, C. A general structure of achievement functions for a goal programming model. Eur. J. Oper. Res., 2004; 153: 675- 686.

SabouhiSabouni, M. Application of mathematical programming in agriculture economics with a focus on using the excel software. Publication of Zabol University. 2012; 294 p. (In Persian)

Salimifard, Kh., and Mostafaee Dowlatabad, Kh. Applying Stochastic Goal Programming to Water Resource Management. J. Water Soil., 2013; 2: 282-291. (In Persian)

Sistan and Baluchestan Regional Water Company.A report of water resources status in Sistan and Baluchestan province.2014; 4-24. (In Persian).

تعیین الگوی کشت بهینه برای مدیریت منابع آب منطقه سیستان در ایرانبا استفاده از روش برنامه ریزی آرمانی

محمدرضا دهمرده قلعه‌نو[۱]، واحد بردی شیخ[۲]، امیر سعدالدین[۲] و محمود صبوحی صابونی[۳]

۱- دانش‌آموخته دکتری، گروه آبخیزداری، دانشگاه علوم کشاورزی و منابع طبیعی گرگان، گرگان، ایران. در حال حاضر: استادیار، گروه مرتع و آبخیزداری، دانشگاه زابل، زابل، ایران

۲- دانشیار، گروه آبخیزداری، دانشگاه علوم کشاورزی و منابع طبیعی گرگان، گرگان، ایران

۳- استاد، گروه اقتصاد کشاورزی، دانشگاه فردوسی مشهد، مشهد، ایران

تاریخ دریافت: ۲۵ خرداد ۱۳۹۵ / تاریخ پذیرش: ۱۴ مرداد ۱۳۹۵ / تاریخ چاپ: ۱۹ آذر ۱۳۹۵

چکیده الگوی کشت بهینه با استفاده از روش برنامه‌ریزی آرمانی در محیط برنامه نویسی GAMS و مقایسه آن با وضع موجود برای مدیریت منابع آب سیستان بررسی شد. نتایج بیانگر افزایش ۱۸/۱ درصدی سطح زیر کشت بهینه و ۳۹/۸ درصدی سود خالص بخش کشاورزی نسبت به شرایط فعلی می‌باشد. با افزایش راندمان آبیاری در مزرعه از ۳۵ به ۵۵ درصد، ضمن کاهش ۶/۴ درصدی مصرف آب، سود خالص بخش کشاورزی ۴۹/۷درصد نسبت به شرایط بهینه پایه افزایش پیدا خواهد کرد. افزایش حدود ۲۰ درصد راندمان انتقال آب به اراضی کشاورزی نیز باعث افزایش ۸/۲ درصدی سطح زیر کشت و ۱۷/۲ درصد سود خالص بخش کشاورزی نسبت به شرایط بهینه پایه شد. همچنین نتایج بررسی ترکیب دو سناریوی افزایش راندمان آبیاری در مزرعه و افزایش راندمان انتقال آب نشان داد که ضمن کاهش ۲/۳ درصدی مصرف آب سود خالص بخش کشاورزی ۶۴/۳ درصد نسبت به شرایط بهینه پایه افزایش پیدا خواهد کرد. در شرایط ترسالی سطح زیر کشت و سود بخش کشاورزی به ترتیب ۳۲ و ۴۴ درصد افزایش پیدا می کند. اما الگوی کشت در شرایط خشکسالی حاکی از کاهش ۸۶/۹ درصدی سطح زیر کشت و ۸۷/۳ درصدی سود خالص بخش کشاورزی می باشد.

کلمات کلیدی: الگوی کشت بهینه، برنامه‌ریزی آرمانی، سیستان، مدیریت کشاورزی
