AGRICULTURAL DEMAND MANAGEMENT OF KASHAF RUD CATCHMENT: ESTIMATION OF WATER SAVED AND PROJECT EXECUTION COST

GESTION DE LA DEMANDE AGRICOLE DU BASSIN VERSANT DE KASHAF RUD : EVALUATION DE L'EAU ECONOMISEE ET DU COUT D'EXECUTION DU PROJET

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ABSTRACT

Iran, with mean annual precipitation of 260 mm is counted as an arid country with limited amount of water resources. According to UN classification report, Iran shall not only experience stress and pressure situations due to shortage of water, but also shall encounter sever water scarcity.

One of the significant long-term strategic objectives of integrated water management in Iran is establishment of balance between water demand and supply at the lowest possible cost.

Most of the surface water resources of the Kashaf Rud basin are controlled or being used. Water levels in most of the groundwater aquifers have declined

Studies conducted in 2006-2007 within Kashafrud basin indicate that by application of water demand management schemes in agricultural sector in the basin area, such as pressure irrigation, modifying of cropping pattern, development of greenhouse cultivations, and proper reuse of municipal treatment plant sewage effluents, the current situation can be improved and also balance between water consumption and existing recourses can possibly be achieved in future.

Key words: *Kashafrud basin, Wastewater reuse, Water quality, Agriculture, Development alternatives.*

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RESUME

L'Iran est un pays aride avec une quantité limitée des ressources en eau, qui reçoit des précipitations annuelles moyennes de 260 mm. Selon le rapport de classification de l'ONU, l'Iran non seulement sera affrontée par les situations de stress hydrique et de pression dues à la pénurie d'eau, mais elle aussi fera face à la pénurie d'eau.

La création d'un équilibre entre la demande et la fourniture d'eau au meilleur coût possible est l'un des importants objectifs stratégiques à long terme de la gestion intégrée de l'eau du pays

La plupart des ressources en eau de surface du bassin Kashaf Rud est contrôlée ou utilisée. Les niveaux d'eau dans la plupart des aquifères ont diminué.

Les études menées en 2006-2007 au bassin de Kashafrud indiquent que par l'utilisation des régimes de la gestion de demande d'eau dans le secteur agricole du bassin, tels que l'irrigation sous pression, la modification des systèmes agricoles, le développement des cultures de serre, et la réutilisation appropriée des eaux traitées d'effluents municipaux, la situation actuelle peut être améliorée et il sera possible atteindre un équilibre entre la consommation d'eau et les recours existants.

Mots clés: *Bassin de Kashafrud, réutilisation des eaux traitées, qualité de l'eau, agriculture, alternatives du développement.*

1. INTRODUCTION

Kashafrud catchment basin is located northeast of Iran between 58°,18' to 61°,13' E longitude and 35°,38' to 37°,04' N latitude. The 16750 km^2 Kashafrud is regarded as the most important basin in Khorasan province, encompassing the Mashhad, Chenaran, Narimani, Sangbast and Aghdarband plains. Kashafrud River is the main drain in this basin. Around 1200 MCM of water is being used for agricultural purposes in this basin, out of which 1000 MCM is supplied through groundwater, and 200 MCM through surface water.

Table 1. Total water consumption by agriculture in Kashfrun basin

Plain	Water consumption (MCM)	Consumption percent	
		Groundwater	Surface water
Aghdarband	8	72	28
Narimani	126	91	9
Mashhad	1002	85	15
Sangbast	72	89	11
Total	1209	86	14

The Holy city of Mashhad located in the center of Kashafrud catchment basin and hosting about 20 million people each year also puts pressure on water resources. Statistical information

indicates that during 4 decades of 1966- 2006, the population in the basin has grown up 4.5 times and the extent of Mashhad municipality area has gone from 15, up to 160 km^2. The population of 3 million in 2006 is estimated to grow up to 6 million in 2041 and proportional to this population growth, municipal and industrial water demands shall rise up from 200 MCM in 2006, to something around 600 MCM in 2041. If the current trend continues, the water table will decline by 21% then. In these conditions only by implementation of demand management approaches, it could be possible to improve the current situation and achieve a balance between water consumption and existing resources in the basin. The agricultural sector is the main water consuming sector of all and according to the result of studies, about 80% of total water consumption is allocated to this sector. This issue makes it quite clear that studies of demand management in agricultural sector are considerably significant.

2. MATERIALS AND METHODS

For the purpose of achieving the mentioned objectives, the following actions are taken:

(i) collection of information and statistical data, reports, maps and drawings, etc.

(ii) Conducting interviews and sessions with local farmers

(iii) Review, and analysis of gathered data and deducting conclusions

All the costs are based on prices of 2006-2007. Considering the above issues, proposed approaches in the agricultural sector demand management are:

1. Using pressure irrigation methods

Based upon information obtained from agriculture jihad organization of Khorasan province, the total irrigation efficiency for sprinkler and drip irrigation systems are estimated 60-65 percent, and 80-90 percent respectively. Water use efficiency grows up by equipping and renovation of agricultural lands (14%), with implementing of lateral irrigation networks (10%), by water transmission pipeline (15%), via covering traditional streams (10%), and by pressure irrigation water usage efficiency increases by 40%.

Currently about 13000 hectares of Kashafrud catchment basin is under pressure irrigation system out of which 11000 is under drip, and 4000 is by sprinkle system. Considering that about 130,000 hectares of lands are under cultivation, only about 10% of it are under pressure irrigation. Following Table 1a shows the area under pressure irrigation divided into different cities located in Kashafrud basin.

Table 1a. Area under pressure irrigation (hectares)

City		Mashhad	Chenaran	Fariman	Total
Area under pressure irrigation	Implemented	6050	5000	2312	13392
	Under construction	305	886	144	1335

Based on studies carried out, extents of areas capable for pressure irrigation within Kashafrud catchment basin lands are determined. These studies used climatic conditions and analysis,

surface water and groundwater resources, land and soil resources, irrigation and agricultural reports, land classification maps, land use maps, soil resources evaluation maps, and maps of land slopes with the results shown in Table 1b. As observed in this Table, total area suitable for pressure irrigation in this basin is around 140,000 ha.

Table 1b. area suitable for pressure irrigation in Kashafrud catchment basin lands

Row	Study area	Gross area (hectares)
1	Mashhad, Chenaran	120533
2	Narimani	13643
3	Sangbast	5734
4	aghdarabad	2700
5	Total	142610

Thus, increasing the coverage area under pressure irrigation in Kashafrud catchment basin, is one of the main approaches towards increasing the water use efficiency and therefore decreasing the aquifer depletion speed.

About 7000 ha of gardens within region are irrigated by wells and around 18000 ha is allocated for production of summer crops and vegetables. Beetroot is cultivated in 5000 ha using the groundwater resources mainly. Considering the above, sprinkle irrigation system in this part of the lands is of higher priority. By changing the irrigation system in these lands, the area under pressure irrigation shall go up from 13000 ha at present up to 30000 ha. Accordingly, by execution of the plan the current irrigation efficiency of 40 - 45 per cent shall go up to around 85% (keeping the same area under cultivation) so that for each hectare about 7000 m^3 of water would be saved. Now considering the area under cultivation of around 17000 ha, and multiplying it by 7000, we get something about 120 MCM that is reduced from annual aquifer extraction.

Table 1c gives the summarized results of water conservation and the initial cost of execution of the plan.

Table 1c. Initial estimation of conservable water once pressure irrigation is implemented

Crops	Cultivation area	Water Consumption per ha (efficiency 40%)	Water Consumption per ha under pressure irrigation (efficiency 85%)	Total water saved (MCM)
Gardens under Groundwater	7000	10000	4700	37
Vegetables	10000	15000	7100	79
Watermelon	8000	11000	5150	47
Sugar beet	5000	18000	8770	48
Total	30000		211	

Table 1d. Initial cost estimation for Implementation of pressure irrigation (drip irrigation)

Total area under pressure irrigation (ha)	Implementation costs (million Rials)	Total Implementation costs (interest rate 7%) (billion Rials)	Equivalent annual costs during 10 years (interest rate 7%) (billion Rials)	Cost of 1m³ conservation water (Rials)
17000	50	1250	178	1500

2. Using unconventional water

During recent decades extensive groundwater withdrawal has taken place to meet the growing water demand. As a result, the water table has declined considerably. In these conditions, using unconventional water such as wastewater treatment plant outflows in agricultural sector becomes quite significant. Like in many countries in the world, in Iran also, application of the sewage treatment plant effluents in agriculture has become more and more important and common, and is considered as the prioritized issues in water resources management plans. Presently, around 72 MCM annual effluents is produced in wastewater treatment plants (Owlang, Pakandabad, and industrial towns). Table 2.a displays sewage effluents produced by each of the municipal and industrial sewage treatment plants within the basin and total volume at present time.

Table 2a. Treatment plants effluent production within the basin area

Treatment plant	Daily	Annual
	m³/day	m³/day
Olang Mashhad	10,000	3,650,000
ParkandAbad 1	17,828	6,507,220
ParkandAbad 2	43,890	16,019,850
Kalat industial town	14,478	539,470
ChrmShahr industial town	1,401	511,365
Total	74,597	27,227,905

It is estimated that the effluent volume may reach 372 MCM annually, out of which 95% will be from the study area between Mashhad and Chenaran. This amount of effluent corresponds to a flow rate of 12 m³/sec, which can be used for irrigation of around 15000 ha of farmlands. During two months of Jan and Feb when water demand of farmland decrease, this effluent can be used for artificial recharge of groundwater aquifers, or irrigation of forest parks outside the city.

Table 2b gives the effluent produced in Kashafrud basin for target year of 2041, and initial cost estimates for implementation of this plan.

Table 2b. Effluent produced in Kashafrud basin for target year of 2041, and initial cost estimates for treatment plants

Sewage production in target year 2041 in m^3/s	Implementation costs in billion Rials	Cost of 1 m^3 sewage treatment in Rials (2006 price level)
12000	390	1050

3. Cultivation pattern modification

One of the demand management approaches in agriculture sector is modification of cultivation pattern with the objective of optimizing the water resources utilization and cultivation of crops or plants having the highest efficiencies for water consumption. Table 3a shows the current cultivation pattern in Kashafrud basin farmlands.

Table 3a. Current cultivation pattern in Kashafrud catchment basin

Row	Crops	Cultivation area (ha)	Percent
1	Cereal	71270	52.3
2	Industrial crops(beetroot)	7300	5.4
3	Vegetables	10300	7.6
4	Summer crops	8600	6.3
5	Forage	8600	6.3
6	Gardens	28000	20.6
7	Other crops	2000	1.5
8	Total	136000	100

Suitable cropping pattern for this basin was selected by considering climate, soil, water quality, local choice, economic viability, etc., using Lingo software. The highest income per unit volume of water consumption was from saffron amongst the existing agricultural products. Another product cultivated in recent years is pistachio nuts. The top 4 priorities from the point of view of high incomes per unit volume water consumption and in that order are saffron, summer crops like melons, forages, and fruits. Therefore it is recommended to reduce beetroot share of land.

Considering the arid and cold climate of the region, priority shall be given to those crops that are heat and sunshine tolerant, and resistant to aridity, such as “sorghum” or crops with high water use efficiencies like corn (due to circulation C4). Therefore increasing land allocation to corn and sorghum is recommended. Also to take the advantage of rainfall and river flow, cultivation of autumn cereals is to be taken into account. Considering all the above issues, the initial proposal of cropping pattern for the Kashafrud basin farmlands is recommended as it is shown in table 3b. As can be observed in this table, water demand of one hectare farmland with the recommended cultivation pattern, has reduced by 1000 m^3. Considering the area under cultivation in this basin which is around 130,000 hectares, it means that

by modifying of the cultivation pattern in this basin something about 130 MCM of water conservation is achievable.

Table 3b. Initial recommended cultivation pattern for Kashafrud catchment basin

Cropping group	Crop	Proposal	Current pattern%
Cereals	Wheat	40	33
	Barley	20	22
Industrial crops	Cotton	2	4.3
	Beetroot	2	4.4
	Colza	1	0.1
vegetables	Potato	1	2
	Tomato	2	2.5
Summer crops	Melon/watermelon	8	11.2
Forage/fodder	Alfalfa	1	3.4
	Sorghum	2	0.1
	Corn	2	1
Gardening	Apple	11	11
	Pistachio	3	0.5
	Saffron	3	2
Other	Other crops	2	2.3
Net income per hectares in million Rials		11.6	11.7
Gross water demands per hectares in m^3		11500	12.700
Water income per m^3 in Rials		1020	916

Considering that some parts of groundwater resources of Kashafrud basin like Mashhad, Chenaran, Sangbast and Narimani, contain brackish and saline water with high ECs of greater than 3 dS/m, crops resistant to salinity may be selected for such regions to increase the efficiencies in using water resources. The main crops resistant against salinity within the study region are wheat, barley, beetroot, cotton and pistachio nuts.

4. Development of greenhouse cropping

Greenhouse cultivation is one of the main approaches to be taken for increasing the benefit to cost ratio of water resources utilization in arid and semiarid regions. Presently, about 200 hectares of farmlands are allocated to greenhouse cropping including tomato, cucumber, and decorating flowers in the Kashafrud basin. Table 4a gives area under cultivation of greenhouse cropping divided into different cities within the Kashafrud basin.

Table 4a. Area under greenhouse cropping in different cities in Kashafrud basin (ha)

City	Mashhad	Fariman	Chenaran	Ghoochan
Vegetables	48	5	70	0.7
Flowers	54	1	25	0.5

Reference: Khorasan Agricultural Jihad

In some regions greenhouse crops are raised in hydroponics. Studies have shown that the production of some crops like tomato is 10-15 kg/m^3 of water in greenhouse cultivation whereas in normal cultivation, the yield is 3-5 kg/m^3 of water. Therefore greenhouse irrigation development in the region has been considered as an important matter. It is possible to allocate about 7000 ha of the Kashafrud basin farmlands to cultivation for production of summer crops and vegetables. This is equivalent to 850 ha of greenhouse cropping.

Table 4b displays the initial cost estimates for land areas, executional cost, and cost of water supply for greenhouse cropping within the current plan conditions. As observed in this table, total cost of construction of 850 ha of greenhouse for 10 year period and interest rate of 4%, is 4740 billion Rials. Due to high costs of construction of greenhouses, it is suggested that this plan is executed over a 10 year period. Table 4c shows the initial estimate of water conservation by adopting greenhouse cultivation in the development plan. This would save around 80 MCM of water annually.

Table 4b. Initial estimation of land area and costs for greenhouse development project

Income from 1 m^3 of water use in GH (Rials)	Cost to supply 1 m^3 of water (Rials)	Annual fixed costs during 10years (@ 4%) (billion rials)	Total fixed cost during 10years (@ 4%) (billion rials)	Fixed cost/m^2 of land area (Rials)	Equivalent GH land area (Assumed yield in GH: 200 t/ha (ha)	Total yield (ton)	Area under suitable crops for GH (ha)	Cultivation area under GH (ha)
1000	7740	631	4740	380000	850	210000	7000	200

GH: Green house

Table 4c. Initial estimating of saved water due to greenhouse cropping

Total saved water due to completed projects (MCM)	Annual saved water in 10 years (MCM)	Current total water consumed in GH (MCM)	Average annual water consumed in GH (m^3/ha)	Equivalent GH area (Assumed yield in GH: 200 t/ha (ha)	Total water consumption in land area (MCM)	Average water use in land area (m^3/ha)	Area under crops suitable for GH (tomato cucumber) (ha)
81	8	24	22440	1050	105	15000	7000

GH: Green house

3. CONCLUSIONS

Considering the above mentioned issues, summarized results in regard to possible water conservation and initial costs of execution of recommended plans for each of the demand management approaches are given in Table 5a. Since any innovation initially is looked at with suspicion by the farmers, switching over to new cropping pattern and green house technology should proceed with low speed. Besides, the modification of cultivation pattern should be given a lower priority.

Table 5a. Initial estimate of water saved and execution costs of proposed works in KRB

Description	Saved water on project completion (MCM)	Implementation costs (billion Rials)	Value of 1 m^3 of saved water (Rials)
Implementation of pressure irrigation systems	120	1250	1500
Development of greenhouse	80	4020	5850
Use of wastewater	150	3090	1050
Correction of cultivation pattern	130	-	-
Total	480	5660	

KRB: Kashaf Rud Basin
Wastewater in year 2041 is 12000 lit/sec. 150 MCM use in cultivation season

Achievement of any of the objectives mentioned for demand management will require at least a time period of 30 years (target year of 2041), and this is an important factor that is to be considered by responsible authorities. Execution of each of the above plans, along with application of other management methods in agriculture including establishment of water cooperative communities, integrated water resources management, water pricing for irrigation, leveling and integrating the farmlands and on-field soil management can speed up the achievements in the above mentioned objectives.

It is predicted that potable and industrial sectors water demand within Kashafrud basin shall increase by 400 MCM per annum in target year of 2041. Regarding the 160 MCM reservoirs deficits in the basin, the total water demand in the basin shall be 560 MCM annually. Around 100 MCM shall be supplied through Doosti Dam constructed a few years ago and 30 MCM by transmission from neighboring basins. Therefore total water demand increase in Kashafrud catchment basin is estimated 430 MCM in target year of 2041. It is expected that the consumption and demand for water will reach equilibrium by the target year 2041.

Table 5b. Prediction of available water, water requirement and cultivation area in Kashaf Rud Basin (2006 – 2041)

plain	available water (mcm)							water requlrement per har with deficit irrgation 20% (m3)							cultivation area (ha)						
	Year							Year							Year						
	2006	2012	2018	2024	2030	2036	2041	2006	2012	2018	2024	2030	2036	2041	2006	2012	2018	2024	2030	2036	2041
Aghdarband	7	12.5	12.4	12.4	12.4	12.3	12	7871	7926	7206	6605	6097	5662	5284	1320	1571	1723	1875	2026	2176	2325
Mashhad	954	915	875.0	834.6	796.5	756.0	716	9100	7934	7427	6982	6464	6019	5630	117800	115392	117812	119537	123209	125613	127090
Narimani	119	109	108.9	108.7	108.4	108.1	108	10670	7274	6597	6036	5562	5158	4808	16420	15014	16513	18005	19489	20966	22436
sangbast	72	49	48.4	47.9	47.3	46.7	46	13470	11226	10206	9355	8636	8019	7484	5900	4367	4747	5116	5475	5823	6161

Considering the above issues, changes to be applied to areas under cultivation, water demand of farmlands and amount of available water for agricultural sector for each of the plains of Kashafrud catchment basin in target year of 2041 shall be as given in Table 5b.

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