Journal of Applied Research in Water and Wastewater

E-ISSN: 2476-6283

Journal homepage: https://arww.razi.ac.ir

Modeling the effects of changes made in Sistan's water resources system using WEAP

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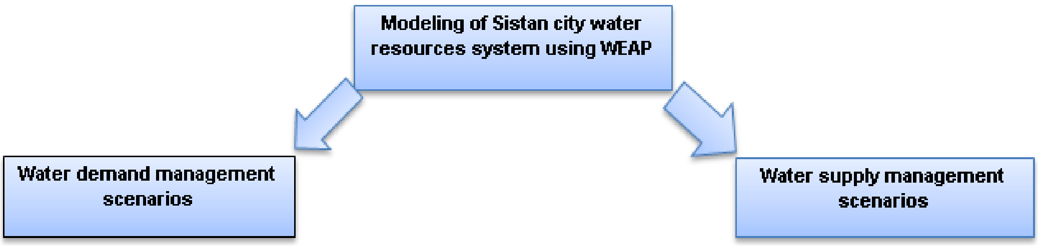
GRAPHICAL ABSTRACT



ARTICLE INFO

Article type:
Research Article

Article history:
Received 28 January 2024
Received in revised form 28 February 2024
Accepted 29 February 2024
Available online 30 February 2024

Keywords:
River of Hirmand
Supply-side policiesm
WEAP

ABSTRACT

Water is one of the most basic environmental resources and plays an important role in human life. The Sistan river is the only source of water supply in this area and is completely dependent on the border river of Hirmand. The water of this river fluctuates greatly due to the interference of the country of Afghanistan, climate changes and the existence of Hamon international wetland, which has made the issue of decision-making regarding the management of water resources in Sistan region more than in other regions. This study, using the WEAP model, deals with modeling the effects of changes made in the water resources system in the Sistan region, which has special weather conditions. The results of this study showed that policies implemented in recent years have a positive effect on increasing water resources and decreasing water shortages in agriculture, drinking water, and the environment sectors, and supply-side policies combined with demand-side policies like increasing irrigation efficiency and reducing the per capita consumption of water can have a greater effect on economic, social and environmental development. It was also found that domestic water needs were met in all months, but in the agricultural sector, only 20% of agricultural water was provided to farmers in the summer months. Therefore, based on field observations, the agricultural sector is facing more problems in supplying water to the regions. Finally, for environmental needs, 184,000 cubic meters of water needed by Hamon Hirmand has not been supplied.

1. Introduction

Water is one of the most important rare natural resources that human life and survival depend on. Most of the world's waters are in seas and oceans. Only 2.5% of the world's water is fresh and 0.26 % of it is available for human use which is not equally distributed among the people of the world. And 0.26 percent of it is available for human use (Mishra, 2023), which is not equally distributed among the people of the world. Therefore, the management of its production and consumption, especially in arid and semi-arid regions, is an important and vital issue, and the poor management of water resources acts as a serious limitation for development (especially for developing countries (Fethullahi, Najafi, and Farhangian, 2022). On average, taking into account the total annual spatial and temporal rainfall; Aridity of Iran is considered to be arid and/or semi-arid on an international scale. In addition, population growth and the development of various economic sectors have led to a continuous increase in the demand for water. In this situation, various solutions have been proposed for the optimal use of water resources, which can increase the supply of water and the optimal use of water resources from the perspective of supply and demand (Salmani Sabzevar *et al.,* 2021). In the plain of Sistan, which is located in the north of Sistan and Baluchistan province, due to very low rainfall (average 50 mm per year) and high evaporation (4 to 5 thousand mm) on the one hand and its complete dependence on the Hirmand border. River, on the other hand, the issue of water management becomes more important from both aspects (Ministry of Energy, 2022). In the complex conditions of water resources in this region, the consequences of different management scenarios can be evaluated to some extent by building decision support systems. These systems are computer programs that combine data, decision-maker opinions, and various models to solve water management problems and provide solution recommendations (Hamlat, Errih, and Guidoum, 2013; Li *et al.,* 2015; Agarwal *et al.*, 2019). So far, different models have been used in the world to allocate water resources in a catchment area.

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Cite this article: H. Esnaashari, N. Ganjali, A. Sardar Shahraki, Modeling the effects of changes made in Sistan's water resources system using WEAP, *Journal of Applied Research in Water and Wastewater*, 11 (2), 2024, 67-74. doi: https://doi.org/10.22126/arww.2024.10060.1318

For example, Nadalal and Sakthivadivel (2002) use the ShellDP model, which is based on simulation and optimization techniques, are used to obtain the optimal amount of water released for electricity generation and agricultural land irrigation in Sri Lanka. The results of their investigations showed that these techniques are suitable for reservoir planning and achieving optimal policies also show that the irrigation of the downstream agricultural land should be reduced in order to generate more electricity upstream. Weng, Huang, and Li (2010) used a Scenario-based Multi-Criteria Decision Support System to manage river basin water resources in China. The results showed that different management policies can have different effects on socio-economic development and environmental protection of the region. This model is also widely used to manage basins with complex conditions with many conflicting goals and many uncertainties; therefore, can be a good option to analyze the Sistan plain water resource usage. Georgakakos *et al.* (2012) used agreement management to manage water in Northern California. They combined the HRC-GWRI decision support model with the hydrological modeling of the area and finally evaluated this model with four simulated management and hydrological scenarios. Their results showed that the agreement model better considers future climate change, so it can be used for sustainable decision-making of water resources. WEAP models have been used to examine the effects of different policies in countries such as Ethiopia and the Philippines. These studies have been used to evaluate current policies on water resources at present, short-term and long-term, and various criteria have been examined in them (Fassio *et al.,* 2005; Booker *et al.,* 2012; Goshime *et al.,* 2021; Schneider *et al.,* 2019). WEAP is a tool for integrated management of water resources and can be used for scenario planning and policy analysis. This software was created in 1988 and supported by the Stockholm Environmental Institute. WEAP creates a suitable environment for entering the input information of reservoirs and rivers and the amount of their water supply to the drinking, agricultural and industrial sectors under different management scenarios and according to the quality of the river (Purkey and Joyce, 2008; Piao *et al.,* 2010; Mo *et al*., 2017). In this study, the WEAP model will be used for water management in the Sistan region. To this end, Decision Support Systems were first designed and modified in recent years. Then, using WEAP, the main questions of the present research, which are the management scenarios introduced to this software, are answered. These questions are whether the changes made in the Sistan water resources system in the past few years have improved the conditions of agricultural water supply, reduced the likelihood of a shortage of drinking water, and reduced water flows to the Hamoon International Wetland.

2. Materials and methods
2.1. Study area

Zabul (Sistan) is one of the cities of Sistan and Baluchistan province, which is located in the east of Iran and in the north of Sistan and Baluchistan province with geographical coordinates of 31 degrees and 2 minutes north latitude and 61 degrees and 39 minutes east longitude. Considering that understanding the conditions of water resources in the region is very important to creating a decision support model in water resources management, a comprehensive explanation of water resources and uses in the Zabol region will be provided below. Due to rainfall of about 50 mm per year and high evaporation in the region, which is about four to five thousand mm per year, rainfall, which is one of the water sources, will not be considered in this study. Also, in this area, due to the presence of a layer of clay with a thickness of 850 to 1000 meters below the surface layer of gravel and sand, there are no continuous underground aquifers in the true sense. The depth of these aquifers in different seasons of the year is between 50 to 85 cm from the ground, which reaches its maximum in April. However, the possibility of underground aquifers from a depth of 3 to 10 meters is low. Therefore, groundwater can not be used as a source of water in the region. (Ministry of Energy, 2022). One of the water resources of the region is the Sistan river. Two-thirds of the Hermand River flows into the Parian River and the rest into the Sistan River. The annual water flow of the Sistan River has fluctuated sharply in different years so it has fluctuated from close to zero in 2001 to 7200 million cubic meters in 1990 (Ministry of Energy, 2022). In addition to fluctuations in river flow in different years, the amount of water in the months of the year also fluctuates a lot. As shown in Fig. 1, over the past 50 years, on average, about 60% of river flow has occurred in the spring (Ministry of Energy, 2022).

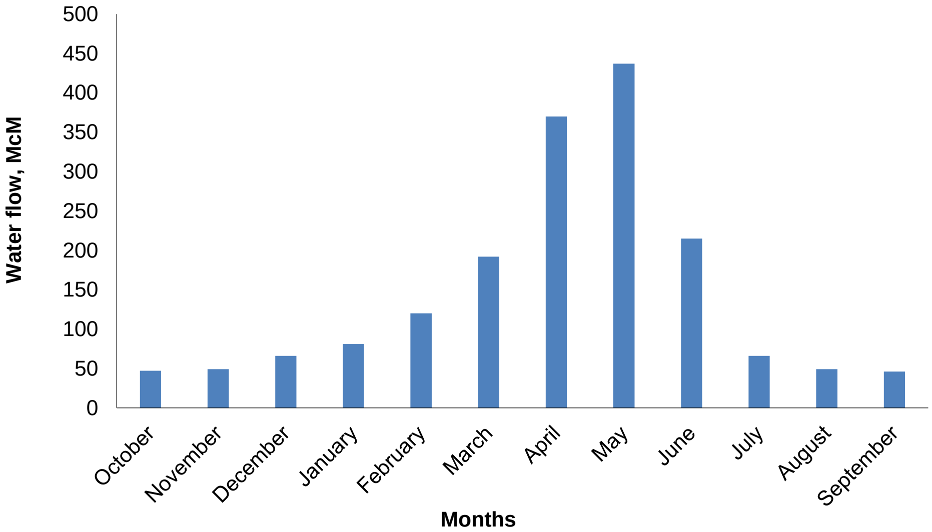

Fig. 1. Average monthly water distribution in Sistan River (1970-2020).

As can be seen in this diagram, the highest river flow occurs in Spring, especially in May and April, and the lowest river flow takes place in September and October.

Due to the dependence of the life of Sistan plain, Chahnimeh, and wetlands on the share of Sistan water intake from Hirmand; the shortage caused by the reduced water inflow due to 1) climate change, 2) projects implemented in Afghanistan to capture and retain a larger share of the flow, the Sistan River has been the first priority of regional officials. For this reason, many studies were conducted to supply water to the region, and changes such as dredging rivers, removing some dams, and proper management led to minimal water entering the Sistan River and storing it in the region.

The next source of water for the region is the Parian River. The Parian River is the second tributary of the Hermand River, which forms the north (about 55 km) border of Iran and Afghanistan from its route and after passing through the areas of Dost Mohammad Khan, it finally flows into Hamoon pozak. Exact statistics on the water flow of the common Parian river are not available and there is no agreement between Iran and Afghanistan to use the common water of Parian. Its tributaries, including Shirdel, Golmir, and Canal No. 1, use the common river water as much as possible, depending on the available discharge and the natural conditions of the river. Therefore, in this study, the input data from these streams will be used as Parian river discharge data (Ministry of Energy, 2022). The water flow of these canals has been declining in general. On the other hand, despite the changes in the river in different years, there are many fluctuations between the months of the year, which is shown in Fig. 2, the average of these changes (Ministry of Energy, 2022).

According to Fig. 2, like the inflow of water to the Sistan River, the maximum amount of inflow to these rivers occurs in spring and the minimum in autumn and summer, so that in the 50-year average, 43% and in the 10-year average, 53% of the water enters the rivers in the first three months of the year. As can be seen in the above diagram, the 50-year average is higher than the 10-year average by 1.6 times. It can be said that in recent years, due to Afghanistan's greater use of common Parian water, less water has entered Iran. For this reason, by dredging the inner Parian river and the streams connected to the common part of Parian, more water can enter the Miankangi area, where the executive operation has begun.

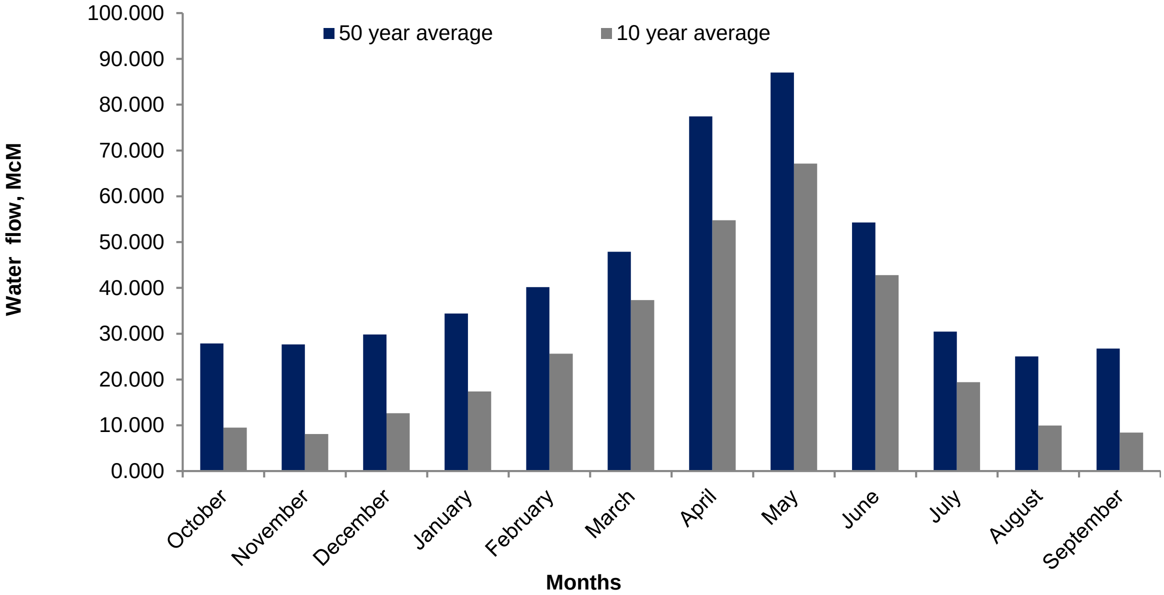

Fig. 2. 50 and 10 year average of monthly water distribution in Shirdel, Golmir and canal number one streams (1970-2020).

Although the primary purpose of constructing Chahnimeh was to control floods in the spring and to regulate water for agricultural use during the growing season, in recent years, due to prolonged droughts, drinking water supply has been the main purpose of exploiting these reservoirs and providing proper regulation of agricultural water is targeted for a second stage (Ministry of Energy, 2022). Output values for consumption of these tanks in the last 10 years are shown as a percentage in the below diagram.

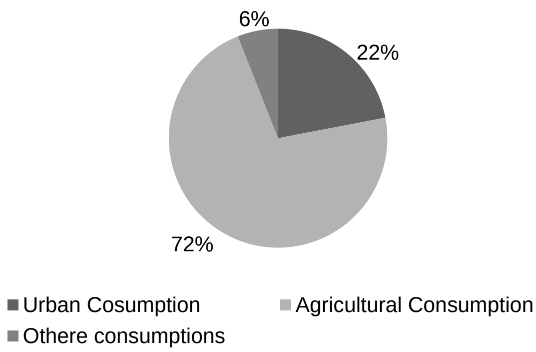

Fig. 3. Different uses of Chahnimeh (percentage).

As can be seen in the chart above, the highest amount of consumption in these years belongs to the agricultural sector and the drinking sector has only 22% of consumption. Chahnimeh reservoirs can also be used for fish farming and recreation. Two important factors of water loss in Chahnimehs are high evaporation from the surface of reservoirs and high volume of water infiltration during water transfer to them, which is due to high temperatures and strong winds in Sistan (Ministry of Energy, 2022). Currently, drinking water for about 850,000 residents of Zabol, Zahedan, and rural areas is supplied from Chahnimeh water, which is about 62 million cubic meters per year. About 150 thousand hectares of arable land are located in Sistan region. The level of crop cultivation depends on the flow of the Hirmand River in that year. The area under cultivation is very different due to severe fluctuations in the inflow of the Sistan and Paryan rivers. Annually, 1250 million cubic meters of water from the Chahnimeh, Sistan, and Parian rivers are used to irrigate agricultural products. About 177 million cubic meters of this water is supplied by Chahnimeh. In Sistan plain, about 70% of the crop composition is allocated to wheat and barley, followed by weeds and vegetables have the highest area under cultivation. Forage crops such as alfalfa and clover are found in the crop composition, especially during drought years (Ministry of Energy, 2022).

Finally, the environmental part of Hamoon Wetland is divided into three separate parts called Hamoon Pozak (northeastern end of the region), Hamoon Sabouri (northern part of the region), and Hamoon Hirmand (southern part of the region). The water entering Hamoon is supplied from the Hirmand River (feeding Hamoon Hirmand) and Farahrood and Haroutrood rivers (feeding Hamoon Sabouri). Also, Shileh river is the drainage of the Hamoon wetland and drains the excess water of this wetland through Hamoon Hirmand. These three wetland areas are connected and join at the highest water level. In recent years, due to successive droughts and the construction of several dams on the rivers leading to Hamoon Wetland and the use of their water for agricultural and domestic purposes, water inlet to this wetland has decreased significantly, and conversely during periods of short intense rains uncontrollable flooding, convert part of the wetlands into swamps. In order to supply water to these wetlands, the Environment Organization has recently allocated 60 million cubic meters of water from Chahnimeh, and if water enters from Afghanistan, water will enter the wetland. The innovation of this study is the system designed for Sistan and the allocation of water resources to separate drinking, environmental and agricultural sectors. This content has made this research different from other similar researches.

2.2. Methodology

The first step in using this software is a precise definition of the study area visually. Therefore, first the desired location is selected from the world map embedded in the software and then in the existing schematic model of rivers, reservoirs, water transfer channels and domestic and agricultural uses in the studyarea using the shapes in the software are drawn. in such a way that the inflow water to Sistan is from two rivers, Paryan and Sistan, after entering the water flow of the Sistan river into Chahnimeh reservoirs, the remaining amount enters the river and is allocated for agricultural purposes under the diversion of Zahak and Sistan diversion dams. On the other hand, the water entering the Parian River is allocated only to the agricultural sector of the Miankangi region. Also, some water from Chahnimeh reservoirs is used for agricultural purposes in all three regions, and finally, the water of both rivers flows into Hamoon Wetland.

Defining the current situation in the region is one of the main issues in simulation. Therefore, first, the base year data considered here in 2021 is entered into the model for water transfer canals, Chahnimeh reservoirs, dams, river flow, agriculture, drinking water, and agriculture, and the results of water allocation for consumption. The results of the current water allocation for current use in this model will be stored as a baseline scenario.

The water transfer capacity of the existing canals in the region is given in Table 1, and in the next section, the canals that will be created in the future will be added to the program with respect to their specific requirements. The required reservoir data in WEAP is divided into different physical, operational, cost, and water quality components, each with its own subset. The physical part includes data on water altitude in different amounts of water volume, evaporation in different months, reservoir capacity, and initial storage. The capacity of each Chahnimeh reservoir (1, 2, and 3) is 660 mm and the storage capacity of the Chahnimeh 4 reservoir is 820 mm. In this study, Chahnimehs 1, 2, and 3 are considered together, so we call them Chahnimeh reservoirs. Water is transferred from the Sistan River to Chahnimeh I. After the water enters the reservoirs, the water is transferred to Chahnimeh 4, so that its water can be used for various purposes in the required seasons. Other required information is given in Table 2.

Table 1. Water transfer capacity of canals in the region.

Name of stream or canal	Canal capacity, m3/s	Name of stream or canal	Canal capacity, m3/s
Shirdel River	30	Taheri Channel	20
Golmir River	15	City Channel	35
Canal number one	25	Water canals to Shibab lands	35
Water transfer canals to Sistan	0.8	Old Chahnimeh entrance canal	450
Old Chahnimeh output channel	50	Water transfer canals to Phoshtab lands	35

Table 2. Evaporation values in Chahnimeh reservoirs and Chahnimeh 4 (mm).

Month	Chahnimehs 1,2 and 3	Chahnime 4	Month	Chahnimehs 1,2 and 3	Chahnime 4
October	359	366	April	327	327
November	207	160	May	472	473
December	132	129	June	670	626
January	109	109	July	816	871
February	126	126	August	853	854
March	206	216	September	656	634

In the operational part of WEAP software, a dam or reservoir is divided into four parts: Inactive Zone, Buffer Zone, Conservation Zone, Flood Control Zone: Inactive Zone in Chahnimehs 1, 2, and 3 is 320 million cubic meters, and Total Active Zone and Flood Control Zone is 340 million cubic meters. The inactive zone in Chahnimeh 4 is 200 million cubic meters, and according to the total Conservation Zone in Chahnimeh 4, the total active zone and flood control will be 620 million cubic meters. In the domestic water sector, the amount of domestic water consumption in the cities of Zahedan and Zabol will be entered according to their population, and reduction of water consumption will be considered in management scenarios. Daily water consumption in different areas of Sistan is 200 liters per person. The next highly ranked water consumer is agricultural consumption. The agricultural lands of the region are divided into three parts: Zahak, Sistani, and Miankangi. The area under cultivation of each and their monthly water consumption are based on the water needs of the cultivated plants and the efficiency of 35% of the region is given in Table 3. In these areas, wheat has the highest level of crop cultivation, followed by barley and forage corn in later stages. Watermelon and a type of red grapes are also grown as native crops in these areas.

Table 3. Cultivation level and annual water consumption of Sistan agricultural areas.

Area	Area under cultivation, Hectares	Annual water consumption, Cubic meters per hectare
Zahak	15000	118514
Sistan	45000	181685
Miankangi	36000	173857

Source: Ministry of Energy, 2020

Water requirement data in different months of the year are entered into the software as a percentage using NETWAT software. Also, for 2500 hectares of Hamoon Hirmand wetland, 60 million cubic meters of water was considered annually in order to achieve environmental goals. After entering the basic information and the amount of water entering the Sistan and Parian rivers in the software, the model can be solved and the results can be obtained in the base year.

By entering the data in the model, the model can be initially calibrated. In order to manage the water resources of Sistan, various projects have been implemented or are being implemented. Water supply management scenarios (Chahnimeh water transfer to Zahak and Miankangi lands, water outlet plan from Chahnimeh 4 to irrigate Sistan lands, construction of a second water transfer pipeline to Chahnimeh 1 from Sistan river, water supply to Sistan cities, Implementation of the second line of water transfer to Zahedan and implementation of a supplementary water supply plan to the villages of Sistan region and use of Chahnimeh 4 only in flood conditions and its elimination in other cases), And water demand management scenarios include implementation of piped water transfer project to about 3000 hectares of Shibab lands, construction of irrigation and drainage network of Miankangi, implementation of water transfer project to Sistan farms with pipes and change of irrigation system of Miankangi area, all of which increase efficiency Water consumption will be in agriculture. Increasing water use efficiency in agriculture in the agricultural sector means less water demand during the months of the year. According to the previously implemented plans in the region, the efficiency was increased from 35% to 45% and its effects on the water supply of wetlands and agriculture were investigated. It should be noted that the change in water demand management is due to the implementation of all the above plans, except for the elimination of the Chahnimeh 4.

3. Results and discussion

Chahimeh Chahar, in the spring season when the water flow of the river reaches its maximum in the year, comes to the aid of reservoirs and collects excess water in order to be able to transfer water to Chahnimeh reservoirs during peak months. In the domestic water sector, according to the first priority of the needs of the cities of Zahedan, Zabul, Zahak and Chandshahristan, the need for domestic water was 100% supplied in all monthsThe agricultural sector, which was placed the second priority, uses rivers in addition to reservoirs. The percentage of meeting the needs of this sector is shown in Fig 4.

As mentioned in the previous sections, the current data was first entered into the model. The following are the results of entering this information and the results are consistent with the existing reality and conditions in the region. After calibrating the model, different management scenarios were created in the model to investigate their effect on domestic water supply, agriculture, and the environment.

In March, there is a sharp decline in water supply in Sistan and Zahak. Finally, in the summer, about 20% of the water required by these sectors will be met in the current situation. As can be seen in the diagram, on average, Zahak has the most unmet water needs; therefore, the agricultural sector of Zahak has more problems in meeting its water needs than other cities. Because in Sistan agricultural lands, in addition to Sistan river, Chahnimehs are also used during water shortages. Also, the agricultural sector of Miankangi city is the only user of Parian river and can withdraw the required amount of water from the river. Therefore, in the current situation, it is suggested that farmers transfer the planting of autumn crops, about 70% of which consists of barley and wheat grains, to the end of October so that their first irrigation will not be a problem. The second water is in mid-January, which farmers do not have much trouble obtaining. However, in order to supply the third round of crops with water, in March, farmers should irrigate their fields in April, due to the slight delay in planting the crop in the first period. On the other hand, summer crops such as watermelon and cantaloupe, which are planted in March and require little water at the time of planting (800 cubic meters per hectare), are suitable for production in this region.

It was found that domestic water needs are met all months of the year, agricultural water needs in Miankongi have been met more than in Sistan and Zahak, and in summer, only 20% of the water needs for agriculture have been available to farmers in the region.

Also, the Sistan red grapes variety, which matures early in the season, can be offered to the consumer market in the first week of June, which is generally a time of severe dearth of options in the country's fruit markets. With higher seasonal flow rates of the Sistan and Parian rivers and the percentage of water supply for planting in these areas, continuing to support and grow the Sistan red grape varietal appears appropriate. Since the Hamons are in the third priority, after allocating water to the agricultural sector, the water of the Sistan River is transferred to them according to their assigned portion. The percentage of water supply of each of Hirmand and pozak wetlands are shown in Fig. 5.

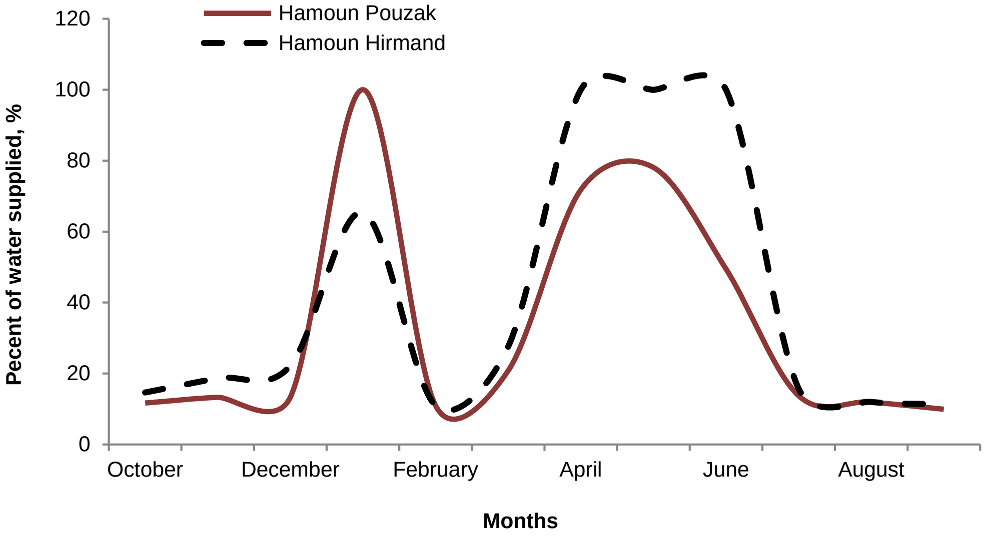

Fig. 4. Percentage of water supply in wetlands in Sistan.

According to Fig. 4, a total of 184,000 cubic meters of water required by Hamoon Hirmand will not be provided. So that in October the lowest amount of water enters this wetland and in spring the highest amount of water will flow into this wetland. The above results are based on the current system of Sistan water resources and the current and future measures are not mentioned in it, so it is necessary to create new scenarios in the model and enter the required data into the model to analyze the results obtained for the water resources management policies. On the other hand, due to the importance of demand management in water resources management, by creating different management scenarios such as increasing irrigation efficiency and reducing per capita domestic water consumption, water supply can be increased and its effect on other sectors can be observed. The results of these discussions are given below.

3.1. Water supply management scenarios

In recent years, various projects have been implemented or are being implemented in order to manage Sistan water resources. In order to determine the effect of these projects on Sistan water supply management, new scenarios in the model will be created and discussed. One of the scenarios is the transfer of Chahneimeh water to the Zahak and Miankangi lands and the other scenario is the exit plan from Chahneimeh 4, for irrigation of Sistan lands which is under study. With the construction of the Miankangi canal and the transfer of water to the Zahak lands from the Chahnimehs, more water is transferred to these two areas, which can be seen in Fig. 4. According to this diagram, the water supply of Miankangi and Zahak lands will be increased by 102 and 41 million cubic meters, respectively, but in Sistan lands, about 120 million cubic meters less water will be transferred than the baseline scenario, which indicates more water transfer from Chahnimeh reservoirs to Zahak and Miankangi lands.

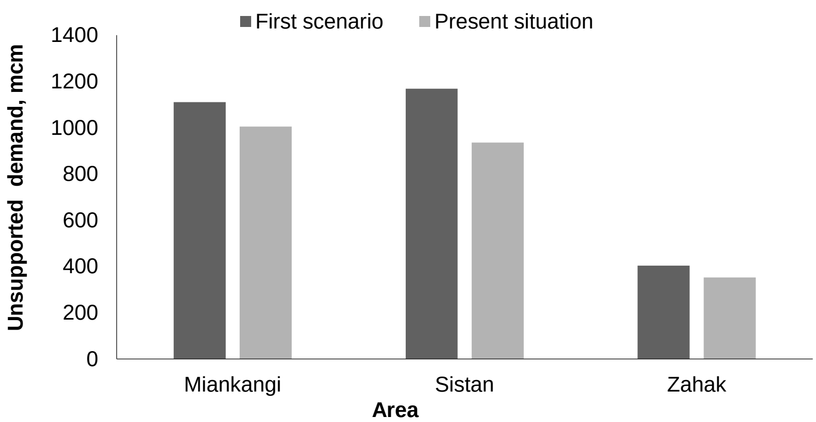

Fig. 5. Unsupplied demand for agricultural water in the current situation and the first scenario.

In previous years, only the lands of Sistan could use the water of the Chahnimehs. With the recent policies, Zahak lands will also use Chahnimeh water and in the near future, Hirmand lands will use this water permanently, but if the river flow is suitable for agriculture, water will not be released from Chahnimeh. Due to the fact that the lands of Sistan are located after Zahak, the river water is first allocated for agricultural purposes in Zahak and then transferred to Sistan. For this reason, in the first period, most of Chahnimeh water is transferred to Sistan lands and in case of water shortage in other areas, Chahnimeh water is used for irrigation. On the other hand, due to the priority of domestic water, water will not be released for agriculture when Chahnimeh reserves are less than required for domestic consumption after the evaporation and infiltration.

According to the results obtained in the Miankangi region, only in June, 36% of water was added to the current situation, and in other months, the volume of water transferred is the same as before. In drainage lands, in October, April, May, and June, there will be an increase of 2.5%, 14.6%, 13.6%, and 1.7%, respectively, and in August, there will be an 11% decrease in water transfer. In Sistan region, there is a 13.5% and 3.2% increase in water in October and June, respectively, but due to a 29% decrease in water in July and August, less water is transferred in total.

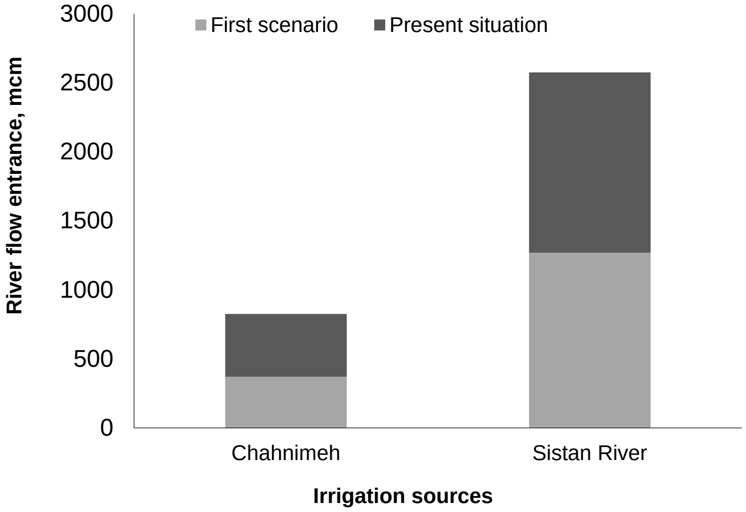

Fig. 6. Agricultural water supply of Sistan from irrigation sources (Transfer of Chahnimeh water to Zahak and Miankangi lands).

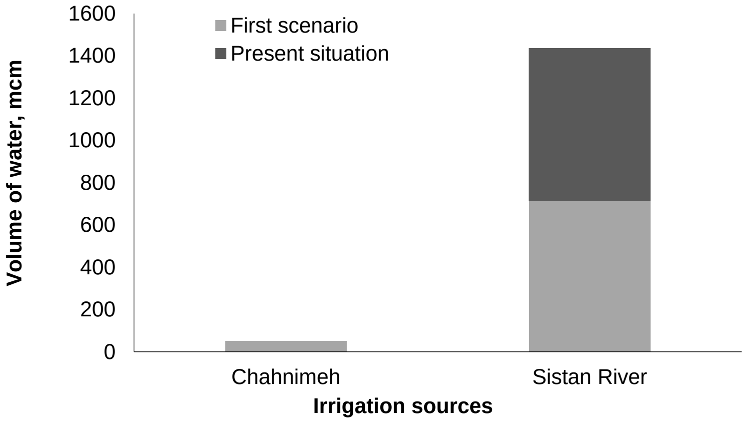

Fig. 7. Zahak agricultural water supply from irrigation sources (Transfer of Chahnimeh water to Zahak and Miankangi lands).

Thus, the amount of incoming water from Chahnimeh I, Sistan River and Paryan River to irrigate agricultural lands in different areas is shown in Figs. 7, 8 and 9. The construction of the new Chahnimeh entrance canal is another operation that, according to studies, will be implemented in the not-too-distant future. This will probably increase the water storage capacity of the Chahnimes. According to the river water flow, the maximum amount of water stored in the Chahnimehs after the construction of the water transfer pipeline (600 m3/sec) in a year is a total of 20,000 cubic meters in Chahnimeh 1 and 21,000 m3 in Chahnimeh 4. By adding this pipeline, as shown in Fig. 7, about 64 and 100 million cubic meters will be added to the Chahnimeh inlet water in April and May. This water is divided between different agricultural lands.

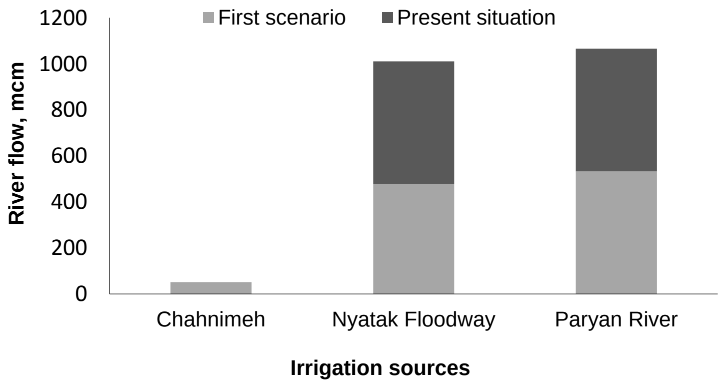

Fig. 8. Miankangi agricultural water supply from irrigation sources (Transfer of Chahnimeh water to Zahak and Miankangi lands).

According to the obtained results, the volume of output from the reservoir of Chahimeh one for agricultural purposes will increase or decrease in different months as shown in Table 4 compared to the current situation.

As can be seen, there is an increase in agricultural water supply in all areas in May and April. So that Zahak and Sistan lands have had an increase in the water supply of 99 and 30 thousand cubic meters and an average of 105 million cubic meters, respectively. Of course, it should be noted that with the increase in river flow, water supply will increase and as a result, it will meet a higher volume of demand. On the other hand, the water supply project to the cities of Sistan, the implementation of the second line of water transfer to Zahedan, and the implementation of the supplementary water supply project to the villages of the Sistan region are other cases that are being implemented. These cases will increase the consumption of the domestic water sector, which is the first priority of the region, according to the volume of water transmission pipes. To investigate the effect of these projects on water supply in the region, the water consumption population of Chahnimeh in Zabol city was changed to 450 thousand people and Zahedan to 500 thousand people. domestic water consumption increased by about 13,000 cubic meters in Zabul and 18,000 cubic meters in Zahedan after the population change.

Table 4. Volume of incoming water to agricultural lands from Chahnimeh after creating a new inflow (thousand cubic meters).

Month	Sistan Lands	Zahak Lands	Miankangi Lands
October	0	2	0
November	0	0	0
December	-4	3	0
January	-2	16	0
February	-8	0	-26
March	0	0	0
April	40	20	51840
May	8	22	53568
June	0	20	0
July	0	10	0
August	0	3	0
September	-4	2	0
Total	30	98	105382

As domestic water is the region's number one priority, as expected, this amount of water was provided in all months of the year. However, due to the fact that wetlands are in the third priority of water supply after agriculture, the water supplied to the agricultural sector in different areas has not changed and only the water supply to Hamoon Hirmand wetland has been reduced. The results showed that the water supplied to Hamoon Pozak would not change. Because this wetland is taken from the fairy river. On the other hand, due to the increase in domestic water demand, the volume of Chahnimeh reserves decreased to a total of 38,000 cubic meters to meet another amount of domestic water demand. According to the above results, as the water supply increases, if the water demand increases, the environmental needs will not be met and the main damage will be done to this sector. Since wetlands in Sistan play a key role in the ecological conditions of the region, reducing water supply and drying them will lead to social problems in addition to economic problems. For this reason, and since supply management is as efficient as it is, it will not have a favorable effect without demand management, in the next section, demand management scenarios in the region will be simulated and compared with the above results.

3.2. Water demand management scenarios

The projects that have started their studies are the implementation of the water transfer project with pipes to about 3000 hectares of Shibdar lands, the construction of irrigation and drainage network in Miankangi, the implementation of water transfer project to Sistan farms with pipes and the change of irrigation system in Miankangi area. All of which will increase irrigation efficiency in the region. Increasing irrigation efficiency means reduced water needs in certain months of the year. According to previous projects implemented in the region, irrigation efficiency was increased from 35% to 45% and its effects on wetland water supply and agriculture were investigated. It should be noted that since domestic water is the first priority, all domestic water demand is met.

In the agricultural sector, after increasing efficiency, more water will go to different areas and more water will be available for agricultural use, which can be seen in Fig. 9.

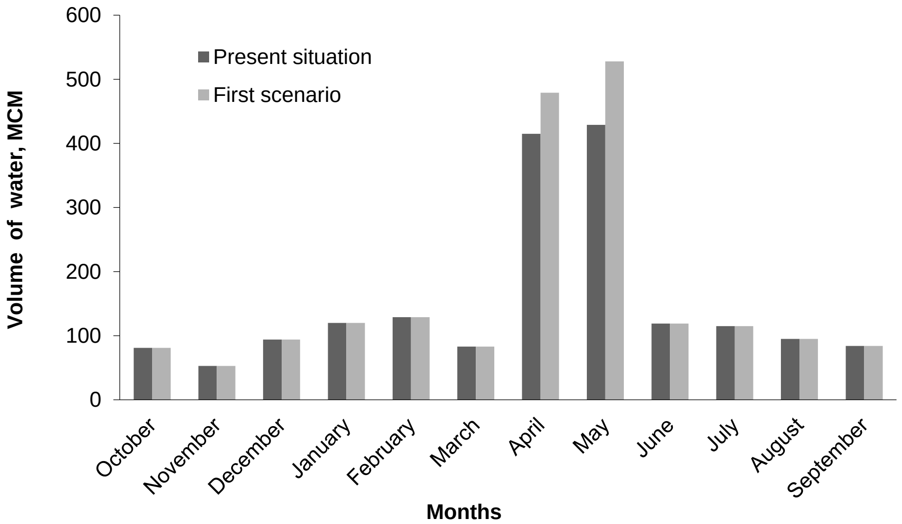

Fig. 9. Volume of incoming water to the agricultural areas before and after changing irrigation efficiency.

According to the results, the increase in efficiency will lead to the supply of 683 million cubic meters more water in Sistan, 221 million cubic meters in Zahak and 181 million cubic meters of water to the agricultural farms of Miankangi city. Thus, the percentage of water supply will increase in different months and more water will be supplied to the farmers of the region.

On the other hand, the water supply of wetlands, which is very important, will increase with increasing irrigation efficiency, and the incoming water to Hamoon Hirmand wetland will be 10,000 cubic meters and to Hamoon Pozak 23,000 cubic meters more. This means that we will have 5% more water to Hamoon Hirmand and 11% more water to Hamoon Pozak. Also, the volume of water stored in the reservoirs has increased with increasing irrigation efficiency and in October, February, July and September, Chahnimeh I reservoirs are facing a decrease in water storage, but in other months of the year, increasing the volume of stored water will compensate for this shortcoming. Eventually there will be an increase in volume of 23 million cubic meters of water in the Chahnimeh 1 reservoirs. There is also a 12% increase in the volume of Chahnimeh IV water, after increasing the irrigation efficiency, which varies in different months. For example, in December and March there is a slight decrease in water storage, but in other months there is an increase in water volume. Another measure that can be taken to manage water demand is to increase efficiency in domestic water consumption per capita. Assuming that all supply-side measures are taken, the per capita consumption of domestic water changes from 200 liters per day to 170 liters with increased efficiency under the scenario. Thus, the demand for domestic water in Zabol will decrease from about 85,000 cubic meters per year to 77,000 cubic meters and for Zahedan from 90,000 cubic meters to 86,000 cubic meters.

After the implementation of the mentioned scenario, the water supply of agricultural and wetland sectors increased. Zahak agricultural sector had the highest increase in agricultural water supply and Miankangi had the lowest increase in water supply. Also, the amount of water stored in the reservoir of Chahimeh 1 will increase by 4890 cubic meters per year. Although these amounts are very small, they will be very important for an arid region like Sistan, which suffers from a shortage of domestic water and agriculture.

In recent years, the transfer of water wells to the lands of Zahak and Miankongi and the outlet plan of Chahnimeh 4 for the irrigation of the lands of Sistan are under study. In the first phase, after the construction of the canal, it is expected to transfer water to Miankongi. More water is received in Zahak and less water is transferred to Sistan. After the creation of the new canal, the output of Chahmina 4 will also increase the water supply needed by agricultural lands (although it may not be fully supplied). Water supply to the cities of Sistan, the implementation of the second water transmission line to Zahedan and the implementation of the additional water supply plan to the villages of the Sistan region are among other things that are being implemented. With the implementation of these plans, the need for domestic consumption was completely met, the agricultural water did not change much, but the supply water of the Hamon lagoon was significantly reduced. Since wetlands in Sistan play an essential role in the ecological conditions of the region, the reduction of water and their drying will lead to social problems in addition to economic problems.

The results of different scenarios show that there is a strong competition between the three sectors of agriculture, household and environment in their water supply in the region, which is confirmed by the study of Georgakakos *et al.* (2012) is consistent with different scenarios, they concluded that an increase in the demand of one of these sectors causes a decrease in water supply to other sectors and vice versa. On the other hand, it was observed that by increasing irrigation efficiency or reducing per capita domestic water consumption, in addition to the positive effects of supplying water to other sectors, the destructive effects of environmental, social and economic impacts in the region can be reduced.

Also, as the results show, in addition to demand policies, it is possible to improve the water supply conditions of the region by managing water supply and creating various structures, including canals and dams and river dredging. These results are consistent with literature (Schneider *et al.,* 2019; Goshime *et al.,* 2021). As a result, it can be said that if the supply and demand of water are managed by the executives together, they will have favorable effects on the economic, environmental and social conditions of the region.

4. Conclusions

In this research, using WEAP software, the effects of changes made in recent years in Sistan's water resources system were investigated. It was observed that supply management will not have the desired effects if it is not accompanied by demand management. One of the water demand management scenarios is to increase the efficiency of water consumption in the agricultural sector, which has increased from 35% to 45%. With this policy, water consumption in the agricultural sector will increase, and on the other hand, water in the environmental sector will also increase. In addition, the volume of water stored in the reservoirs has increased, which allows for water storage during the months with the highest demand. By increasing the efficiency in domestic water consumption, the available water for agriculture and environmental needs will be more easily supplied. Finally, it can be said that the three sectors, household, agriculture and environment, compete with each other for water supply, and improving water consumption in one sector increases the water needed by other sectors and increases income, employment and welfare of people. Considering that since 1400 the water input of the Hirmand River has been insignificant and there is no agriculture in this area, it is better to conduct other studies in drought conditions.

Author Contributions

Hajar Esnaashari: Review & editing, data curation, investigation, formal analysis, validation.
Narges Ganjali: Conceptualization, methodology, writing original draft, writing - review & editing
Ali Sardar Shahraki: Supervision, writing

Conflict of Interest

The authors declare no conflict of interest.

Acknowledgment

The authors appreciate the Regional Water Company of Zabol and Zahedan, Iran, for sharing the required information with them.

Data Availability Statement

Data will be available on request due to privacy and ethical restrictions.

References

Agarwal S. *et al.* (2019) 'Assessment of water supply–demand using water evaluation and planning (WEAP) model for Ur River watershed, Madhya Pradesh', India. *Journal of The Institution of Engineers (India)*. 100, PP 21-32, doi: https://doi.org/ 10.1007/s40030-018-0329-0

Booker J.F. *et al.* (2012) 'Economics and the modeling of water resources and policies', *Natural Resource Modeling*, 25(1), PP 168-218, doi: https://doi.org/10.1111/j.1939-7445.2011.00105.x

Fassio A. *et al.* (2005) 'A decision support tool for simulating the effects of alternative policies affecting water resources: an application at the European scale', *Journal of Hydrology,* 304(1), PP 462-476, doi: https://doi.org/10.1016/j.jhydrol.2004.07.048

Fethullahi, J. Najafi, M.B., and Farhangian, S. (2022) 'Identifying and prioritizing factors affecting water scarcity in Kermanshah province with the help of analysis process Hierarchy', *Journal of Water and Sustainable Development,* 8(4), PP 33-42, doi: http://doi.org/10.22067/JWSD.V8I4.2108.1073

Georgakakos A.P. *et al.* (2021). 'Identifying and prioritizing factors affecting water scarcity in Kermanshah province with the help of hierarchical analysis process', *Journal of water and sustainable development*, 8(4), PP23-42. (In Persian), doi: https://doi.org/10.22067/JWSD.V8I4.2108.1073

Goshime D. *et al.* (2021) 'Implications of water abstraction on the interconnected Central Rift Valley Lakes sub-basin of Ethiopia using Weap' *Journal of Hydrology: Regional Studies*, 38, PP1-20, doi: https://doi.org/10.1016/j.ejrh.2021.100969

Hamlat A., Errih M., and Guidoum A. (2013) 'Simulation of water resources management scenarios in western Algeria watersheds using WEAP model', *Arabian Journal of Geosciences*, 6(7), PP2225-2236, doi: https://doi.org/ 10.1007/s12517-012-0539-0

Li X. *et al.* (2015) 'Application of Water Evaluation and Planning (WEAP) model for water resources management strategy estimation in coastal Binhai New Area, China', *Ocean & Coastal Management,* 106, PP 97-109. doi: https://doi.org/10.1016/j.ocecoaman.2015.01.016

Mo X. *et al.* (2017) 'Impacts of climate change on agricultural water resources and adaptation on the North China Plain', *Advances in Climate Change Research,* 8 (2), PP 93-98. doi: https://doi.org/10.1016/j.accre.2017.05.007

Mishra, R.K. (2023). 'Fresh Water availability and Its Global challenge', British *Journal of Multidisciplinary and Advanced Studies*, 4(3), PP 1–78. doi: https://doi.org/10.37745/bjmas.2022.0208

Nadalal K., and Sakthivadivel R. (2002) 'Planning and management of complex water resource system: Case of Samanalawewa and Udawalawe reservoirs in the Walawe River, Sri Lanka', *Agricultural Water Management*, 57(3), PP207-221. doi: https://doi.org/10.1016/S0378-3774(02)00070-7

Piao S. *et al.* (2010) 'The impacts of climate change on water resources and agriculture in China'. *Nature*, 467(7311), PP 43–51. doi: https://doi.org/10.1038/nature09364

Purkey B., and Joyce S. (2008) 'Robust analysis of future climate change impacts on water for agriculture and other sectors: a case study in the Sacramento Valley', *Climatic Change*, 87, PP109–122. doi: https://doi.org/ 10.1007/s10584-007-9375-8

Salmani Sabzevar M., Rezaei A., and Khaleghi B. (2021) 'Incremental adaption strategies for agricultural water management under water scarcity in Northeast Iran', *Regional Sustainability*, 2(3), PP224-238. doi: https://doi.org/10.1016/j.regsus.2021.11.003

Schneider P. *et al*. (2019) 'Potential and versability of Weap model (Water Evaluation and Planning System) for hydrological assessments of AWD (Alternate Wetting and Drying) in irrigated rice', *Agricultural Water Management*, 224(1), PP1-13. doi: https://doi.org/10.1016/j.agwat.2019.03.030

The Ministry of Energy. (2022*), Report on river water resources planning and reservoirs of Chahnimeh in Sistan. Sistan and Baluchestan Regional Water Company, Zabol.* Available at https://www.moe.gov.ir (23 September 2022).

Weng S.Q., Huang G.H., and Li Y.P. (2010) 'An integrated scenario-based multi-criteria decision support system for water resources management and planning – A case study in the Haihe River Basin', *Expert Systems with Applications*, 37(12), PP 8242-8254. doi: https://doi.org/10.1016/j.eswa.2010.05.061