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RESEARCH PAPER

A new approach in irrigation of Sistan plain by applying special social, climatic conditions and available resources

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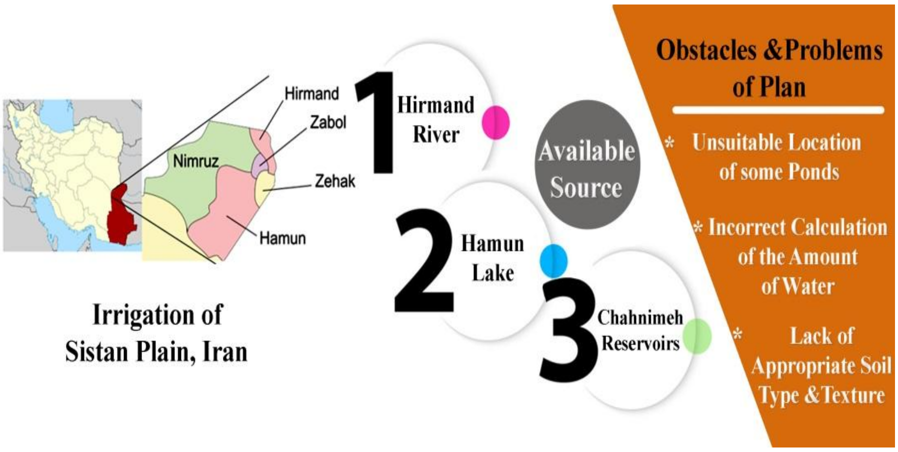
Highlights

• Limited soil and water resources and special social conditions are an integral part of agriculture in Iran.
• The formation of water groups in the form of cooperatives has a significant role in the successful implementation of irrigation projects and cost reduction
• Proper and balanced use of available resources leads to the optimal and practical use of costs incurred.

Graphical Abstract



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Abstract

Water and soil are the most important and main available capital available in geographical areas. Case study of large and fertile plains has always been considered as a turning point in terms of productivity and increasing efficiency in this sector. In addition, the social dimension has the most flexibility in the study of factors. This issue can pave the way for the formation of different approaches. In general, irrigation management is possible through three sectors: public (government), private sector and private organizations (water users). Irrigation plan of Sistan plain in 46000 hectares of lands of this region within the lands of Zabol, Hamun, Zehak, Hirmand and Nimruz cities in 17 civil development units and the form of water supply to the lands in the form of detailed studies in the fields of soil science, hydrology and is hydraulically operated. In this research, the conditions of implementation of this project in terms of the type of implementation and operation have been studied in detail. The results showed that in arid and semi-arid regions, special social conditions, the state of resources lead to the fact that the operation of irrigation projects requires special conditions and without considering the direct role of farmers in the form of cooperatives and Water groups should be able to achieve the best efficiency conditions.

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1. Introduction

Optimal use of available human resources has long been considered and with the development of science and technology, attention to this issue has become more important. This process has been affected by factors and conditions and relationships between these factors at different times and efforts have always been made to improve them. Iran is one of the arid and semi-arid regions of the world with an average annual rainfall of about 250 mm. Therefore, proper use of resources related to the life of human societies is essential. Water and soil are the most important and main assets available and available in geographical areas that human survival and survival ensure their existence and proper use. Currently, more than 90% (of course, taking into account the existing measures in recent years to optimize and reduce consumption, which is sometimes mentioned up to about 70%) of the country's available water for agricultural use (Ebrahimzadeh, 2009) which, considering the amount, type, method of operation, is appropriate by creating an efficient system of operation and maintenance of water and irrigation resources and facilities and increase efficiency, in accordance with what is in the development plans The country is expected to reduce this percentage.

In general, the agricultural mechanism has been formed since ancient times based on the social, climatic and natural conditions of each region. A noteworthy point in this regard is the need to make changes tailored to the new conditions. As mentioned, the general conditions and general situation of Iran have an arid and semi-arid climate. Therefore, continuous efficiency and up-to-date policies in the agricultural sector have always been considered. Case study of large and fertile plains has always been considered as a turning point in terms of productivity and increasing efficiency in this sector. In addition, the social dimension has the most flexibility in the study of factors. This issue can pave the way for the formation of different approaches. In general, irrigation management is possible through three sectors: public (government), private sector and private organizations (water users). The transition of irrigation management reached its peak in the 1990s. Such reforms date back to the 1960s in Bangladesh and the United States, the 1970s to Mali, Colombia and New Zealand, and the 1980s to the Philippines, Tunisia and the Dominican Republic (Senanayake et al., 2015).

Today, more than 60 countries are witnessing reforms in their irrigation sector, which account for 75% of the world's population and 80% of the world's irrigation area 27 million hectares. Adopting an appropriate policy in irrigation management ensures the conservation of resources even in the face of climate change in different regions, especially in arid regions. The importance of this issue is very important and one of the main priorities in the implementation of irrigation projects, so that it deserves to be considered and evaluated in conjunction with technical issues, however, so far on a large scale and a large scale. Irrigation and resource management in the country is not fully implemented. In recent years, attention to this issue has led to the implementation of the huge irrigation project in the Sistan plain in a realistic way of managing resources, taking into account the social and climatic conditions in the region. Mohammadghasemi et al., 2021, concluded that increasing subscribers' knowledge and expectations, as well as declining water resources and funding, prompted large numbers of governments to shift irrigation management responsibilities from the public sector to local service providers. Transfer water such as cooperatives and production companies and non-governmental organizations (Mohammadghasemi et al., 2021). Jafari Shalamzari and Zhang, 2018, studied the role of agricultural organizations in managing the operation of modern and traditional water networks in Golestan province (Jafari Shalamzari and Zhang, 2018).

The results showed that in Golestan province, there are successful experiences in attracting farmers 'participation in the implementation of water supply projects and it is possible to simultaneously provide areas for farmers' participation in the operation and management of irrigation networks. These provided agricultural water through the establishment of consumer organizations. Also, a significant number of agricultural organizations called "agricultural production cooperatives" have been created in modern and traditional networks that if trained, strengthened and supported cooperatives, can be effective in managing irrigation networks (Jafari Shalamzari and Zhang, 2018). In the other study, Panahi et al., 2020, concluded that successful and unsuccessful experiences in the country contain lessons that will be useful in designing an integrated approach, commensurate with the complexity of the issues of operation management and maintenance of irrigation networks in the country (Panahi et al., 2020). Hunecke et al., 2017, evaluated understanding the role of social capital in adoption decisions and its application to irrigation technology. Results showed that support that extension efforts should consider social networks, not just economic or individual-level predictors, in promoting agricultural innovations (Hunecke et al., 2017). The results of the one study, show that the farmers' contribution to the maintenance of canals, including clearing water weeds and dredging ditches, was required to maintain quality even after the transition to KRC management in accordance with political and social issues. The survey also confirmed that some actions have to be implemented to improve irrigation management by encouraging farmers' participation under the public irrigation management (PubIM) system (Choi et al., 2016).

2. Materials and methods

2.1. The area of study

Sistan plain with an area of 1054609 hectares in the north of Sistan and Baluchestan province is a fertile plain whose agriculture is affected by surface water resources. In addition to the available lands, Hamun Lake covers an area of one square kilometer of this plain (Rahnama et al., 2016). Sistan plain in the range of longitude 60 degrees and 15 minutes to 61 degrees and 50 degrees east and latitude 30° 5" to 31° 28" N occupies about 8.1% of the province. The region is bounded on the north and east by Afghanistan, on the south and southwest by Afghanistan and the Haramak Mountains of Iran, and the west and northwest by the Chehel Dokhtar, Palangan, and Nehbandan mountains. Part of the border is the boundary of the conventional boundaries, and part of it, especially the Palangan Mountains, the Chehel Dokhtar, and the sanctuary of natural boundaries. Sistan plain includes the cities of Zabol, Zehak, Nimruz, Hamun and Hirmand. Fig. 1 shows the geographical location of the Sistan plain and the cities located in it.

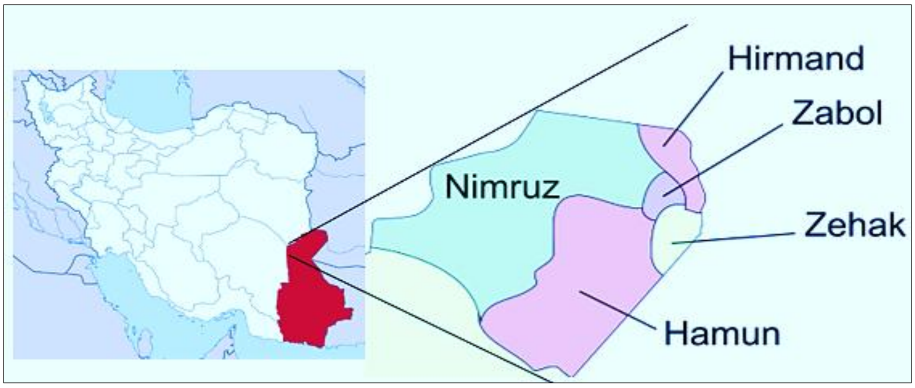

Fig. 1. Geographical location of Sistan plain in Sistan and Baluchestan province.

Sistan region in terms of national divisions has three cities of Zabol, Zehak and Hirmand, seven cities, 18 villages and more than 985 villages and hamlets. This region is ecologically part of steppe and semi-desert areas and in terms of hot and very dry climate. The average annual rainfall in this region is 53 mm, the annual evaporation from the water level is 4500-5000 mm, the average annual temperature is 21.7 °C with an absolute minimum of -12 °C in winter and an absolute maximum of 51 °C in summer. Among the index characteristics of this region can be the number of sunny days more than 2190 days, the number of dry days more than 260 days, the annual relative humidity of 39.3%, the existence of maximum hours of sunshine equal to 14 hours in June and 10.4 hours in January. 120-day winds with a range of winds from June to September with severe sandstorms. The irrigation project of Sistan plain with an area of 46,000 hectares of lands in the region that are capable of agriculture and have common waterfalls in the region, was considered by the Ministry of Jihad Agriculture. The project is planned in two phases, the first phase includes the main network in most parts of the project area has significant progress and in some construction units, executive operations have been completed. The second phase includes the design of the network inside the agricultural lands. At the present time, it is being followed up and done by the agents and stakeholders. Fig. 2 shows the climate of the Sistan plain based on the Domarten classification.

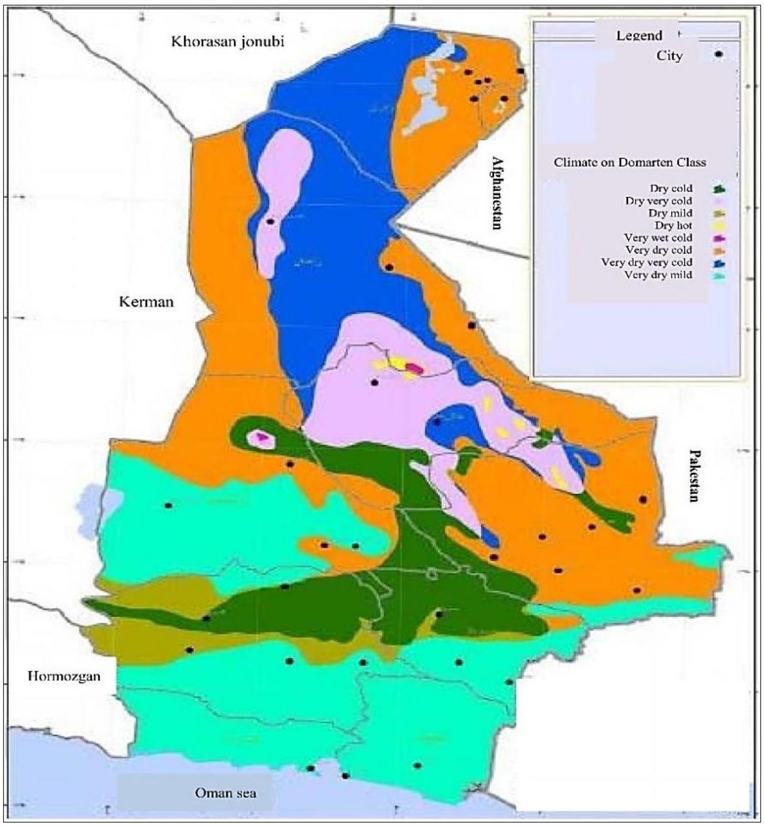

Fig. 2. The climate of Sistan plain based on Domarten classification.

3. Results and Discusion

3.1. Water condition

The surface water resources of the Sistan plain are unique to the Hirmand River, which originates from Afghanistan and the Hindu Kush highlands and enters the Iranian border after about 1100 km (Fig. 3). This river is divided into two main branches at the border (Goes et al., 2016). One of these branches is the common Parian that flows in the inner border of Iran and drinks the regions of Azar, Milk, Golmir, and Miankangi in Iran and flows into Hamun Lake. The other tributary is the Sistan River, which flows into the Sistan Plain and eventually flows into Lake Hamun. The water of this river has been used for agriculture and in order to facilitate the exploitation, it has been constructed at 2, 17, and 30 km distances from the place and in the downstream, Kahak, Zehak, and Sistan diversion dams have been constructed. There are Chahnimeh reservoirs, holes and natural pits that are located 50 km away from Zabol city and 5 km away from Zehak city and next to Qala-e-Novi village. In Sistan, there are four Chahnimeh reservoirs in the 1st, 2nd, 3rd and 4th halves to which the excess water of the Hirmand River is directed by a canal.

The capacity of 3 reservoirs 1, 2, and 3 is equal to 700 million m^3 and the Chahnimeh 4 is up to 800 million m^3, which has become an artificial lake (Fig. 4). The average depth of Chahnimeh reservoirs is about 12 meters, which act as flood reservoirs with brief construction operations. The water potential of the Sistan plain (under normal hydrological year conditions) will be about 800 million m^3 (total flow of Helmand river). Therefore, the share of consumer sectors in gross (excluding evaporation and infiltration) is equal to 60 million m^3, which provides only the net amount of domestic water, drinking water, urban and rural services, which if efficiently 50% of this water should be available, equal to 15% of the total gross water entering Iran from Helmand. Therefore, the volume of gross water will be 120 million m^3 (out of 800 million m^3 of Hirmand river in a normal year) (Ebrahimzade, 2009).

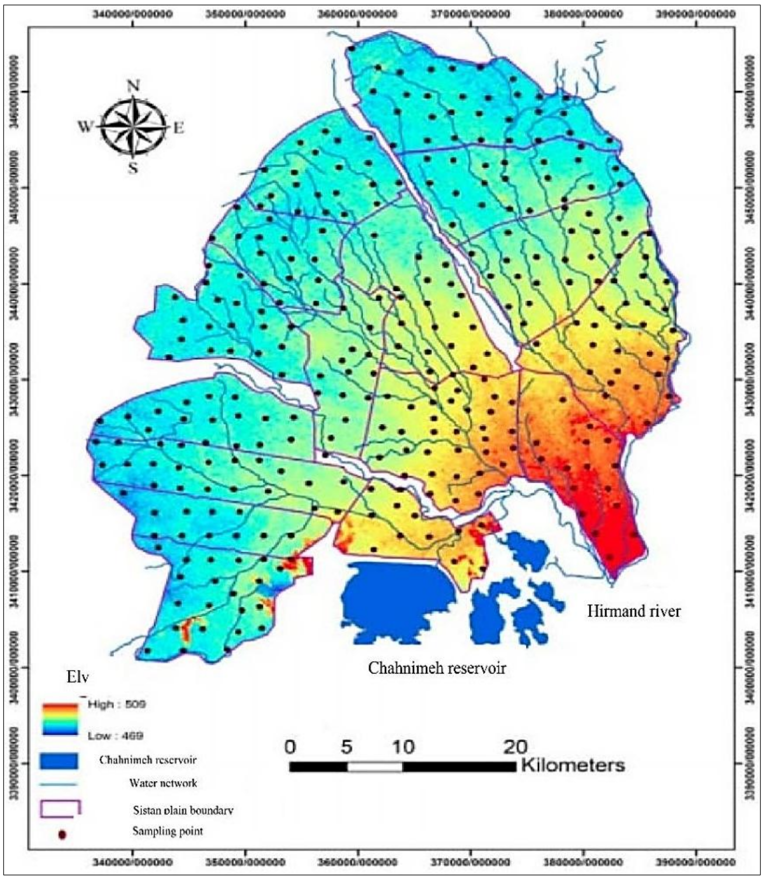

Fig. 3. Status of water resources in Sistan plain.

Fig. 4. View of number 2 Chahnimeh reservoir.

The study area of Sistan plain does not have any groundwater source and the alluvial aquifer is significant in terms of discharge. During the years 1338 to 1340, 5 exploratory wells were drilled in different parts of the plain, none of which had the necessary discharge. During the last 50 years, another exploration well has been drilled in the area, the status and specifications of which are not available. In addition, a 200-meter-long exploratory well was drilled in the Jezinak area in 2004. In total, the Sistan region does not have deep wells and in contrast, has 4209 semi-deep wells that have a discharge of about 59.05 million m^3 per year and most of them are in Zahak city and southern areas of southern cities and Hirmand.

3.2. Water quality

Investigating water quality and its desirability is always one of the most important factors in the efficiency and effectiveness of the irrigation system used (Dahimavi et al., 2021; Ghumman et al., 2014). In addition, accurate knowledge of the water used is a good guide to the use of equipment and facilities as well as treatment supplies. Expert and analytical studies on the water of Helmand river as the only supplier of water resources used in the region indicate that in different discharge conditions from the minimum to the conditions with maximum discharge in 4 relevant stations are determined and related values was measured and recorded (Table 1).

Table 1. Water quality status of Sistan plain.

Row	**1**		**2**		**3**		**4**	
Station/ River	Sistan/ Kahak dam tailwater		Canal 1/ Derikeh entrance		Shirdel Canal/ Shirdel bridge		Canal 1/ Tailwater	
Date	1369/2/18	1388/8/30	1388/1/30	1389/4/29	1387/11/16	1388/8/30	1389/1/28	1388/8/30
Discharge (cms)	Max	Min	Max	Min	Max	Min	Max	Min
	554.4	0.2	212.7	0.1	124	0.2	2050	0.2
HCO^{2-} (mEq/L)	1.4	10.3	2.3	6	8.9	10.7	2.2	10.7
Cl^- (mEq/L)	1.1	3.3.	1.2	2	2.4	3.3	1.1	3.1
SO^{4-} (mEq/L)	0.8	1	0.8	1.1	1.1	1.2	0.5	1.3
Ca^{2+} (mEq/L)	0.2	5.6	0.3	25	4.7	6	0.9	5.5
Mg^{2+} (mEq/L)	0.8	4.5	0.8	3.1	3.9	4.6	0.5	4.9
Na^+ (mEq/L)	2.2	4.2	2.1	3.7	3.6	4.3	2.1	4.3
PH	8.5	8.4	7.5	7.5	8.2	8.4	8.4	8.4
TDS (mg/l)	2015	920	321	750	902	1111	276	1117
EC (ms/cm)	310	1416	395	1154	1288	1110	425	1119
Drinking class	Good	Acceptab le	Good	Acceptabl e	Acceptable	Middle	Good	Middle
Irrigation class	C2S1	C2S2	C2S1	C2S1	C3S2	C3S2	C2S1	C3S2

3.3. Soil condition

Sistan plain is a physiological unit of alluvial river plain whose soils have a light to very heavy texture. In this plain, several studies have been conducted to identify the characteristics of the soil and lands of the region, the purpose of each of which has been related to the knowledge of soil resources. The following are some of the characteristics related to the soil condition of this region.

3.3.1. Soil Salinity

The study of salinity and alkalinity of soil available for agriculture is an important limiting or effective factor in this regard (K'akumu et al., 2016). Sistan plain area is considered as a dry area due to special climatic conditions and lack of rainfall during the year, and one of the main characteristics of dry areas is the limitations in their soil. Accumulation of salt and other solutes in the surface soil layer can be considered as one of the biggest results of this issue. However, the occurrence of floods, which usually occur during the year, is very important and, to a large extent, along with the problems that have arisen, can be a solution for agriculture in the region and the problems caused by its soil conditions. Many researches have been done on the soil of the region in terms of salinity and alkalinity and classification of their values (Fig. 5).

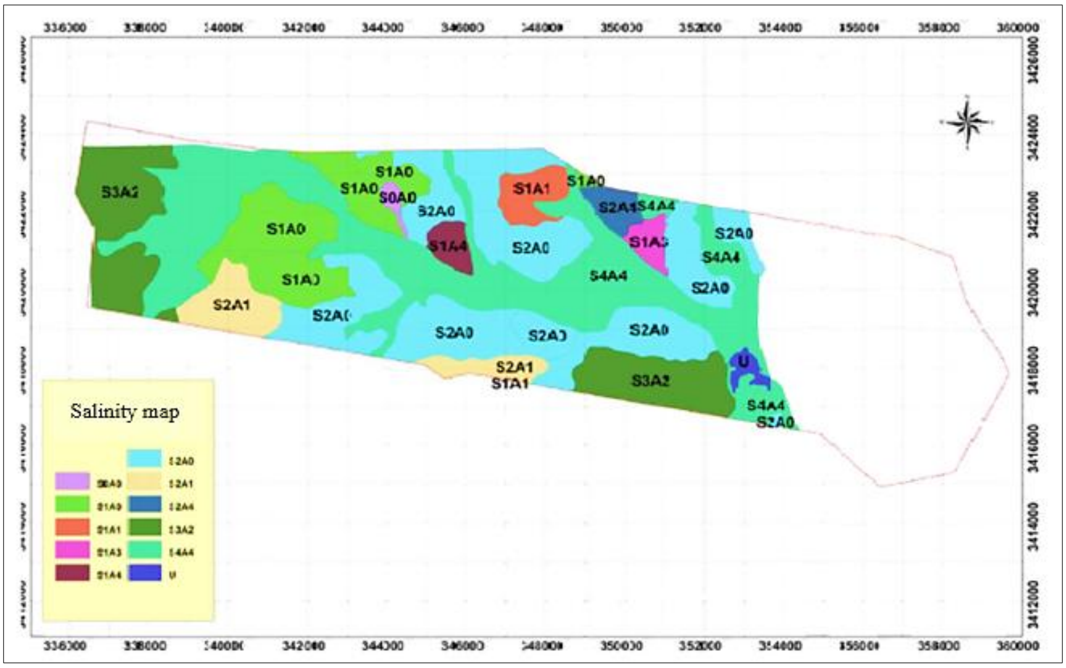

Fig. 5. Salinity and alkalinity of existing lands.

The general condition of the soils of the Sistan plain region in terms of salinity and alkalinity is in the range of good to suitable soils for agriculture. In the meantime, some lands are in poor condition and not very suitable for agriculture. According to the field visit, this issue became quite evident. Farmers in the region have not been able to cultivate in this part of their lands in recent years and have remained poor.

3.3.2. Soil pattern

Soil texture is an indicator for determining the relative content of particles that exist in different dimensions in the soil (Chow, 1965; Mguni et al., 2016). This index shows the percentage of sand, silt and clay in the soil. Soil texture affects the ease of use of the soil and depends on factors such as particle size distribution, particle shape, and particle grain size. When considering soil texture classification, we consider only the particle size distribution. Therefore, it will be difficult to include the other two parameters in this classification (Fig. 6).

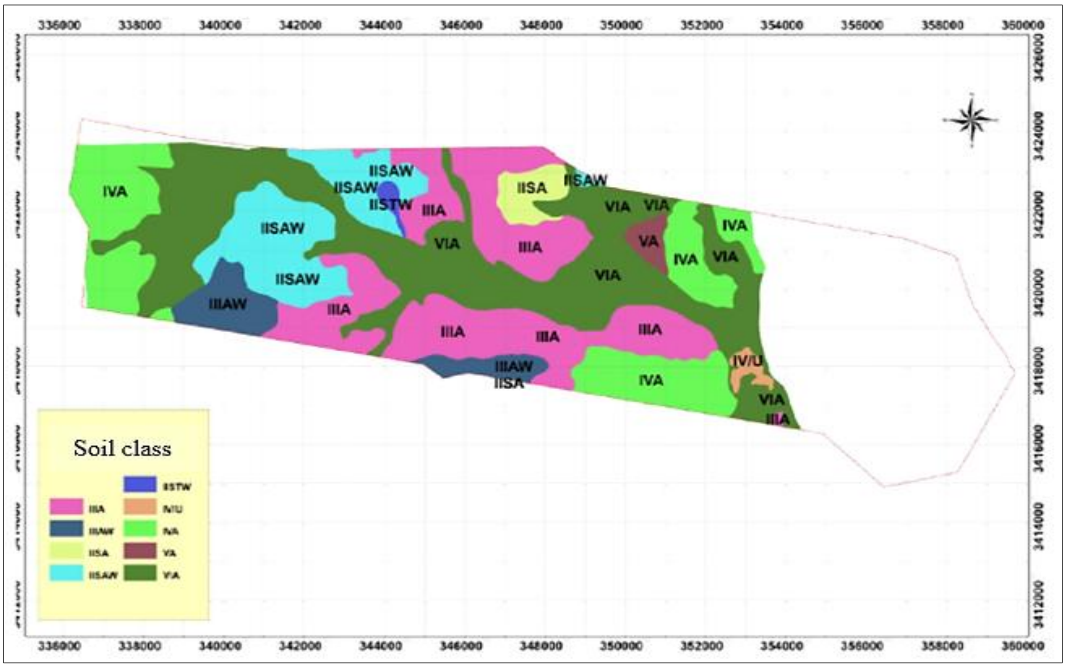

Fig. 6. Soil texture in the irrigation area of Sistan plain.

3.4. The approach used in irrigation

All the existing factors in the region have caused the irrigation method used in this region for the first time in the country to be widely integrated and in accordance with the traditional system and integrated with new methods. Irrigation plan of Sistan plain at the level of 46000 hectares of lands in this area within the lands of Zabol, Hamun, Zehak, Hirmand and Nimruz counties in 17 civil development units and the form of water supply to the lands in the form of detailed studies in soil science, hydrology And is hydraulically operated. The water supply of the reserves in the Chahnimeh reservoirs of the region is implemented in two phases. The first phase was carried out as a transmission line using the desired types of pipes and fittings using the power of internal engineers in both public and private sectors. A distinctive point about this project is the use of aggregate and multi-hectare ponds for each village. In other words, the lands of each village that have water can be treated in two ways. The rewards used are based on the so-called carafe offices, which belong to the 1340s, and are based on the divisions and rewards determined at that time. Over time, due to various issues such as division of land between heirs, sale of land to others, relocation of lands with water to another location due to various conditions such as better soil and salinity, etc. has led to the current situation, There are many problems in this case.

Another issue is the small ownership of land. Unlike the agricultural lands of the Baluchistan region, the lands of the plain in question in Sistan are in different dimensions and the range of 3000 to 20,000 m^2 per owner. So that the average area of agricultural land of this project is equal to 0.35 hectares. The implementation process was based on the fact that by dividing each village into several groups, all-water groups are formed (Fig. 7). Each group of all water consists of a land area of about 20 hectares, which in a more detailed division, are divided into groups of 5 hectares. At the beginning of each group is the water of a pond called 20 hectares. This pond branches from the main line and includes a meter for measuring the amount and pressure of the flow. This pond branches from the main line and includes a meter for measuring the amount and pressure of the flow. According to the water of each group of 5 hectares, the minimum branch diameter used in 5-hectare ponds is 200 mm.

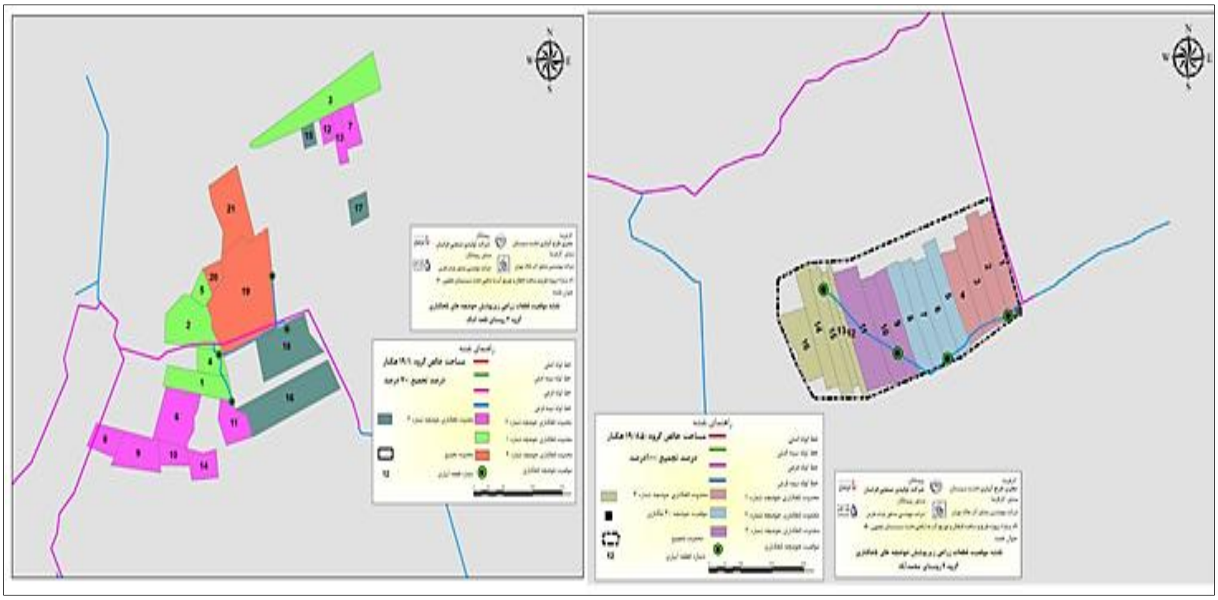

Fig. 7. An example of an all-water group.

The main issues regarding these issues include the location of ponds, the condition of the surrounding lands in relation to the ponds, the method of exploitation, the amount of water available, the cultivation pattern used and the social issues of Jakem on the region. Some of these cases, including the cultivation pattern, have been done by upstream government units according to the conditions of the region and taking into account technical views. Table 2 shows the selected cultivation pattern of Sistan plain. At the same time, the implementation of the irrigation project in this area, the implementation of activities related to the people and cooperatives have been strengthened. Table 3 shows the general situation of Sistan plain in terms of water companies and cooperatives.

Table 2. Selected cultivation pattern of Sistan plain irrigation project.

Crop type	Crop name	Cultivation (%)	Cultivation (hec)
Grains	Wheat	12	5520
	Barley	6	2760
	Sum	18	8280
Industry	Canola	4	1840
Cereals	Green beans	6	2760
	Green fava bean	4	1840
	Sum	10	4600
Vegatable	Garlic	4	1840
	Onion	6	2760
	Eggplant	6	2760
	tomato	4	1840
	Sum	20	9200
Melon ground	Watermelon	6	2760
	Cucumber	6	2760
	Melon	6	2760
	Sum	18	8280
Forag	Clover	6	2760
	Ghasil barley	6	2760
	Fodder corn	6	2760
	Sum	18	8280
Garden	Grape	6	2760
	Other	6	2760
	Sum	12	5520
Sum		100	46000

Table 3. General status of Sistan plain irrigation project.

Civil area	Hamoon	Zahak	Zabol	Hirmand	Nimrouz	Sum
Number of villages in the cooperative area	199	166	57	265	79	766
Number of operators	20469	13912	100067	11285	9265	65000
Number of water groups	596	361	269	537	311	2047
Number of irrigators	75	41	37	97	51	301
Number of head irrigators	6	6	3	7	7	29
Number of cooperatives	4	4	2	4	3	17
Receive farmers' demand	4	4	2	4	3	17
Number of initial licenses	4	4	2	4	3	17
Number of banking operations	4	4	2	4	3	17
Forming the founding board	4	4	2	4	3	17
Formation of the general assembly	4	4	1	4	2	15
Registered	4	4	1	4	2	15

4. Conclusion

One of the factors that, like the droughts of previous decades, did not lead to the increasing migration of the people of Sistan out of the region, was the existence of natural and artificial wells in the wells that can store 13. 5 billion m^3 of water. This amount of reserves is equal to the reserves of 9 major reservoir dams in Iran, such as Dez, Shahid Abbaspour, Sefidrood, Dorodzan, Miandoab and Minab dams (Noori, 2008). The average volume of evaporated water from the surface of 47 square kilometers of wells and semi-wells is about 100 million m^3 (Delft hydraulic ITC Altera, 2006). The irrigation project of Sistan plain is considered as a strong point in this arid region and in case its goals are properly laid and implemented, the possibility of becoming a great potential becomes. The main issue of this project, especially in the second phase and the implementation of the sub-network within the farms, has been to pay attention to the local conditions of land irrigation in accordance with the wishes and tastes of farmers and to consider technical issues. Forming facilitation teams, using cooperatives as a powerful tool in realizing the real needs, using the existing technical potentials in the region and, most importantly, the effective role of indigenous forces in justifying new conditions with farmers One of the main differences between this project and other similar projects.

Another point in this regard is the type of project implementation. Studies conducted on other projects implemented in the country indicate that so far in hot and dry areas with such severe water shortage have not been implemented. Various social factors have led to the need to invest in this region and of course, the way it is implemented is different from other places. These factors have led to this method of implementation can be a strong point in handing over the project to the public-affiliated cooperatives, and without the existence of common bureaucracies in this field, it is possible to operate in the best conditions. Thus, it is possible to achieve the main goal of the project, which is to prevent deep intrusion along the route due to soil texture and reduce the rate of evaporation from storage surfaces, and the potential of the region can be used effectively. It is suggested that due to the obstacles and problems in the plan, such as the unsuitable location of some ponds, incorrect calculation of the amount of water, lack of appropriate land allocation in terms of soil type and texture, justification of some farmers who want to use They do not have new methods and etc. it is possible to improve the situation.

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