# WATER PRODUCTIVITY OF IRRIGATED WHEAT IN THE MAROON IRRIGATION NETWORK OF IRAN

# PRODUCTIVITE DE L'EAU DE BLE IRRIGUE DANS LE RESEAU D'IRRIGATION DE MAROON EN IRAN

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## ABSTRACT

*The rapidly growing population and the trend of economic development in different sectors have caused an increasing demand for water. This demand, coupled with limited water resources in Iran are the reasons for searching ways and means to enhance water productivity, particularly in agriculture. Behbahan (Maroon Irrigation Network) district, which is located in Khuzestan province and belongs to an arid to semi-arid region in Iran, regularly faces widespread drought. Water scarcity in the region enforce famers to use water supply as efficiently and as productively as possible. One of the most water consuming sectors in the region is the irrigated agriculture. Therefore, improving the productivity of existing water resources is the most attractive option to produce more food for the increasing population. Water productivity of irrigated wheat in Maroon is analyzed in this paper. A total of 125 farmers from north and south of Maroon network were selected using stratified random sampling method. Data were collected through surveying by using questionnaire and interview. Data were analyzed with statistical package for social sciences named SPSS16. The results showed that most of the farmers in the region were in the middle ages and with low level literacy. Based on the results, water in Behbahan region is considered as service commodity rather than economically high value commodity. Due to high water consumption, the CPD index in comparison with similar regions was much lower from the average, as the average of CPD index in 2007 and 2008 was 0.48 and 0.41kg/m$^3$ respectively.*

**Key words:** *Irrigated wheat, Maroon Irrigation network, crop water productivité, Behbahan region, economic profitability*

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# *RESUME*

*La croissance de la population et la tendance du développement économique des différents secteurs ont donné lieu à la croissance de la demande en eau. Cette demande, accompagnée de la disponibilité limitée des ressources en eau en Iran sont les raisons de rechercher les moyens pour amliorer la productivité de l'eau, particulièrement du sector agricole. La région de Behbahan (Réseau d'irrigation de Maroon) située dans la province de Khuzestan (région aride et semi-aride de l'Iran) est affrontée par la sécheresse. La pénurie d'eau de la région oblige les fermiers à utiliser autant que possible l'eau de manière efficiente. La bonne part d'eau est utilisée par le secteur d'agriculture irriguée.*

*Donc, l'amélioration de la productivité des ressources en eau existantes est une option plus viable pour produire plus de nourriture pour la population croissante. Cette étude est menée pour examiner la productivité de l'eau de blé irrigué à Maroon. Un total de 125 fermiers ont été retenus au nord et au sud du réseau Maroon utilisant la méthode d'échantillonnage randomisée stratifiée. Les données ont été recueillies en utilisant la méthode de questionnaire et d'entretien. Les données ont été analysées par SPSS16, méthode statistique des sciences sociales Les résultats ont montré que la bonne part des fermiers d'âge moyen, n'étaient pas assez éduqués pour pouvoir comprendre la technologie. L'eau est considérée comme étant un bien commun destiné aux services plutôt qu'économique. En raison de la haute consommation, l'index de CPD était bas par rapport aux régions similaires, la moyenne d'index de CPD en 2007 et 2008 était de 0,48 et 0,41kg/m$^3$ respectivement.*


**Mots clés:** *Blé irrigué, Réseau d'irrigation Maroon, productivité de l'eau agricole, région de Behbahan, rentabilité économique*

# 1. INTRODUCTION

Limitation in Iran's water resources, fast growing population, water demand by the other developing sectors and the country's dependence on agriculture, imply the necessity to improve water consumption efficiency.

Water scarcity threatens food security for millions of people, particularly in the arid and semi-arid regions. In dry-land environments due to high temperature, wind and low humidity, water shortage is a major problem. Much of the water that is available to people living in dry-land regions flows in large rivers that originates in areas of higher elevation. Groundwater resources can also be available to foster development process, but relatively limited recharge of groundwater resources is dependent largely on the amount, duration and intensity of rainfall as well as soil properties (Dastorani, et al. 2008).

Behbahan (Maroon network) district is located in an arid to semi-arid region in Iran and regularly faces widespread drought. Given current water scarcity, the limited available water should be used as efficiently and productively as possible. Irrigated agriculture is the largest water-consuming sector and it faces competing demands from the industrial and the domestic sectors (Zwart and Bastiaanssen, 2004). Irrigated agriculture makes a major contribution to food security, producing nearly 40% of food and agricultural commodities on 17% of agricultural land. Irrigated areas have almost doubled in the recent decades and contributed much to the growth in agricultural productivity over the last 50 years. Irrigated agriculture uses more than 70% of the water withdrawn from the earth's rivers; in developing countries the proportion exceeds 80%. Food production via irrigated agriculture, however, does not correspond to the current rapid population growth (Albaji, et al. 2009). With an increasing population and less water available for agricultural production, the food security for future generations is at risk (Zwart and Bastiaanssen, 2004). The agricultural sector faces the challenge to produce more food with less water by improving Crop Water Productivity (CWP).

The concept of CWP has remained a subject of interest to plant, soil and irrigation scientists for almost 100 years now (Igbadun et al., 2006). Crop water productivity (CWP) is a quantitative term used to define the relationship between crop produced and the amount of water involved in crop production. It is a useful indicator for quantifying the impact of irrigation scheduling decisions with regard to water management ( Bastiaanssen et al., 2003).

In this state, CWP is important for the following reasons:

1. To meet the rising demand for food from a growing, wealthier, and increasingly urbanized population.
2. To respond to pressures to reallocate water from agriculture to cities and to ensure that water is available for environmental uses.
3. To contribute to poverty reduction and economic growth. For the rural poor more productive use of water can mean better nutrition for families, more income, productive employment, and greater equity. Targeting high water productivity can reduce investment costs by reducing the amount of water that has to be withdrawn ( Molden and Oweis, 2007 ).

Also, improving crop water productivity (CWP), is one important strategy for addressing future water scarcity which is driven particularly by potential changes in climate and land use (Rijsberman, 2001; Molden et al,. 2001). The adoption of techniques to improve water productivity requires an enabling policy and institutional environment that aligns the incentives of producers, resource managers, and society and provides a mechanism for dealing with tradeoffs (Molden and Oweis, 2007). However, it is clear that CWP improvement is a critical condition for sustained human development (Mdemua et al., 2009).

Maximum crop water productivity often does not coincide with farmers' interests as their objective is to maximize land productivity or economic profitability. Therefore attaining higher yields with increased water productivity is only economical when the increased gains in crop yields are not offset by increased input costs) Oweis et al., 1998.).

The globally used phrase: "more crops per drop", implies a water revolution, which is more difficult to achieve than green revolution. With regard to this condition, improvement of water resource efficiency is an important key for economical and social development of societies, especially in developing countries where agriculture is the major vocation of most of the people (Keshavarz 2005). Thus, in terms of agriculture inputs like water that faces with serious limitations, it seems that the water consumption patterns have to viewed technically, managerially, agriculturally and legally for finding a solution of the water scarcity problem. In a predominantly agriculture-dependent country, all efforts must focus on improvement of agriculture efficiency in order to prepare the world to face the rapidly growing food demand of growing population (Sanar 2001). With regard to importance of water in agriculture, it can simply be judged that most of irrigation water in farms gets out of farmers hand, as irrigation efficiency in Iran is between 33 to 37% (Keshavarz, 2005). Efficiency of Marron irrigation network is about 25%. With regard to the water scarcity problem, the Marron irrigation network has faced too many limitations (designated water from from Marron Company was about 247 million cubic meter and harvested water in 2007 and 2008 were 298 and 118 million cubic meters, respectively).

Therefore productivity growth for answering to future demand is only reachable by improvement of water harvest efficiency. In this study, index of agriculture water productivity for wheat from a farmer's view point was surveyed. To access to proper result, studies of other researcher including Montazery and Kosari (2007), Qureshi (2009), Afshar (2004), Sarwar and Perry 2002, were studied. Other studies based on measurements of water by amount of evaporation and transpiration method is presented in Table 1.

Table 1. Index of agriculture water productivity for wheat

| Water productivity Kg/m$^3$ | Author | Area | Methodology |
|---|---|---|---|
| 9/1-6/0 | Musick & Porter. (1990) | Texas | /ETYg |
| 63/0 | Zwart and Bastiaanssen, (2004) | World | /ETYg |
| 36/1Error! Reference source not found. | Hussain, et al. (2003) | Haryana | /ETYg |

# 2. THE STUDY AREA

Behbahan township is located in Khuzestan province, at a distance of 210 km from Ahvaz, which lies at the center of. The altitude of Behbahan is 370 meter amsl. The climate is hot and dry with long and hot summer. Most of rainfall occurs between November and March. Freezing situation is seldom reported and for a very short period. Average temperature is 23.7$^0$C and the annual evaporation is 2900 mm. The 15000 ha of irrigated lands around Behbahan township has an old background. Maroon dam on the Maroon River provides water of maroon network. Maroon dam which is located in north east of Behbahan Township is 175 meter height with a reservoir storage capacity of 1.2 billion cubic meter. Almost 79% of its water is transported to farms by gravity. Marron network is divided into two parts: north and south. The agricultural fields at the north and south of network are 6500 and 7000 hectares, respectively. Totally there are 182 fields in the network and area of each field is between 1.6 to 9.7 hectares. Marron River carries 50m$^3$s$^{-1}$ flow, and finally reaches Shadegan lake. Maroon network covers more than 20 villages with a total inhabitant of more than 2500 families.

Groundwater resource of the region is not of good quality according to the data of Behbahan water organization. There are 392 wells in Behbahan region and 32 of them are out of service. Also availability of surface water from the Maroon irrigation network limits the use of deep and semi-deep wells. According to the collected information, 29.14 million cubic meter of water which is exploited from this shafts and 73% of this water used in agriculture, 21% in industries and 6% in domestic activities. Minimum and maximum flow of region’s wells is 44 and 789 m$^3$ per day, respectively. Average flow of region’s wells is about 445 m$^3$ per day (Khuzestan,2010).


Fig. 1. Location of Maroon network

The most important factor in losing water in the Maroon system is low efficiency of irrigation due to traditional style of irrigation like flood system in all sections. There is no workshop or training class organized for the farmers on methods of irrigation and water management. Satisfaction from agriculture activities and tendency to continue these activities among farmers was high but most of them believe that the main reason to pursue farming is that they don't have any other choice.

Increasing level of wheat production from 2200 kg ha-1 in 1984 to 3900 kg ha-1in 2007 in the region was as a result of land leveling, using new equipments, construction of drainage system and using chemical fertilizer. Yet, the productivity of wheat is lower than other parts of Iran whereas amount of applied water in the fields were 2 times more than the crop need. Thus, it is not surprising that the water use efficiency of wheat in the field is 0.5kgm-3, which is very low.

# 3. DATA COLLECTION AND METHODOLOGY

Information from Jahad Keshavarzi organization in Behbahan region and the Maroon water company were collected for the two years: 2007 and 2008 and were analysed. Classified sampling method was used in this research. In addition 125 farmers from south and north of Maroon network were selected to get information on the amount of fertilizer and water consumption per hectare and use of wells, through questionnaire interview and survey. The water consumption per hectare, which was measured by some farmers, were collected in order to compare these data with applied water rate. Amount of water used per hectare in 2007 were assessed by FAO 56 method and then it was compared with needed water per hectare for wheat production in 2007. SPSS16 software was used to analysis data. By means of first and second information, the physical and economical efficiency of irrigated wheat in the Maroon network were calculated.

In this research the index of physical efficiency of agricultural water is CPD (crop per drop), as defined below. A higher index value implies a better use of water.

$$CPD_{(AWI)} = \frac{\text{Yield}}{\text{Applied irrigation water}} \quad (kg / m^3)$$

(Ref:Molden, 1998; Sakthivadivel, 1999; Tuong, 2000 and Van Dam, 2003)

NBPP is the index of assessing economical-physical efficiency of agriculture water. The relation given below was used to assess this index.

$$NBPP = \frac{\text{Added value of production}}{\text{Applied Irrigation water}} \quad \$/m^3$$

Ref: (Molden, 1998; Sakthivadivel, 1999 and Tuong, 2000)

Gross value of production=yield*product's prices
Net value of production= Gross value of production-total cost of production
Added value of production=Net value of production + cost of labor

# 4. RESULTS AND DICUSSION

## DESCRIPTIVE STATISTIC

According to the collected information, most of the farmers were between 30 to 50 years old and their average age was 47 years. In terms of level of farmer education in villages of researched region, 12% are illiterate, 22.4% have passed primary education, 20.8% have passed guidance school, 8% were in high school level, 26.4% have got diploma and 8.8% had bachelor grade.

## DEDUCTION STATISTICS

### CROP YIELD

Information of 2008 and 2009 showed that cultivated fields smaller than 5 ha, between 5 to 10 ha, between 10 to 20 ha and larger than 20 ha were 24.3%, 42.1%, 20.7% and 2.1%, respectively. Also 50.4% of farmers used between 250 -300 kg ha-1 seed, 31.2% more than 300kgha-1 and 7.2% less than 250kgha-1. Field studies showed that competitiveness in rural regions, especially at the north of the network have caused more land to be cultivated. Distrust to managerial measures and lack of appropriate programming by Jahad Keshavarzi resulted all of farmers insuring their fields. On the other side Maroon Company as a result of water scarcity only supplied 25% of farmer's land and imposed penalty to those farmers who had cultivated extra lands. But the hope to receive good annual rainfall have caused farmers to cultivate all of their lands in order to keep their land insurance. These problems have resulted in decreasing crop yield and intensifying water scarcity. Average wheat yield in north and south of Maroon network is shown in Table 2. Average yield in 2007 and 2008 were 4700 and 2000 kgha-1, respectively. Yields in the south of the network were lower than north. Besides, competitiveness in south was less than north lands due to the fact that in north of network lands are common and farmer use more fertilizer in order to increase their production, especially in 2 recent years with notice of water shortage farmers used more fertilizer. For example in one period they used 11 bags (each bag is 50 kg) from each kind of fertilizer. While private lands in south of network were not fertilized too much. Also, the soil quality in north of network was better.

Table 2. Average wheat yields in irrigated areas of the Maroon's network

| Areas | Average wheat yield (kg $ha^{-1}$) | |
|---|---|---|
| | 2009-2008 | 2008-2007 |
| 2500 | 5000 | North |
| 1500 | 4400 | South |
| 2000 | 4700 | Maroon |

Ref: Research findings

Other studies have showed that yield of wheat had significant relation with the amount of fertilizer consumption (Table 3(. Yield had direct but weak relation with K- and P- fertilizers at 99% confidence level. Also it had weak and indirect relation whit $NO_3$ fertilizer at 99% confidence level. Negative relation of yield and $NO_3$ fertilizer is the result of dynamic behavior of nitrogen. Consumption of nitrogen more than need had more negative effect. In maroon network in one cultivation period more than 400 kg of nitrate fertilizer were used.

Table3. Pearson correlation between wheat yield and fertilizer used.

| Fertilizers | P | K | N |
|---|---|---|---|
| Yield of wheat | 231/0* | 337/0** | -0/372** |
| Significance level 95%* | Significance level 99%** | | |

Ref: Research findings

## APPLIED WATER FOR IRRIGATION

The average of applied water in 2007 and 2008 were 9700 And 4700 $m^3ha^{-1}$, respectively. According to a National Document prepared by power ministry, the amount of water needed for wheat in Behbahan region is 8300 $m^3ha^{-1}$. According to FAO 56 method, value of applied water was 6381 $m^3ha^{-1}$. Thus, there is a significant difference between these two values. In 2008 the water used was lower than both the values due to drought.

Many experts believe that the estimation in the national document is erroneous, as it did not consider all the aspect of water need of plant. Unfortunately, still the National Document is used as reference in this area. Average of applied for wheat in Maroon network is given in Table 4.

Table 4 . Irrigation water applied to wheat ($m^3$ $ha^{-1}$) in the Maroon

| Areas | Average of water applied to wheat ($m^3$) | |
|---|---|---|
| | 2009-2008 | 2008-2007 |
| 4948 | 9850 | North |
| 4530 | 9600 | South |
| 4700 | 9700 | Maroon |

Ref: Research findings

## Analysis of table 4 according field study

In Maroon network management plan and actual schedule of irrigation differ because sometime Jahad Keshavarzi allow farmers to cultivate their fields but Maroon Company is not ready to release the demanded water at a particular time. This is a major problem and is much different than the earlier situation when the farmers had demand-based access to water. This has deterred the farmers to have any special plan for improving their irrigation system. They follow traditional style of cultivation according their knowledge and they do not refer to supervisor engineers. Most of the farmers make decision depending on amount and time of access to water; while, there is difference between applied water and the wheat water need. While most of the farmers believe that there is a relation between water used and wheat yield, only 17 per cent of them believe that water application should be according to a specific schedule.

The survey data were used to develop the relationship between irrigation water applied and yields for wheat, and the results are presented in Figure 2. The relation is not straightforward, as it is often assumed by the farmers. The $R^2$ values of the relations in the two indicated years are low for this crop, implying effects of non-monitored co-variables on wheat yield. This nevertheless shows that there is a great need for farmers to shift their thinking from maximizing crop production through excessive water use to optimizing crop production with minimum irrigation supplies, deficit irrigation and water harvesting. This result is consistent with the findings of Qureshi, et al., (2009) and Dehghanisanij, et al., (2009).

According to existing evidence and information gained from some progressive farmers in Behbahan zone, in the 2009 planting year, there was no planned programme for releasing irrigation water for different crops and irrigation intervals had also varied as compared to the previous years. Most wheat fields were damaged either due to dry climate or due to excessively wet fields in that year.

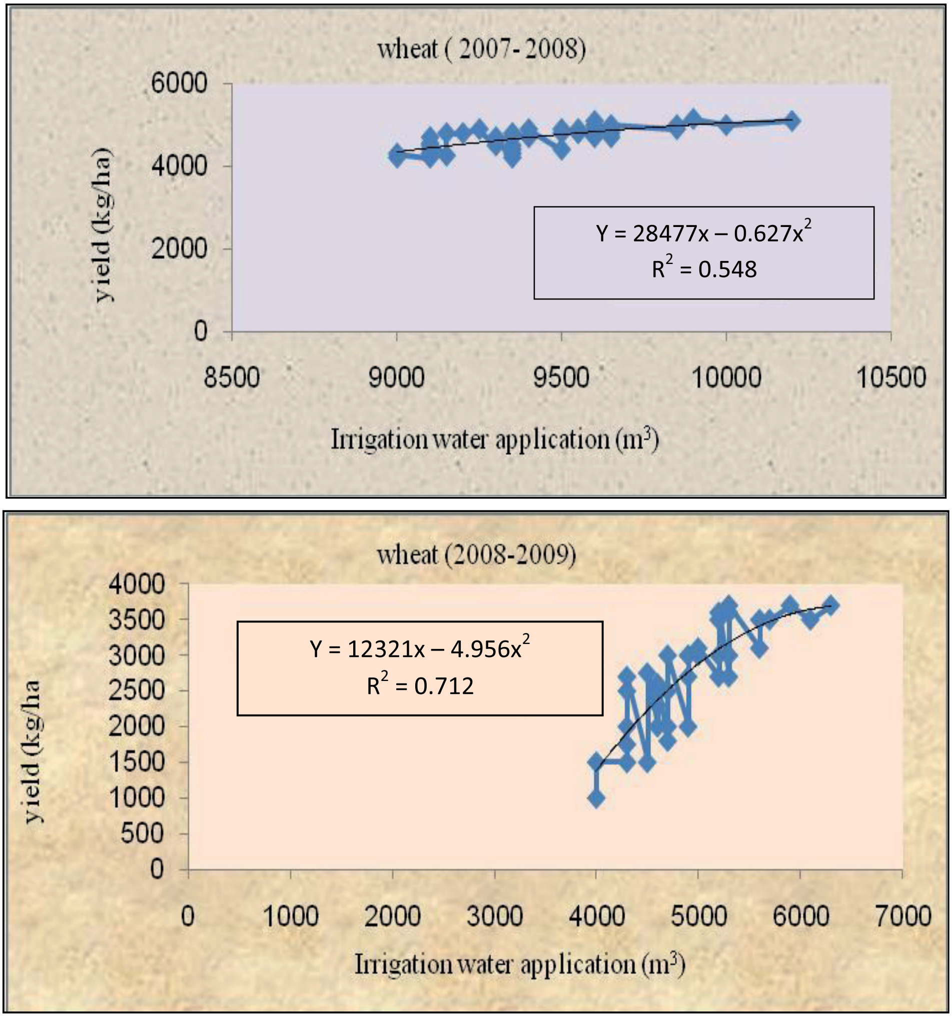


Fig. 2. Relationship between yield and irrigation water applied for wheat

## WATER PRODUCTIVITY

Table 5 shows the physical and economical productivity of wheat in Maroon Network. Average CPD index in years 2007 and 2008 was 0.48 and 0.41 kg/m$^3$, respectively. The results suggest that CPD index had slight variations, mostly related to yield reduction, not the reduction of applied water. The index in Maroon Network was much lower than at other places in Iran. According to Montazar and Kowsari (2007), the average wheat productivity index in Iran had been 1.62 kg/m$^3$. Other study on Karkhe zone estimated wheat productivity index 1 kg/m$^3$ (Qureshi, et al, 2009). Afshar (2004) calculated 1.32 kg/m$^3$ for wheat physical productivity in Mashhad region.

Sarwar and Perry (2002) reported that water productivity of wheat under limited irrigation conditions had risen to 1.46 kg/m$^3$ in Punjab, Pakistan. Comparison of wheat water productivity values of different regions in Iran indicated that variations in Iran are similar to the the other places in the world. Highest productivity index is reached provided that cultivation operational and management systems are fully developed. The lowest index in Iran has been caused by traditional cultivation and the absence of efficient management and appropriate irrigation systems. However, many parameters such as water, soil, climatic conditions, management and operational factors and agricultural inputs have also been influential. Finally, main reason for low CPD index in Maroon Network is high water usage in farms of this region, compared with other regions of Iran.

Table 5. Physical and economic productivity of water for Maroon network

| Areas | (8-2007) CDP (kg/m³) | (9-2008) PDC (kg/m³) | NBPP (2007-8) m³/$ | (9-2008) NBPP m³/$ |
|---|---|---|---|---|
| North | 0.52 | 0.5 | 583 | 464 |
| South | 0.46 | 0.33 | 597 | 507 |
| Network | 0.48 | 0.41 | 592 | 489 |

Ref: Research findings

From the economic point of view, efficiency of agricultural water means realizing more net value per unit of water volume (NBPP). Hence, in order to increase efficiency of water consumption in agriculture, it is appropriate to use this method for measuring agricultural water efficiency. According to the definition, each crop that could be produced more with less water is better for cultivation. It is important that when this index is interpreted, issues like job safety, flexibility of the operational rules of the water organizations, economic value of the crop and its by-products, etc., are to be considered.

# 5. SUMMARY OF THE RESULTS

1. Most of farmers in the region are in their middle ages and have low level of literacy.
2. Lack of suitable exploitation system in the region and problems of smallholder ownership system in extended area in Maroon network is considerable.
3. Farmers in the region are not aware about actual needs of each crop; consequently, they try to irrigate their farm more than the crop need.
4. Water in the region is considered as a service good rather than an economic good, obscuring its real value.
5. There is a significant difference between Maroon network and other places in Iran in terms of water application, yield of wheat and index of wheat efficiency. Farmers in this region consider product promotion as highly related to the amount of water used and ignore other effective factors in wheat production. Therefore, as a result of changing in the weather condition and the amount of rain, wheat production range varies greatly.
6. Index of NBPD in comparison with the other regions, is placed in suitable condition which means variation of efficiency index is influenced by amount of production rather than applied water.
7. On the basis of this study, the problems faced by agriculture in the Behbahan region is presented in Figure 3.

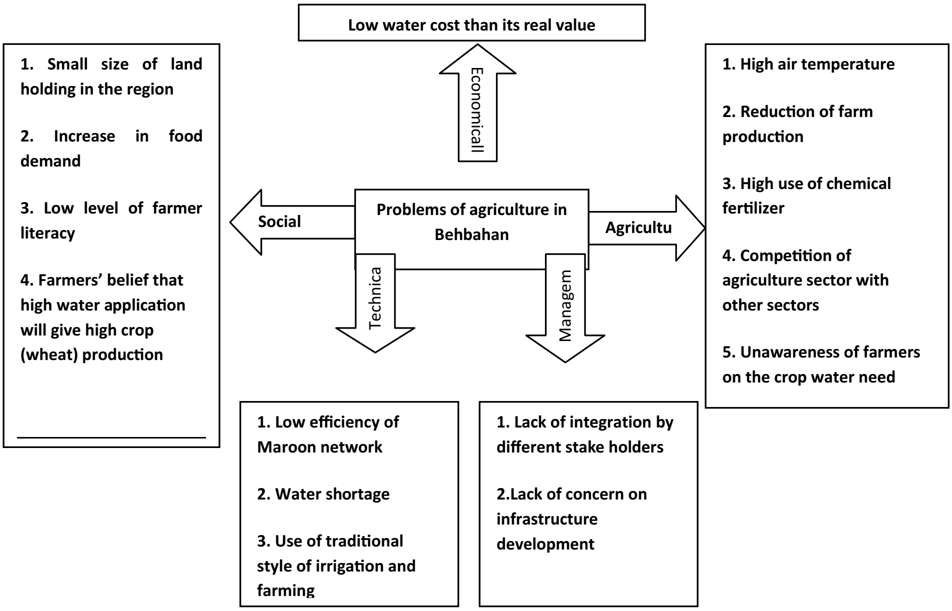


Fig. 3. Problems of agriculture in Behbahan

# 6. RECOMMENDATION

1. Educational program related to agricultural productions and agriculture water consumption for farmers in Behbahan region can solve some problems. In addition, financial support from the government from land consolidation in the network is important.
2. Economic incentive such as selection of progressive farmers in the region who save irrigation water and obtain high water use efficiency and rewarding them can decrease amount of water use.
3. There must be a concrete understanding between the farmers and the water managers on appreciating each other's problems and find out means to bring in some certainty on the volume and time of water release to the farmers.
4. Price of water in Khuzestan must be evaluated based on actual value of water which involves considering investment cost, depreciation of canals and infrastructure and costs of management services.
5. Water efficiency measurements in this study were done by Point Method (in small area in a region) and some of them were done by sampling method. Such measurements many times do not represent the realities in a large region. Hence, extended area survey needs to be done using new technologies such as remote sensing or GIS. Point measurements may be used as ground truth observations

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