WATER REUSE IN ON-FARM IRRIGATION AND DRAINAGE NETWORK OF THE SALMAN FARSI DAM

REUTILISATION DE L'EAU DANS LE RESEAU D'IRRIGATION ET DE DRAINAGE DE LA PARCELLE DU BARRAGE SALMAN FARSI

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ABSTRACT

The common examples of water sources reuse are: water reuse from irrigation, run off resulting from rainfall in plains and basins and urban and Rural Wastewater. Current limitations of water resource make a strong case for planning and using drainage water more than ever before. The sources of this water may be the rivers, canals or subsurface flow from the in basin land.

The on-farm network over about 23000 ha at the downstream of the Salman Farsi dam covers five plains: Ghir, Aliabad, Dotilaghz, Afzar and Laghar where water is supplied from one reservoir dam and three diversion dams. These dams are constructed on the Ghareaghaj River.

The annual surface water allocation to agriculture from the reservoir dam is about 195 MCM. The total annual water reuse is about 40 MCM. But in Laghar plain the water reuse is about 16.43 MCM due to poor water quality. Studies show that about 24 MCM of water can be extracted back there and mixed with the local water to take care of the water quality. By adopting conjunctive water use, the amount of water reuse is estimated about 20%. The results of this research are encouraging and the suggested method will increase the potential utilization of soil and water resources and agricultural production, improve living standards and social welfare.

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Key words: *Drainage water reuse, Salman Farsi dam, conjunctive water use, Ghareaghaj river.*

RESUME ET CONCLUSIONS

Aujourd'hui, la limitation des ressources en eau et provoquer augmentation de la population pour rendre l'eau de drainage planifier et utiliser plus de choses nécessaires à jamais. Retour de l'eau est un écoulement à se ramifie d'abord de rivières ou de toute canaux, après que de drainage ou sous forme d'infiltration écoulement souterrain dans les rejets du bassin et enfin à la rivière.

Dans le réseau de la ferme des terres en aval du barrage Salman Farsi qui impliquent zone pure environ 23000 ha, cinq plaines comme Ghir, Aliabad, Dotilaghz, Afzar et Laghar sont fournis avec un barrage-réservoir et de trois barrages de dérivation. Ces barrages sont construits le long de la rivière Ghareaghaj. Ces plaines adjacentes à la rivière et répartis sur les deux côtés à 40 km de la rivière Ghareaghaj. l'excédent d'eau agricoles et les précipitations transférés par le drainage mineur au collecteur principal situé dans chacun des plaines, puis déversées dans la rivière Ghareaghaj. Les sources communes réutilisation de l'eau dans les conditions du projet sont les suivants: réutilisation de l'eau de l'irrigation, le ruissellement résultant de précipitations dans les plaines et les bassins et les eaux usées urbaines et rurales.

Le volume total des eaux de surface du barrage réservoir alloués à des fins agricoles est d'environ 195 MCM par an, l'enquête de la réutilisation de l'eau dans ce projet montre que la réutilisation de l'eau annuelle totale est d'environ 40 MCM. Mais selon Laghar conditions plaine et ses qualité de l'eau, la réutilisation de l'eau de cette plaine qui est d'environ 16,43 MCM n'ont pas été considérés dans les programmes de ressources en eau. Les études mentionnées dans le réseau a indiqué que près de 24 MCM de l'eau peut être extraite là-bas et restrictions qualitatives résultant de la réutilisation de l'eau de mélange avec l'eau, provenant du réservoir et réglé dans le lieu de toutes les écluses. Par conséquent, nous décidons de l'utiliser. Réutilisation de l'eau est estimé par des méthodes directes et conjonctives à de nombreux projets différents. Dans cette recherche, nous utilisons la méthode conjonctive et selon cette méthode, le montant de réutilisation de l'eau est estimé à environ 20 pour cent. transmission prévue, la distribution et efficacité de l'application que sur la base des premières études pour la phase de conception sont respectivement 95%, 80% et 66% et l'efficacité totale du projet est de 50%. Le montant de la réutilisation de l'eau obtenir du système de traduction de l'eau est de 1,5 pour cent, mais à partir du système d'application de l'eau est d'environ 12,9 pour cent qui montrent la plus grande quantité de réutilisation de l'eau obtenir du système d'application de l'eau.

Il est évident que par la mise en œuvre complète de l'irrigation sur la ferme et le réseau de drainage et de son utilisation, le projet qualité de l'eau diminue à travers le transfert de sels accumulés dans le sol, qui dégradent la qualité des résultats au fil du temps au cours des années plus tard et fera la promotion de lixiviation sels. En conséquence l'utilisation des eaux salines, les plantes halophytes qui est suggéré dans la revue de la FAO 61 peut être utilisé.

Il convient de noter que pour la culture de ces plantes si le sol n'a pas un bon drainage, système de drainage doit être utilisé. En conséquence la gestion et l'utilisation de réutilisation de l'eau ont causé de fournir les besoins en eau pour 2000 ha de terres. Il provoque pour obtenir 3,3 millions de dollars de cette augmentation des prestations de gestion et de projet. Les résultats de cette recherche sont beaucoup et certains d'entre eux sont très importants comme l'augmentation de l'utilisation potentielle des ressources en sols et en eau, accroître la production agricole, améliorer les conditions de vie et le bien-être social.

Mots clés: *Réutilisation des eaux de drainage, Barrage Salman Farsi, usage combiné de l'eau, rivière Ghareaghaj.*

(Traduction française telle que fournie par les auteurs)

1. INTRODUCTION

Water reuse pertains to the water that flows from rivers or streams and emanate from drainage or subsurface flow and finally going back into the river downstream.

Water quality must be considered in water reuse projects for irrigation. The following properties are critical to plant and soil health and environmental quality (U.S. EPA, 2004):

- Elemental ions concentration in water.
- Ions retained in dissolved form after separation of solids during water treatment.
- Any salts added during the water treatment process.

Most reclaimed water from urban areas is slightly saline (TDS ≤ 1280 mg/L or EC ≤ 2 ds/m). High salt concentrations reduce water uptake in plants by lowering the osmotic potential of the soil. High levels of sodium in irrigation water are harmful for the plants and its toxic level depends on the plant species and the type of irrigation system. Turf grasses are generally more tolerant to sodium than most ornamental plant species. Although boron (B) and chlorine (CL) are necessary at low levels for plant growth, dissolved boron and chloride ions can cause toxicity problems at high concentrations. Specific ion toxicity varies with plant species, the type of irrigation method used and the water application rates. Using reused water for irrigation and other purposes is common today (Table 1).

Table 1. Information about some case studies in the world

Country	Total Annual Water Withdrawal			Annual Reclaimed Water Usage			Reclaimed Water as Percent of Total
	Year	Mm³	MG	Year	Mm³	MG	
Algeria	1990	4,500	1,188,900	-	-	-	-
Bahrain	1991	239	63,144	1991	15	3,963	6%
Cyprus	1993	211	55,746	1997	23	6,077	11%
Egypt	1993	55,100	14,557,420	2000	700	184,940	1%
Iran	2001	81,000	21,400,200	1999	154	40,687	0.20%
Iraq	1990	42,800	11,307,760	-	-	-	-
Israel	1995	2,000	528,400	1995	200	52,840	10%
Jordan	1993	984	259,973	1997	58	15,324	6%
Kuwait	1994	538	142,140	1997	80	21,136	15%
Kyrgyzstan	1990	11,036	2,915,711	1994	0.14	37	0%
Lebanon	1994	1,293	341,611	1997	2	528	0.20%
Libya	1994	4,600	1,215,320	1999	40	10,568	1%
Morocco	1991	11,045	2,918,089	1994	38	10,040	0.30%
Oman	1991	1,223	323,117	1995	26	6,869	2%
Qatar	1994	285	75,297	1994	25	6,605	9%
Saudi Arabia	1992	17,018	4,496,156	2000	217	57,331	1%
Syria	1993	14,410	3,807,122	2000	370	97,754	3%
Tajikistan	1989	12,600	3,328,920	-	-	-	-
Tunisia	1990	3,075	812,415	1998	28	7,398	1%
Turkey	1992	31,600	8,348,720	2000	50	13,210	0%
Turkmenistan	1989	22,800	6,023,760	-	-	-	-
U. A. Emirates	1995	2,108	556,934	1999	185	48,877	9%
Yemen	1990	2,932	774,634	2000	6	1,585	0%

1.1 Landscape and case study area features

1.1.1 Geographic location and investigation region

Investigation region is located in south-west of Iran in Fars Province between Firoozabad and Larestan Counties and is extended from E52º, 50' to E53º, 20' longitude and from N30º, 28' to N28º, 30' latitude. This region contains Ghirokarzin, Aliabad, Afzar and Laghar Plains. Total investigation region was 55600 ha and the net area of 22855 ha was under irrigation and drainage network. The general location of this region and its plains is illustrated in Figure 1.

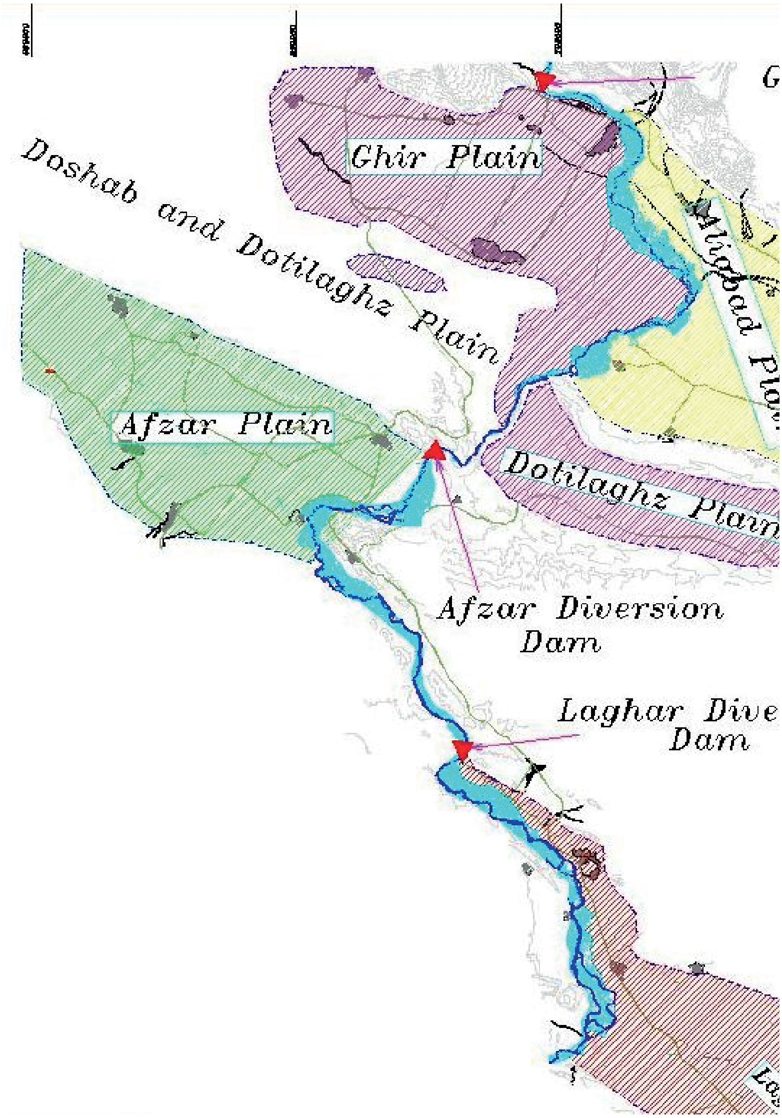

Fig. 1. Situation of plains and diversion dams in studied region (Situation des barrages et le détournement des plaines dans la région étudiée)

1.1.2 Project Objectives

Salman Farsi Dam (storage = 1400 Mm^3) is designed and constructed on Ghare-aghaj River in Fars province, to regulate agricultural water flow to the downstream plains, for supplying potable water to Jahrom, Larestan and other cities along the route and also to control periodic floods. In addition, there are some other goals including reclamation of saline and sodic lands, increasing agricultural and livestock production, creating job opportunities and decreasing emigration to cities and improvement of social conditions and finally building infrastructures for national and regional development.

1.1.3 Project Components

The project components of Salman Farsi are:

- Reservoir Dam
- Ghir, Afzar and Laghar Diversion Dams
- Irrigation and drainage networks of Ghir, Ali-Abad, Afzar and Laghar plains

1.1.4 Ghir Diversion Dam

Ghir Diversion Dam is designed to meet the water demand for 10090 ha of land in Ghirokarzin and Aliabad plains. This dam has concrete ogee crest with the design flood of 2710 m^3/s having a return period of 100 years. This dam is 180m in length and 4m in height above the river bed.

1.1.5 Afzar Diversion Dam

Afzar Diversion Dam is designed to supply water to 4515 ha of land in Afzar Plain. This dam has ogee crest with the design of 3000 m^3/s that has a return period of 100 years. This dam is 97.5m in length and 5.5m in height above the river bed.

1.1.6 Laghar Diversion Dam

In order to supply the water demand of 8250 ha of lands in Laghar Plain, the Laghar diversion dam on Ghare-aghaj River was constructed. This dam has concrete ogee crest to pass a design flood of 3125 m^3/s that has a return period of 100 years. This dam is 250m in length and 4m in height above the river bed.

1.1.7 Irrigation and Drainage Network

At the preliminary studies of development project, total regulated volume of surface water resources for agriculture was 282.6 MCM/year (according to the results of first stage studies) that it has been reduced to 195 MCM according to the change of the allocation for potable water of Jahrom city and environmental needs. This surface water along with 32.9 MCM ground water, meet the water requirement of 22855 ha (net area) with 15523 ha development area and 7332 ha improvement area.

The net area of downstream lands of Salman Farsi (according to the first stage study) that is going to be under irrigation and drainage network are as follow:

- Ghirokarzin Plain: net area of 4030 ha containing 2290 ha improvement area and 1740 ha development area.
- Ali-Abad Plain: net area of 4800 ha containing 860 ha improvement area and 3940 ha development area.
- Afzar Plain: net area of 4515 ha containing 2415 ha improvement area and 2100 ha development area.
- Laghar Plain: net area of 8250 ha containing 1423 ha improvement area and 6827 ha development area.

- Dutilaghaz Plain: net area of 1260 ha containing 344 ha improvement area and 916 ha development area.

2. WATER REUSE IN THIS PROJECT

Considering the position of Karzyn and Ghir, Aliabad, Afzar and Laghar plains in on-farm network of downstream lands of the Salman Farsi dam, diversion dams position towards each other ensure that water can get back by downstream diversion facilities.

Water reuse resources in the project conditions are:

- Water reuse from irrigation.
- Run off from rainfall on the plains and basins.
- Urban and rural wastewater treatment.

2.1 Water reuse from irrigation

At places with inadequate irrigation, use of drainage water is the most important strategy to augment they water resources. Reuse of drainage water will reduce its disposal problem. However, due to its poor quality, proper management of drainage water is necessary to reduce its short and long term adverse impacts on the soil and on agricultural production. Drainage water quality determines type of vegetation that can be irrigated by it.

Since high salt and trace element imbalance can affect crop growth and yield, the drainage water to be utilized for irrigation must be checked from these considerations. High sodium, calcium and magnesium may also damage soil structure. Besides, undesirable high concentration of selenium and arsenic in irrigation water may ultimately enter the food chain and adversely affect humans and animals.

Drainage water of permissible quality can be directly or conjunctively used with water of fresh water reservoirs for irrigation. Conjunctive use may be by mixing the drainage and the fresh water or through certain numbers of independent irrigation by either of the two in the total number of required irrigations. Selection from these options depends on drainage water quality, plant resistance to salinity and surface water availability. The relationship between these methods is shown in Figure 2.

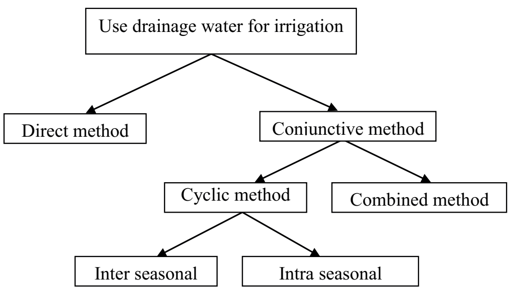

Fig. 2. The relationship between methods that are used for water reuse.(la relation entre les méthodes qui sont utilisées pour la réutilisation de l'eau)

2.1.1 Direct Method: This method is used more in the field. Research conducted in India, Pakistan, Central Asia and Egypt indicates that when using surface irrigation, drainage water can be used directly without significant reduction in the production when the water salinity is not in excess of the tolerance threshold of the plant.

2.1.2 Turning usage: When the salinity tolerance of plants is higher we can mix fresh water with relatively poorer quality water in a proportion that is tolerated by the plants. For example, ratios of 2:1, 3:1 or 4:1 of irrigation water and drainage water have been used for irrigation.

2.1.3 Cyclic usage: Drainage water in this method is alternatively replaced by fresh reservoir water. This method can be used when the drainage water salinity is higher that the threshold.

2.1.4 Intra seasonal approach: This method is similar with the direct method because in this method the drainage water is used directly for irrigation to plants with high salinity tolerance and the fresh reservoir water is used for other crops.

2.1.5 Seasonal approach: In this technique as a rotation the drainage water and reservoir dam water are used for irrigation. It should be noted that during the initial growth, dam water is used and after good plant establishment, drainage water may be used.

2.2 Proposed method for water reuse

In this project according to conditions and locations of the downstream lands, the water reuse volume, the assigned water from diversion dam, the water quality of the Ghareaghaj River and surface drainage water, the turning usage have been used.

3. ESTIMATION OF WATER REUSE

Water reuse may be estimated through observation and experimentation methods. Observations methods comprise run off measurement in experimental fields, farm drains, drainage systems, municipal wastewater and the rivers. Experimental methods are based on previous observations relying on the prevailing conditions of water delivery systems to the main and secondary networks, equipment, irrigation structures and networks that have achieved high irrigation efficiencies.

Considering the above explanations the predicted efficiencies of water transmission, distribution and application were, respectively, 95%, 80%, 66% with an overall efficiency of 50%.

In estimating the water reuse percentage it is worth noting that the amount of water reuse has varied among irrigation methods between 0 in drip irrigation and 50% in rice farms in different parts of the world. According to field studies in areas where groundwater is the source of irrigation, there has been no water reuse.

Because the total volume for surface irrigation from the reservoir dam is about 195 MCM per year, the water reuse research show the water reuse volume in year is about 40 MCM. The water reuse quality will be adjusted with the released flow from reservoir and in river route. Only

Laghar's water reuse quality will be not very good but according to networks implementation schedule, except early years, with utilization of all the irrigation networks it will be adjusted and this amount of water reuse will be for development of irrigation in downstream lands.

Table 2. Chemical analysis of Ghareagaj river and drainages (L'analyse chimique de la rivière Ghareagaj et drainages)

S.A.R	Na	Electerical Conductivity ds.m	PH	Total Hardness mg/l as CaCo3	T.D.S mg/l	Anion (meq/l)					Cation (meq/l)				Station
						Na +	MG ++	Ca ++	K +	Total	SO4-	HCO3-	CL-	Total	
4.37	51	1.792	7.8	425	1130	9	2.5	6	0.18	17.68	5.2	3.5	9	17.7	Tang karzin Station- ST1
3.83	47	1.543	7.6	400	988	7.25	4	4	0.13	15.38	5.5	3.6	6.4	15.5	
1.06	20	0.996	7.6	425	682	2.18	3.5	5	0.05	10.73	5.5	3	2.1	10.6	
2.39	37	1.317	7.9	405	837	4.8	4.1	4	0.1	13	5.75	2.7	4.7	13.15	
3.73	41	2.392	7.7	725	1543	10.05	6	8.5	0.2	24.75	8.25	5	11	24.25	Ghir&Karzin Plain& End of Fathabad Drain- ST2
3.92	41	2.49	8.2	775	1675	10.9	7.5	8	0.19	26.59	10.5	5.6	10.5	26.6	
4.27	43	2.573	7.8	750	1679	11.7	6	9	0.21	26.91	10	5.4	11	26.4	
3.75	41	2.353	7.9	750	1594	10.35	8.5	6.5	0.17	25.52	10	4.5	10.6	25.1	
3.53	39	2.25	7.7	725	1534	9.5	4	10.5	0.21	24.21	10	4	10.5	24.5	Ghareagaj River- Before Fathabad Drain- ST3
3.6	42	2	8.4	600	1320	8.75	5.5	6.5	0.17	20.92	7.25	4	9.1	20.35	
1.14	21	0.996	7.8	425	698	2.34	4.4	4.1	0.08	10.92	5.5	3.2	2.2	10.9	
2.48	38	1.346	7.9	425	887	5.18	4.6	3.9	0.09	13.77	6	2.7	5.25	13.95	
1.59	19	2.775	7.9	1100	1720	5.25	14	8	0.24	27.49	8.75	4	14.5	27.25	Ghareagaj River- Beginning of Afzar Plain-
3.94	42	2.573	8.3	725	1600	10.8	5	9.5	0.21	25.31	10	4	11.5	25.5	
1	19	1.079	7.8	450	721	2.12	5.4	3.6	0.14	11.28	5.5	3	2.8	11.3	
3.3	44	1.554	7.8	440	1011	6.9	3.8	5	0.12	15.82	6.75	2.8	6.25	15.8	
5.12	47	3.195	7.8	825	1978	14.7	8.5	8	0.31	31.51	13.75	4.1	13.5	31.35	Afzar Plain- End of Afzar Drain-ST5
4.7	45	3.012	8.4	825	1920	13.5	7.5	9	0.28	30.28	13.75	4.5	12.5	30.75	
8.14	38	9.96	7.8	4400	7856	54	66.5	21.5	1.02	143.02	90	5.9	32	127.9	
3.1	26	4.758	8	1900	3210	13.5	26	12	0.47	51.97	33	4.1	14.5	51.6	
4.16	40	3.112	7.9	975	831	13	10.5	9	0.27	32.77	12.25	3.7	16	31.95	
4.28	41	3.228	8.4	925	2001	13	10.5	8	0.26	31.78	12.5	3.8	15.5	31.8	Ghareaghaj River- Beginning of
1.02	19	1.162	8	485	731	2.2	5.8	3.5	0.09	11.59	5.5	2.9	3.1	11.5	
3.19	40	1.776	8.2	570	1200	7.5	6	5	0.14	18.64	8.75	2.8	7.37	18.92	
6.93	50	4.59	8	1200	2940	24	13	11	0.35	48.35	28	3.8	15	46.8	Ghareaghaj River-End of Laghar Plain- ST7
19.86	60	6.092	8.3	1225	3810	38	12	12.5	0.37	62.87	17.8	3.8	41.5	62.9	
2.79	34	2.324	7.9	740	1406	7.6	8.8	6	0.13	22.53	4.5	3.1	14.5	22.1	
10.82	64	4.773	8	875	3064	32	8.5	9	0.25	49.75	15	2.3	31.8	49.1	
39.44	77	24.975	7.9	3400	-	230	40	28	1.35	299.35	45	3.3	237.5	285.8	Laghar Plain- End of Takhte Drain-ST8
30.78	74	20.244	8.1	2875	-	165	32.5	25	1.2	223.7	22.5	3.2	192.5	218.2	
36.58	72	29.05	7.8	4750	19630	252	75	20	1.6	348.8	55	3.3	270	328.3	
40.17	78	22.2	7.8	3250	16466	229	40	25	1.2	295.2	58	2.1	212.5	272.6	

On the other hand it is important to note that in the estimated amount of water reuse the runoff from rainfall is not mentioned. In other words the runoff from rainfall is considered to improve environmental conditions for river.

Because the Laghar plain is the latest in this project, information show the amount of reused water in this plain is more than ever before. Reused water from all the plain will accumulate and distributed from the Laghar diversion dam to this plain's on-farm irrigation systems. But the Laghar's reused water quality is poorer, which is expected to improve during the irrigation system implementation. The schematic view, with quantified water accounting of the Ghareaghaj River is shown in Fig. 3. The comparisons of annual and month-wise reuse water in each of the plains are shown in Figs. 4 and 5, respectively.

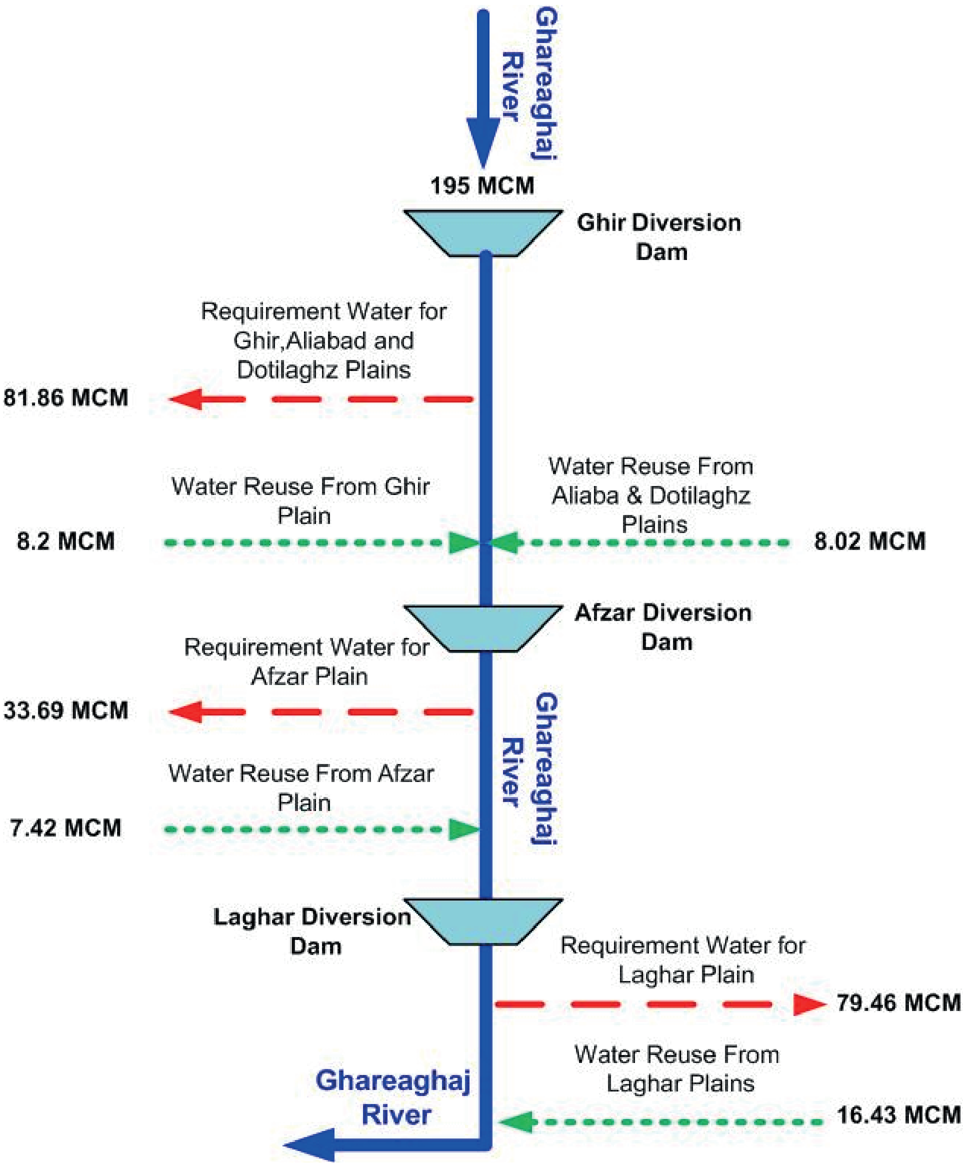

Fig. 3. Ghareaghaj River and amounts of water reuse in each plains (Ghareaghaj rivière et les montants de réutilisation de l'eau dans chaque plaines)

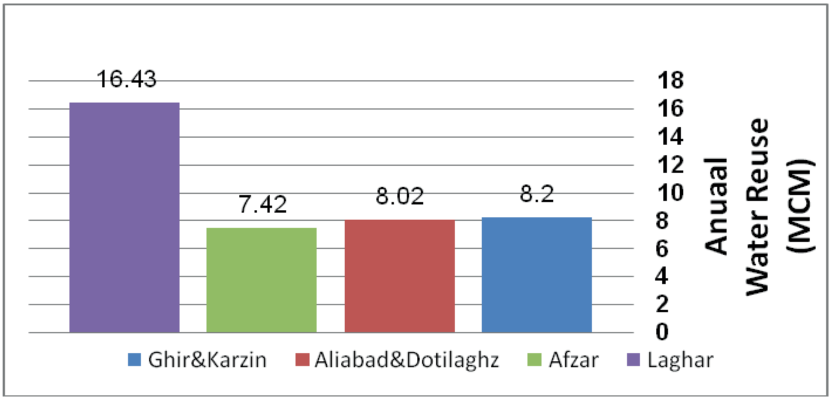

Fig. 4. Comparison the annual amount of water reuse in each plain (Comparer le montant de réutilisation de l'eau dans chaque plaines)

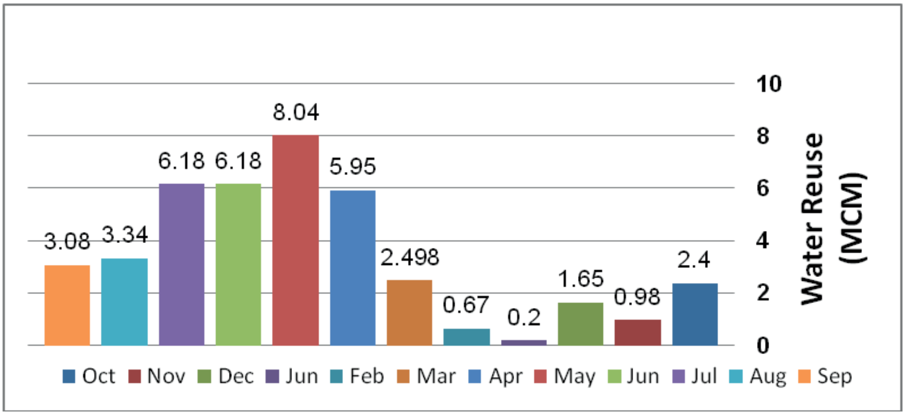

Fig. 5. Comparison the amount of water reuse in each month (Comparer le montant de la réutilisation de l'eau dans chaque mois)

3.1 Ghareaghaj river's water quality

Considering the SAR and EC of water samples in the first stage of studies (Statistics for chemical analysis of water samples – Tange Karzin station), they were transferred on Wilcox diagram, showing that Ghareaghaj water falls in class C3S2, C3S1. The RSC and pH indicate that the water of Ghareaghgaj River does not create any problem of alkalinity. The irrigation water does not have any restrictions in terms of changing soil permeability. According to the SAR values and sodium concentrations, Ghareaghaj River water is of medium to low level. According to ph and bicarbonate content, the water is of medium to low quality.

3.2 Channel salinity calculations

The water reuse quality will be adjusted with the released flow from reservoir and along the river route. Only Laghar's water quality will be not very good but according to networks implementation schedule, except early years, with utilization of all the irrigation networks it will improve and may be used for irrigation in downstream lands.

Plains such as Ghir, Ali Abad and Afzar, will be allocated about 23.64 MCM of drainage water. The salinity in Afzar and Laghar plains will be about 1.5 to 2.5 ds/m. Chemical analysis of water samples is presented in Table 2. Diagram of response to salinity for various plants is shown in Figure 6.

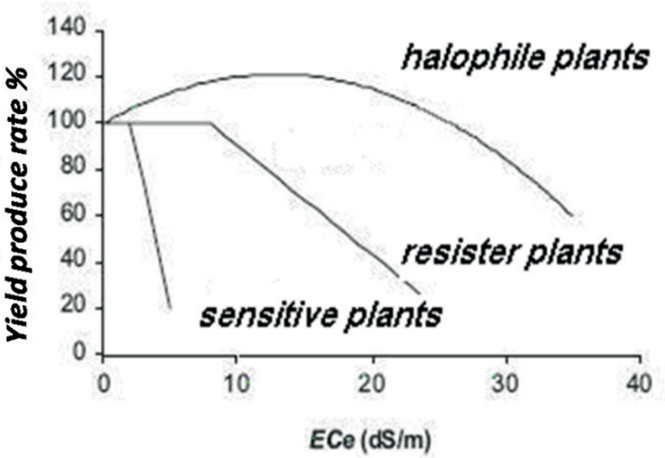

Fig. 6. Diagrams of response to salinity for various plants (Schémas de réponse à la salinité de différentes plantes)

Forage uses: The development and rehabilitation programs of meadows and pastures may be done in saline areas. These plants can be used as nutritional supplements for animals.
Other uses: These plants produce important economic products such as oil, gum, resins, adhesives, fiber, and paper pulp and etc. Also it is beneficial to use these for green spaces.

4. CONCLUSIONS AND RECOMMENDATIONS

Water reuse can have two important benefits. The most obvious is the provision of an alternative water resource. The second is the reduction of environmental impacts by reducing or eliminating wastewater disposal, which results in the preservation of water quality downstream. Therefore, the use of treated wastewater for irrigation means a positive contribution towards appropriate water resources management, particularly in arid and semi-arid regions. In addition to augmenting water resources, the use of reclaimed wastewater for irrigation can reduce the need for fertilizers, as the waste water contains some nutrients.

It is evident that the full implementation of on-farm irrigation and drainage network will promote leaching of salts from the soil profile and simultaneously through conjunctive use of drainage water and fresh water will reduce the problem of saline drainage water disposal. For the use of saline waters, halophyte plants suggested in FAO-61 can be grown. Adoption of this strategy in the project area could meet the water requirement of 2000 ha of lands. This resulted in earning benefits worth 3.3 million dollars from the project. The results of this research are useful and important to plan for increasing the potential utilization of soil and water resources, increasing agricultural production, improve living standards and ensuring social welfare.

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