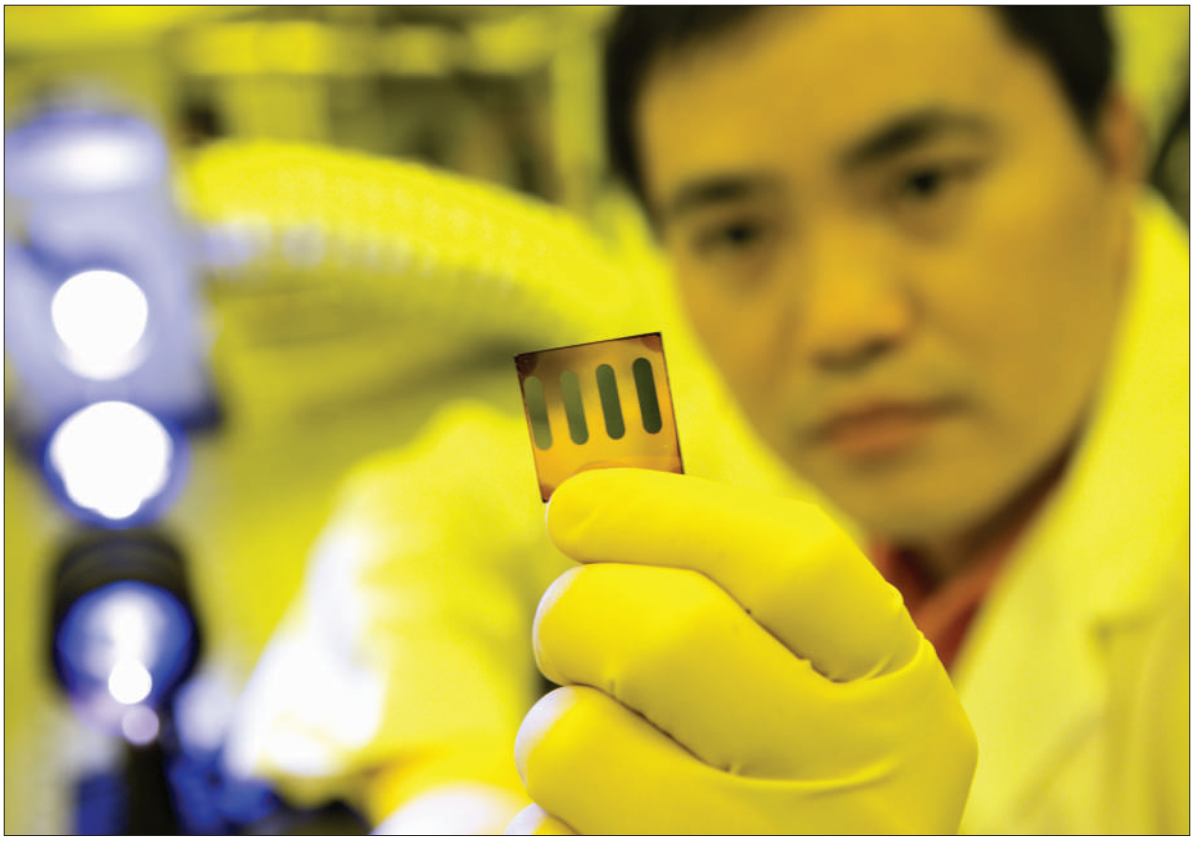

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Research Article
Investigation of Economic Analysis of Water Productivity in the Most Important Crops of Torbat-e-Jam Plain

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Abstract

Background and Objective: Substantially increasing the productivity of water used in agriculture is essential to meet goals of food and environmental security. The purpose of the present study was to investigate the water productivity of agricultural products in Torbat-e-Jam plain of Khorasan Razavi province. **Materials and Methods:** In this study, the required information was collected and analyzed through the Agricultural Jihad Organization of the province and farmers in the region and agricultural and water specialists in the area. For analyzing and evaluating economic productivity, three indices of yield per unit volume of water (CPD), income index per unit of water volume (BPD) and net return per unit of volume of water (NBPD) were used. **Results:** The results showed that crop priority based on CPD indices up to third rank were forage corn, sugar beet and melon and based on NBPD and BPD indices, melon, forage corn and sugarbeet were respectively. **Conclusion:** In conclusion, it is suggested that crops with less water consumption and high profitability for farmers and ranchers cultivated, instead of crops with high water consumption.

Key words: Economic water productivity, crop pattern, drought, Torbat-e-Jam

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

With the rapid growth of the world's population, the pressure on limited fresh water resources has increased and food security for future generations is at risk due to the scarcity of water for agricultural production. Recent studies by the International Water Management Institute (IWMI) showed that one-third of the population of developing countries live in areas facing extreme water shortages, which means that they have sufficient water resources to meet agricultural, drinking, industrial and environmental needs. They will not have the year 2025[1]. Faryab Agriculture is the largest consumer of water and this makes it a strong competitor with other water consumers such as industry and household consumption. The agricultural sector faces the challenges of producing more food with less water by increasing crop water productivity[2]. So, the main goal in agriculture is to produce more with less water. This goal will only be realistic if appropriate strategies for water conservation and more efficient use of water are identified in the agricultural sector. An important strategy to achieve this important goal is to increase water productivity[3].

De Wit[4] coined the first term for this topic and expressed the efficiency of water use in kilograms of product per cubic meter of water consumed. Molden *et al.*[5] used a broader term for water use analysis at different levels to define the scale of water productivity and is user-dependent. Molden *et al.*[3] expressed WP as physical economic output per unit of water consumed (in kg m^{-3} or dollars/m^3). If the whole fraction of dry or wet matter or crop production can be used as economic or physical terms in the fraction, then the transpiration, evapotranspiration, amount of irrigation water and input water at different scales, etc. can be used. Higher water productivity (CWP) means either producing the same amount of less water or producing more of the same water.

The economic value of water in agriculture is much lower than in other sectors[6]. Increasing scarcity of water and on the other hand, the economic crisis of the available water as a result of rising production costs and resource supply have faced other fundamental challenges, such as increasing water productivity in agriculture in order to achieve maximum production or economic value per unit of water consumed[7]. Increasing water productivity is the cornerstone of any demand management strategy[8].

Zamani *et al.*[9] studied the economic productivity of water in different crops in spring plain. The results showed that water productivity in modern irrigation methods was significantly higher than traditional irrigation methods and based on NBPD index of garlic and alfalfa crop, respectively The highest and lowest water productivity were observed in the study area. Studies have also been carried out on the calculation of actual water productivity indicators. The following studies can therefore be mentioned. Vazifedoust *et al.*[10] in the study of agricultural water productivity at field scale in Borkhar area of Isfahan, 2003-2004 which showed that the average WPT for sugar beet, sunflower, forage corn and wheat were 0.99 and 0.22, respectively, 1.76 and 0.49 kg m^{-3}, respectively. The average WPET for these products were reported 1.41, 0.29, 3.03 and 0.87, respectively. In another study by Farahani and Oweis[11], total water productivity in cereals was 0.4 kg m^{-3}. Karimi and joliani[12] emphasized the necessity of increasing agricultural water productivity due to its scarcity and argues that agricultural water productivity is currently in poor condition and is at a lower level than other sectors, they attributed low irrigation efficiency to low productivity. It is necessary to improve the efficiency of agricultural water productivity while improving its efficiency. In a study, Bostani and Mohammadi[13] investigated the water productivity and water demand function of sugar beet production in the Euclid region. They argued that increased productivity, seen as an increase in available water, could have a significant effect on production levels. Kijani *et al.*[7] have introduced several methods to increase water productivity through the application of both plant species breeding methods and better resource management at the plant, farm or basin level. In the field, options include increasing crop yield (CWPF) using irrigation and modifying planting and tillage dates to reduce soil evaporation and increase water infiltration.

Sanij and Moghaddam[14] investigated the use of water use efficiency index and yield function in determining crop pattern with the aim of increasing water use efficiency for two wheat and corn crops in Iran and concluded that wheat cultivation should be a priority in areas with high water use 300 mm, yield of about 1.5 kg m^{-3} and corn cultivation in areas of Iran is recommended that with consumption of 600 mm, yield of corn yield of 1.3 kg m^{-3}.

At present, criteria such as; crop calendars, available water resources, adaptation of crops to crop climate, country policies, soil nutrient status and parameters are considered in preparing the model. In spite of the above, the economic efficiency of agricultural water, which is one of the most important and fundamental criteria has received little attention and no comprehensive researches on this subject in this region have been published. Therefore, the purpose of this study was to evaluate the economical productivity of crop water, determine the appropriate cropping pattern and

provide guidelines for organizing the cropping pattern in order to re-use water in Torbat-e Jam plain in Khorasan Razavi province.

MATERIALS AND METHODS

Study area: This study was carried out on the main crops of Torbat-e-Jam county from 2016-2018. This region is one of the cities of Khorasan Razavi province with an area of about 8,184,000 km^2 located at 35°13' N and 60°38' E (Fig. 1). The city with a minimum temperature of 9°C and maximum average temperature of 22°C and average annual rainfall of 173 mm has a warm and dry climate. The absolute minimum temperature in this city is -24°C and the maximum absolute temperature is 44.2°C. The height of Torbat-e-Jam is about 950 m above sea level. The main crops in this area are wheat, barley, melon, tomato, sugar beet and forage corn.

Model used in the study: Irrigation water productivity refers to the ratio of product to input water. Due to the variety of outputs in the agricultural sector (such as; production, product value, product value added, employment and self-sufficiency, etc.), different indicators have been proposed to evaluate water productivity in agriculture. Agricultural water productivity index includes CPD, BPD and NBPD. Table 1 shows the advantages and dis-advantages of these indices.

The CPD index is actually the ratio of the amount of crop produced (wheat, barley and corn, etc.) to the volume of water consumed. So, the higher this ratio, the better the consumption of water. But, it cannot represent greater

Table 1: Advantages and dis-advantages of different water productivity index

Index	Advantages	Disadvantages
Productivity index (CPD)	Applicable to all agricultural products	Increased computational error coupled with increased product variety, insufficient efficiency to compare products across regions
Gross profit index (BPD)	It is better than the productivity index	Not paying attention to production costs
Net profit index (NBPD)	One of the best indicators for measuring irrigation water productivity	Difficulties in calculating net profit in different situations

Source: Ehsani and Khaledi[16]

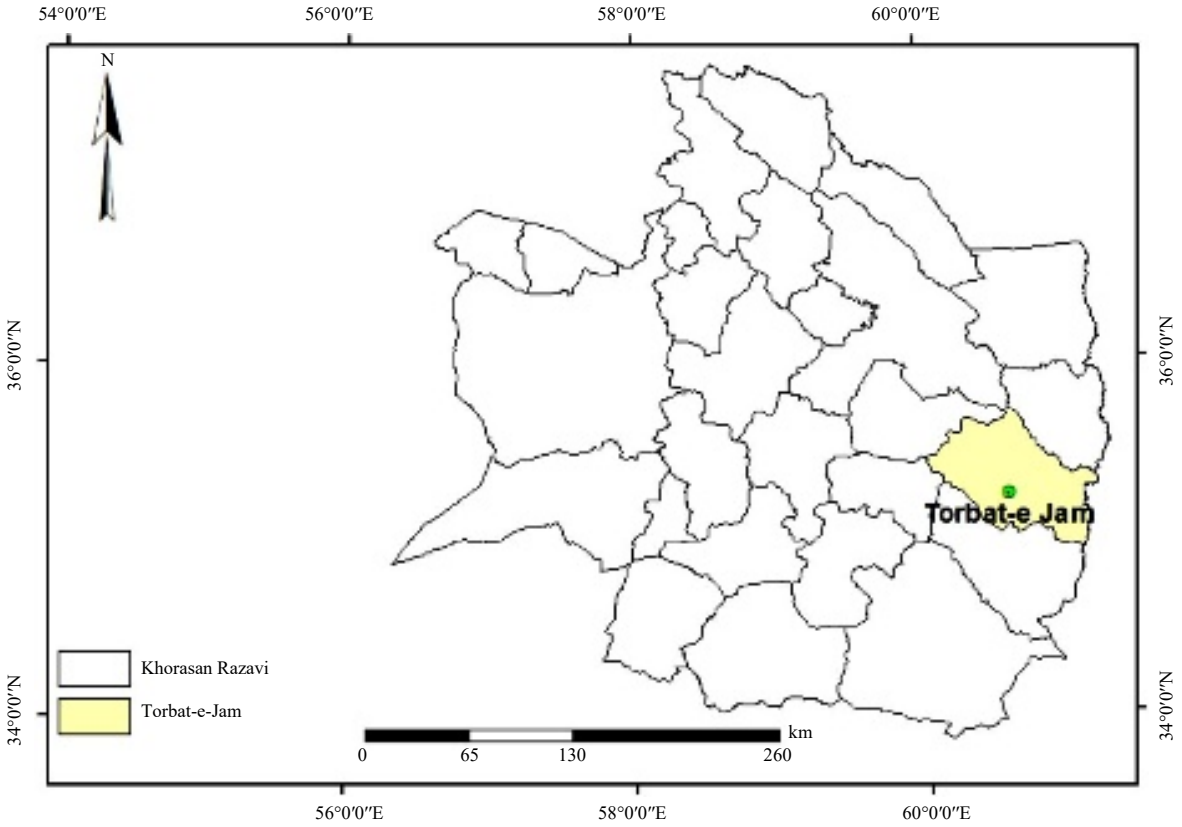

Fig. 1: Layout of the study area in Khorasan Razavi province

economic profits. This indicator can be applied in addition to agricultural products for industrial and livestock products:

$$CPD = \frac{P}{A}$$

Where:

A = Volume of water consumed per hectare regardless of rainfall (m^3)

P = Quantity of crop produced or crop yield (kg ha^{-1})

The BPD is calculated based on the ratio of gross profit per unit volume of water. The water consumption policy in this index should be such that the amount of gross profit is greater than the unit volume of water consumed, but this method does not take into account the cost of producing the product[15]:

$$BPD = \frac{V}{A}$$

Where:

V = Total sales value of product (primary and secondary) per hectare (Rials)

The NBPD index is calculated based on the ratio of net profit per unit volume of water, which is the best indicator from the economic point of view, which not only determines the net profit per unit volume of water consumed, but it is of great importance in pattern planning and composition. Cultivation in arid regions is subject to severe water restrictions. Because of this, scarce water resources can be allocated to crops that produce the highest profits with the lowest water consumption. Based on the above relationship, any product that generates more net income using less water is preferred:

$$NBPD = \frac{C}{A}$$

C = Net profit per hectare (Rials)

Required information for such study such as; crop yield, selling price per kg, cost per hectare and gross production value per hectare and other information required for each crop using the Agricultural Yearbook of Torbat-e-Jam County, Khorasan Razavi Agricultural Organization, 2016, Farmers and agricultural and water specialists were collected in the study area and the Khorasan Razavi Meteorological Organization website. All calculations and graphs are done by using Excel software.

RESULTS

Table 2 showed information on crop area, yield, net and gross water requirement of important crops of Torbat-e-Jam plain. In the following, each of the indices discussed is based on the status of each of the products under study in these indices and prioritization of each of the products under consideration.

CPD index: The status of each crop based on this index is given in Fig. 2. The index showed that Perone cubic meter of water consumed in Torbat-e-Jam plain, 0.6 kg of wheat, 3.6 kg of tomato, 3.9 kg of melon, 4.5 kg of sugar beet and 6.9 kg of forage corn. The priority of each crop based on CPD index is given in Table 3. According to this index, forage corn was in the first place and barley in the sixth place.

BPD index: The status of each crop based on this indicator is given in Fig. 3. The index shows that in the Torbat-e-Jam plain the gross production value per cubic meter of water consumed is 7874 rials, melons 27391 rials, barley 5721 rials, tomatoes 10909 rials, sugar beet 13678 rials and forage corn

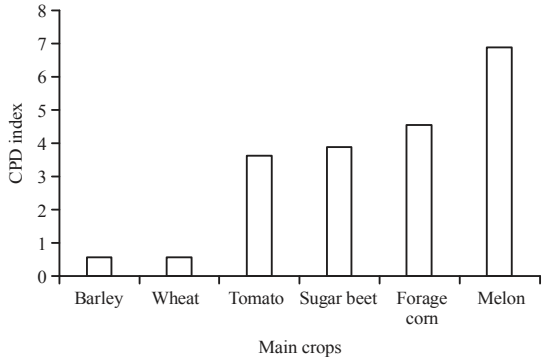

Fig. 2: CPD index values of the products studied

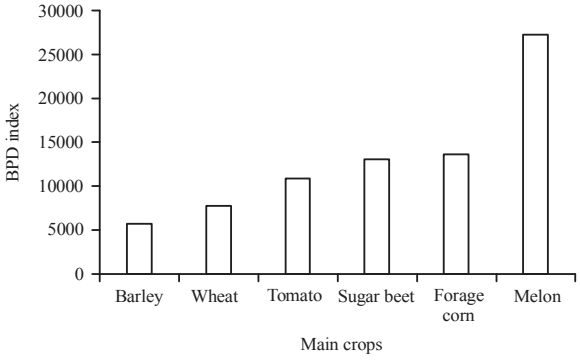

Fig. 3: BPD index values of the products studied

Table 2: Cultures, yield, pure and gross need for important crops in Torbat-e Jam plain

	Products					
Parameters	Wheat	Melon	Barley	Tomato	Sugar beet	Forage corn
Average water consumed (m^3 ha^{-1})	7500.0	5750.0	6750.0	11000.0	11000.0	7250.0
Product sales price (Rials/kg)	13500.0	7000.0	10000.0	3000.0	3000.0	1900.0
Cost of production (Rials per kg)	7083.3	2025.0	8035.7	1523.8	1250.0	520.8
Crop yield (kg ha^{-1})	4250.0	22500.0	3750.0	40000.0	50000.0	50000.0
Total value of product sales (primary and secondary) (million rials)	59.1	157.5	38.6	120.0	150.5	95.0
Net profit (Million rials)	2.89	111.9	8.5	59.0	87.9	68.9
CPD	0.6	3.9	0.6	3.6	4.5	6.9
BPD	7874.0	27391.3	5721.5	10909.1	13678.8	13103.4
NBPD	3860.1	19467.4	1257.2	5368.0	7997.0	9511.5

CPD: Productivity index, BPD: Gross profit index, NBPD: Net profit index

Table 3: List of the most studied products by CPD index

Products	Index (CPD)
Forage corn	1
Sugarbeet	2
Melon	3
Tomato	4
Wheat	5
Barley	6

Table 4: List of the most studied products by BPD index

Products	Index (BPD)
Melon	1
Sugarbeet	2
Forage corn	3
Tomato	4
Wheat	5
Barley	6

Table 5: Priority list of products under study based on NBPD

Products	Index (NBPD)
Melon	1
Forage corn	2
Sugarbeet	3
tomato	4
Wheat	5
Barley	6

13103 rials. But because it doesn't produce as much as it does, it doesn't have much work to do economically. The priority of each crop based on BPD index is given in Table 4. On this index, melon was in the first place and barley in the sixth place.

NBPD index: The status of each crop based on this indicator is shown in Fig. 4. This indicator, which does not indicate the amount of each product in the water consumed, measures the cost of the waste. The priority of each crop based on NBPD index is given in Table 5. The results of the study showed that the net profit of each crop per cubic meter of water consumed is that melon with 19467.4 rials has the highest profit and barley with 1257.2 rials has the lowest profit among agricultural products. corn

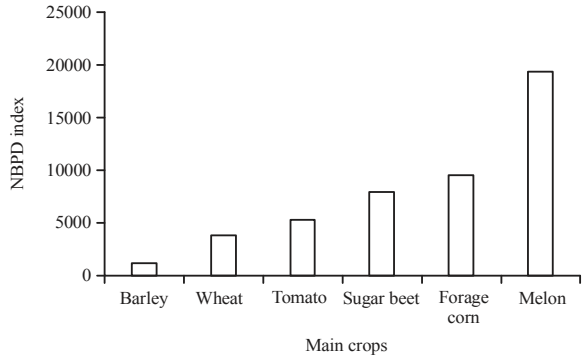

Fig. 4: NBPD index values of the products studied

The results of the index showed that if the farmer's economic benefit is considered, it must be carried out based on the NBPD index.

The results of the index analysis showed that if the farmer's economic benefit is considered, the cropping pattern must be carried out based on the NBPD index. Based on the results and considering that the Torbat-e-Jam plain has hot and dry climate, it can be said that water is an important and essential source in this region and solutions to reduce water consumption and increase crop yields should be considered in order to avoid drought crisis and to prevent aquifer discharge.

DISCUSSION

Water use in agriculture (irrigation) consumes more water than any other human activity and thus the challenges of water sustainability and food security are closely linked. The amount of irrigation water varies globally, not only across different climatic zones but also within climatic zones. The findings that are widely reported in the sources are that production of 1 kg of wheat requires 1 m^3 of water[17,18]. However, these are low requirement data compared to some,

such as; the 3m^3 in arid regions and 0.7 m^3 required for grain yield in temperate zones given by Gregory[19]. In this area, production of 1 kg of wheat required 1.6 m^3 of water and the CPD index for wheat was 0.6 kg m^{-3} whereas. The highest value of this index for cereals in Western Europe is 1.7-4.45 kg m^{-3} compared with the 0.6 kg m^{-3} for this region indicating low water productivity in the region[20]. Zamani *et al.*[9] reported this index 0.63 for wheat which was similar to the results of this study. Other studies reported the value of this index for wheat 0.43 in Mashhad plain, 0.45 in Khatam city, Yazd province, 0.37 in Mashhad-Chenaran, 0.57 in Smallholding system and 0.42 in Rural production cooperative, 0.54 in Iran[12,21-24].

The results showed that in this area, production of 1 kg of tomato required 0.28 m^3 of water and the CPD index for tomato was 3.6 kg m^{-3}. Other researches reported the value of this index for tomato 2.24 in bahar plain hamedan, 2.56 in Mashhad plain,1.46 in Khatam city, Yazd province[9,12,21].

Also, in this area, production of 1 kg of melon required 0.25 m^3 of water and the CPD index for melon was 3.9 kg m^{-3}. Karimi and jolaini[12] reported the value of this index for melon 1.58 in Mashhad plain. Hassan shahi *et al.*[21] reported the value of this index for melon 2.71 in Khatam city, Yazd province.

The results showed that in this area, production of 1 kg of sugarbeet required 0.22 m^3 of water and the CPD index for sugarbeet was 4.5 kg m^{-3}. Other researches reported the value of this index for sugarbeet1.97 in Mashhad plain,1.22 in Mashhad-Chenaran[12,22].

Also, in this region, production of 1 kg of forage corn required 0.14 m^3 of water and the CPD index for melon was 6.9 kg m^{-3}. Zamani *et al.*[9] reported this index 6.05 for forage corn which was similar to the results of this study. Water productivity is dependent on several factors, including crop genetic material, agronomic practices, water management practices and the economic and policy incentives to produce. The results of this study was similar to the results of Zamani *et al.*[9] in bahar plain, emphasize that finding the best opportunity to create higher value added can be an effective step in the growth of agriculture and the regional economy given the high water scarcity and water value in the country.

CONCLUSION

The irrigation water productivity refers to the ratio of crop yield output to water input. Three indices of crop per drop (Productivity index: CPD), benefit per drop (Gross profit index: BPD) and net benefit per drop (Net profit index:NBPD) were used in this study to measure water productivity. The results showed that the priority of the culture of crops based on the CPD index is forage corn, sugarbeet and melon. Based on the BPD and NBPD indices the priority becomes melon, forage corn and sugarbeet. Based on the results of this study, it is suggested that the crops with lower economic efficiency, such as; wheat, barley and tomato should be removed from the cropping pattern and switch to melon, forage maize and sugar beet. This will both reduce consumption and water extraction as well as guaranteeing high economic profits for the farmers.

RECOMMENDATION

Based on the results of this study to improve the cropping pattern in Torbat-e-Jam area and by examining the area and relative recognition of farmer's interest in specific cropping, the following suggestions were made:

Given the low percentage difference between the NBPD and BPD indices, farmers are advised to focus on growing melon and forage corn and sugarbeet in order to maximize profits as well as optimum use of water. Also, it seems that such an evaluation should be done over several years. Certainly, a more accurate assessment yields both more realistic results and more favorable reviews. In order to properly manage water use in arid and semi-arid areas and improve its water quality in addition to restructuring the crop pattern, suitable crop management and irrigation such as; selecting the appropriate irrigation method, determining irrigation intervals and time management, fertilizer effect on crop quality and efficiency. Water, improved and sustainable seed use, use and promotion of modern irrigation systems, mathematical models for cold assessment and optimization of water resource utilization are recommended.

SIGNIFICANCE STATEMENT

This study documented considerable variability in crop water productivity in for main crops in this region. Considering consecutive droughts and water crisis in agricultural plain of this area, it is necessary to use water resources optimally and increase productivity in production of crops. Therefore, water productivity or reduction in irrigated areas could have very serious impacts on global food supply. Conversely, any reduction in irrigation water used would have major benefits to freshwater resources. This study will help the researchers to uncover the critical areas of the water productivity on main

crops of Torbat-e Jam plain in Iran that many researchers were not able to explore. Thus cultivations with high water consumption and low economic should be excluded from cultivation pattern of the region and some cultivations which decrease water consumption and also create high economic benefits for the farmers and agricultural users should be used.

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