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An investigation on water productivity in agriculture with evaluating Iran position

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Abstract

Water has played the most significant role in development all the time and all over the world. On the other hand, agriculture and natural resources section is considered as one the important economic functions due to its critical role in supplying the needed food of a nation, providing food security, and realizing sustainable development. Water is one of the most eminent scarce resources required for supplying agricultural products. Approximately 93 percent of renewable water resources (80 billion m^3) are being used in irrigated farms; however the resultant products (51 million tons) cannot meet the national food needs. Several studies have demonstrated that a large amount of water is being wasted by different ways in agriculture section, so its efficiency ranges not more than 33 to 37 percent. Moreover, the index of water productivity in Iran agriculture section has been reported as 0.7 to 0.8 kg dry product per 1 cubic meter of consumed water which is far from international standards (1.5 - 2.5 kg dry product per 1 cubic meter of consumed water). Increasing demand for water in industry and urban sections together with environmental problems will lead to shortage of water for agriculture in future. One of the useful corrective actions to avoid this problem can be realized through increasing productivity of water usage (increasing quantity of product per each unit of consumed water).

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Introduction

Recent studies conducted by International Food Policy Research Institute (IFPRI) and International Water Management Institute (IWMI) suggest that amount of water that can be allocated to agriculture will be more limited by 2025 due to increase in world's population, growing of urbanization, and developments in industry, besides allocating environmental portion of water to agricultural, domestic, and industrial applications will expose the environment to more threats. Therefore, if the amount of investment in sustainable management of water resources descends, the world will find itself confronted by significant decline in food production, enormous augmentation in food price, and numerous crises in environmental aspects (Ehsani and Khaledi, 2003). Thus, the issue of water resources shortage will very likely be the most prominent disputable subject in future; since world's population is going to reach 9.4 billion by 2050, hence supplying water and food and at the same time protecting the environment will be the most critical concern for governments. This situation will be more acute for Middle East countries which have access to just 1% of world's drinkable water, and yet 5% of world's population (Khosroshahi, 2006). Although only 15% of the world's farm lands are irrigated and remaining 85% are of dry-land farming type, this minor portion provides food for about half of the world's population. This fact adds more significance to role of irrigation in agriculture. At the present time, total water consumption in Iran is about 88.5 bm^3 out of which 82.5 bm^3 (93%) is used in agriculture and 7% has been allocated to domestic and industrial applications (Table 1). This allocated volume of water to agriculture is irrigating totally 7.8 million hectares of farm lands (Ehasani and Khaledi, 2003).

Table 1. Estimation of water consumption rate by different sections of country.

water consumption rate by different sections	water consumption rate	Percentage of total
Agricultural section	82.5	93.2
Urban section	5.6	6.3
Industrial section	0.03	0.03
Others	0.37	0.43
Total	88.5	100

For the purpose of evaluating the status of water resources throughout the world, International Water Management Institute utilizes two factors of IIWMI1 (Current withdrawals as % of Available water resource) and IIwMI2 (Future withdrawals as % of Current withdrawals) simultaneously. The earlier factor stands for the ratio of current withdrawal percent to total annual available water resources and the later stands for the ratio of future withdrawals percent to current withdrawals. The existing situation is demonstrated by figures in Table 2.

Table 2. The index of International Water Management Institute.

Crisis level	The index of International Water Management Institute
High	IIWMI1*>% 50
Average	IIWMI1<%50 & IIWMI2**>% 200
Moderate	IIWMI1<%50 & %200 >IIWMI2>% 125
Low or lack of crisis	IIWMI1<%50 & %125>IIWMI 2

* The ratio of current withdrawals to annual available renewable water resources in percent (I_{IWMI1})

** The ratio of future withdrawals to current withdrawals in percent (I_{IWMI2})

Due to descending trend in annual precipitation and inappropriate dispersion of it in terms of time and location, Iran is classified among dry and semi-dry countries. On the other hand, because of the increase in population, development of healthcare, and expansion of agricultural and industrial sections the demand for water has been increased and this will lead to wider gap between supply of and demand for this valuable material. The wider this gap the more serious concern would be economic planning for water resources and optimal allocating of them. According to several criteria including the index defined by International Water management Institute, Iran is confronted by sever water crisis. As reported by this institute, Iran needs to increase its water resources by 112% until 2025 if only wants to maintain the current situation and considering existing facilities and resources it seems most unlikely to happen. Therefore, the present situation must be among the critical concerns for experts, directors, and government leaders in future strategies in order to

make provisions for solving the problem and preventing the crisis from extending (Ehsani and Khaledi, 2003). In recent years the issue of agricultural water productivity has absorbed the attention of different scientific societies dealing with water and irrigation matters. What makes the fundamental of the water productivity concept, lies in suitable consumption of water along with increasing agricultural products. Presently the rate of water efficiency in agriculture has been measured between 0.7 to 0.8kg per one cubic meter which is far from international criteria (1.5 to 2.5 kg/m^3), and still this rate needs to reach 1.6 by1400 in order to provide this increasing population with necessary food (Keshavarz and Heydari, 2004). Thus, any effort directed toward decreasing consumption and increasing productivity of water will be significant. Some believe that it is possible to reduce water consumption in agriculture and industry by 40-50% and 40-90% respectively (Hayati and Lari, 2000). So, many researchers have proposed several approaches for managing water resources and optimizing water consumption in agriculture. In a study conducted for evaluating the necessity of monitoring soil humidity in increasing water productivity, Farahani and Danaiee Fakhr (2003) argue that the concept of water productivity in agriculture goes beyond the concept of efficiency in production, irrigation, and utilization of capitals. Reviewing the conducted studies in this field, we can identify the main purpose of them as increasing in productivity of water consumption in different sections especially agriculture. Several methods of making productivity in agriculture sections have proposed in different researchers conducted inside or outside the country. Arabi Yazdi *et al.* (2008) reported that lack of balance between supply of and demand for water especially in agriculture poses a challenge in water resources management. International exchange of agricultural products and transit of hidden water inside them which is called virtual water can be one of the useful procedures in water management. In the very article the trace of water ecology was computed based on the available data related to import and export of foods in 2006. The obtained results showed that ecological trace of water during this year was 104 billion cubic meters. By import of pure virtual water and subtracting export of virtual water regardless of 12 percent irrigation efficiency in this year, instead based on an efficiency of 60 percent, Iran has saved 20 billion cubic meters of national water resources; otherwise it could take 112 billion cubic meters of water - which is inaccessible - if these products had been provided inside the country. Kaveh and Abri (2009) examined two types of productivity (WET and WP_{SUPLY}) in Iran and concluded that both of them are in low levels compared with common global principles in agriculture. Akbari *et al.* (2009) indicated that appropriate planning of irrigation and improving management of planting leads to not only a decrease in consumed water but also an elevation in performance of product and productivity of water usage.

Eslami and Farzamnia (2009) examined the effect of mulch on water preservation capacity of soil and performance of pistachio trees and concluded that this factor has significant effects on humidity preservation of soil in surface and deep at 1% and 5% levels respectively. Besides, the obtained results revealed that plastic cover has more lasting effect than other treatments regarding to preservation of water in soil and so, it was identified as the simplest and most applicable intervention. Bodagh Jamali *et al.* (2003) claimed that when irrigation exceeds the soil capacity it leads to formation of waste water and also penetration of water to out-of-reach lower layers and this in turn results in not only waste of water but also a decline in soil nutrients and poor soil texture. Bijan Nazari *et al.* (2013) showed the uniformity coefficient and adequacy have high effect on crops yield and crops WP and integrated study of these indices has high necessarily in irrigation management and deficit irrigation planning. The present paper aims at evaluating all suggested methods for increasing water productivity regarding to different works done either nationally or internationally in this field.

Materials and methods

In this paper with regard to aim of it, we used different library sources (such as researches and books) and internet sources (such as website of Ministry of Agriculture of Iran, website of World Bank, website of Ministry of Energy of Iran and website of Food and Agriculture Organization) to gather data.

Results

Definition of productivity

The most critical focus in agriculture section is producing more food with minimum consumed water for providing it. Firstly, we should identify scarce production factors leading to increase in productivity, then research and planning should be carried out about how to maximize the productivity of those scarce factors. Generally, the concept of productivity in agriculture is examined from different perspectives. The most common points of view include physical, financial, and employment perspectives.

1. Productivity from physical perspective: according to this view, productivity means producing larger amounts of product per each unit of consumed water volume.

2. Productivity from financial perspective: according to this view, mostly deals with more profitability per each unit of consumed water volume.

3. Productivity form employment perspective: according to this view, deals with providing more occupational opportunities per each unit of consumed water volume (Ehsani and Khaledi, 2003).

Considering food-related needs of growing population of our country together with world's population which exceed 75 million and 7 billion now and will reach 110 million and 10 billion people respectively, we should be concerned to increase productivity in water consumption (Howell, 2001). According to statistical analysis carried out by Food and Agricultural Organization (FAO), there was a ascending trend in the area of under-cultivation lands using irrigation systems during years between 2006 to 2008, and has reached to 19% in 2008 from 18.2% in 2006 (FAO, 2013). Whereas, the rate of this trend in the world has declined year after year, since appropriate lands for irrigation-based planting have become scarce (Howell, 2001).

Examining the transitional trend in under-cultivation area for producing different crops in Iran

The trend during 2005 to 2010 indicated that except for a period of one agricultural year from 2007 to 2008 during which there has been a 15.2% and 55.3% decrease in the area harvested of irrigated and dry farming lands respectively, an increase in the area of irrigated lands is detectable (Table 3). It implies an ascending trend in irrigation-based agriculture. The existing situation is illustrated in Figure 1.

Table3. Examining the transitional trend in under-cultivation area for producing different crops in Iran.

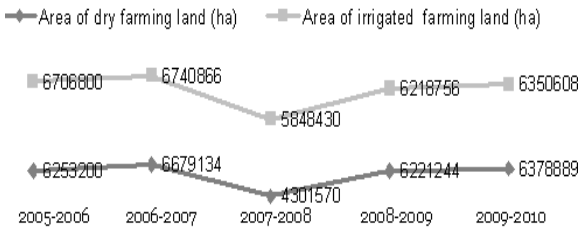
Groups of crops	Area of irrigated farming land (ha)					Area of dry farming land (ha)				
	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010
Grains	42553980	4299768	4952365	3925284	4019552	5116020	5560232	2137635	5154716	5403402
Cereal	146796	165465	124902	126781	127157	794204	791535	572098	742219	663280
Industrial crops	573516	557459	439950	387868	603593	138484	121541	85050	83132	92398
Vegetables	455952	464872	438136	460548	465486	27048	20128	24864	34452	47433
Cucurbits	263020	310393	251522	281815	607433	28980	41607	17478	32185	24820
Forage plants	899334	847925	857499	558000	998478	120666	110075	94501	142000	147556
Total	6706800	6740866	5848430	6218756	6350608	6253200	6679134	4301570	6221244	6378889

Source: Ministry of Agriculture and Statistics, author, 2013

Average consumed water for producing some plants in Iran and the world

Table 4 summarizes average consumed water for producing some plants in Iran and the world. As can be seen, there is a vast difference between Iran and global trend regarding to average consumed water.

Figure. 1 Area harvested of irrigated and dry farming lands



Source: author

Table 4. Average consumed water for different plants in Iran and the world.

Plant	average consumed water in Iran (m3/ha)	average consumed water in world (m3/ha)
Wheat	6400	4500-6500
Sugar beet	10000-18000	5500-7500
Melon	17900	7000-10500
Rice	10000-18000	4500-7000
corn	10000-13000	5000-8000
sugarcane	20000-30000	15000-25000

Source: keshavarz and heidari, 2004

Comparison between different modern irrigation methods used from 1993 to 2003 in Iran

The data excerpted from FAO database about under-cultivation area in Iran comparing traditional and modern irrigation methods is presented in table 5.

Table 5. Comparison between different modern irrigation methods used from 1993 to 2003 in Iran.

Year / Items (1000 hectares)	1993	2003
Areas cultivated by surface irrigation method	3625	3078
Areas cultivated by subsoil irrigation method	3639	5054
Controlled areas equipped with surface irrigation method	7173	7432
Areas cultivated by sprinkler irrigation method	47.2	280
Areas cultivated by localized irrigation method	43.5	420
Total areas equipped with different irrigation systems	7264	8132
Total areas under water resources management	7274	8142

Source: www.FAO.org, 2013

As can be seen, the areas cultivated by surface irrigation method have declined by 15% in 2003, whereas the areas irrigated by subsoil method, controlled and equipped with surface irrigation systems, by sprinkler irrigation systems, and localized irrigation methods have been increased respectively by 39%, 3.6%, 493%, and 856% compared with 1993. Total lands equipped with different irrigation systems have had a 12% increase in area.

Comparison of the productivity changes trend in Iran and some selected countries from 1995 to 2007

Table 6 summarizes the productivity changes trend in total for Iran and some selected countries from 1995 to 2007 according to recent statistics provided in International Bank site.

Table 6. Comparison of the productivity changes trend in Iran and some selected countries from 1995 to 2007- Unit: 1 cubic meter per each unit of gross domestic product (GDP) in dollars (its value in 2000).

Year / Country	1995	2000	2005	2007
Iran	1	1	1	2
United state of America	17	21	23	24
South Africa	9	11	-	14
Argentina	9	9	-	13
Germany	38	49	-	22
Australia	-	17	-	44

Source: 2013 World Development Indicators, World Bank.

As can be seen, a significant difference is detectable in total productivity score during different years in Iran, while there is a growing rate for that of other countries.

Average score of water productivity index in some countries estimated totally and also individually for agriculture and industry sections

Table 7 shows the water productivity indices in some countries during the period between 1987 and 2004 individually in agriculture and industry sections, and then in total. Comparing this index among different countries reveals conspicuous differences between developed and developing countries.

In fact, a vast variance exists in this index which ranges from 28.2% in rich countries to 0.8% in poor countries. According to published data by International Bank, average score of this index in Iran in agriculture, industry, and in total was 0.2, 26.2, and 1.6 by 1987-2004 respectively which is lower than what was estimated for both developed countries and global average (except for industry). As can be noticed, the developed countries owe their success in achieving higher levels of this index to modern technologies, and hence they gain more profitability per each unit of consumed water. It is worthy to note that majority of the developed countries are located on upper latitudes of earth and so are faced with lesser limitations on water resources. Therefore, the issue of increasing the water productivity index finds more significance in the dry countries including Iran (Ministry of Energy report, 2011).

Table 7. Average score of water productivity index in some countries estimated totally and also individually for agriculture and industry sections. Unit: 1 cubic meter per each unit of gross domestic product (GDP) in dollars (its value in 2000)

Country	Agricultural section	Industrial section	Total
Iran	0.2	26.2	1.6
United state of America	0.5	9.6	30.9
Canada	2.5	7.1	16.4
Australia	0.6	41.2	17.4
Turkey	1	10.4	5.3
Azerbaijan	0.1	0.6	1.4
Iraq	-	1	0.5
Pakistan	0.1	4.7	0.5
South Africa	0.5	53	11.3
High income countries	2.7	33.6	28.2
Average income countries	0.6	19	3.3
Low income countries	0.3	0.7	0.8
World	1	18.7	8.6

Source: Ministry of Energy reports, Iran, 2013

Discussion

Summarized

According to table 3., it is obvious that the area of under-cultivation lands - either irrigated or land farming - in Iran is increasing, on the other hand erratic consumption of water resources for producing different crops is detectable in tables 4,6,7 demonstrate the absence of any improvement in productivity of using water either in agriculture or other sections. As table 7, implies, the average efficiency of using water in agriculture has been 0.2% from 1987 to 2004. In recent year this index has reached to 0.7 – 0.8% which is too low yet compared with its global level (1.5-2.5 kg dry material per each cubic meter of water).

Different perspective to increase water productivity

Considering the current trend in water consumption and geographical location of Iran, this country will be confronted by serious problems in its agriculture section. Thus, it seems necessary to take corrective actions concentrated on making improvements in water productivity of agriculture. Wallace and Batchelor proposed four options for increasing water productivity in irrigation-based farming: 1) Agronomic option (including agricultural plants management in order to make improvements in receiving rainfalls or reducing evaporation, using varieties of amended plants, maximum usage of modern cultivation strategies during periods with lower demand for water or when the rainfalls are more likely); 2) Engineering option (including utilization of irrigation systems which minimize waste of water, improve consistency of distribution or physical structure both of which improve in turn rainfall receiving; 3) Management option (including planning irrigation on the basis of demand, minimizing water consumption in irrigation for the purpose of making soil more absorbent of deep waters, preventing decline in performance because of salt near root, maintenance of equipments for minimizing downtime due to failure); 4) Organizational option (including involvement of consumers in exploitation and protection of irrigation area, pricing water, establishing legal incentives for lowering consumption and punishments for wasting, and creating educational opportunities for learning new technologies) (Wallace & Batchelor, 1997). Agricultural water management also is effective in increasing productivity provided that economic, social, and organizational infrastructures are taken into account (Oweis and Hachum, 2003).

In the case of dry farming systems one of the suitable options for creating competition and replacing them with crops cultivation systems lies in developing dry framing farms under micro catchment water harvesting conditions with/without controlled irrigation which will result in productivity improvement (Tavakoli, 2004). Regarding to existing situations in the countries like Iran, applying modern irrigation technologies and water economic management are of possible significant and effective procedures against the crisis of water shortage, since the productivity of irrigation can increase by 80% and 95% with under pressure sprinkler systems and drip irrigation systems respectively (Noruzi and Chizari, 2006). By developing appropriate plans for irrigation and making improvements in agricultural management along with reducing the amount of consumed water in irrigation, we can achieve the higher levels of product performance and water productivity (Akbari *et al.* 2009). One of the most effective methods applicable in this sense is reducing the water consumed for irrigation by which a significant elevation will happen in water productivity (Asadi and Aghili, 2009). Practices used to achieve water productivity include water harvesting, supplemental irrigation, deficit irrigation, precision irrigation techniques and soil–water conservation practices. Practices not directly related to water management impact water productivity because of interactive effects such as those derived from improvements in soil fertility, pest and disease control, crop selection or access to better markets (Molden *et al.* 2010). Focusing on small scale agriculture; investing in rehabilitating degraded land to increase water productivity; and enhancing the multifunctionality of agricultural landscapes. These options can improve water management and water productivity, while also improving the livelihoods of the rural poor (Bossio *et al.* 2010). Irrigation management and irrigation systems upgrading have a high important role in water productivity. when an irrigation depth treatment is proposed as an optimum option for achieving maximum crop yield or maximum water productivity, this value should be proposed regarding to irrigation adequacy and uniformity coefficient values.

In this situation, we can expect that more area of the field had received optimum or near optimum irrigation amount. (Nazari *et al.* 2013).

Conclusion

Considering all the mentioned issues and reviewing available literature on this subject, the following procedures are suggested for the purpose of increasing water productivity in agriculture section: 1. Developing modern irrigation methods for increasing watering yield and avoiding waste of water resources; and funding the establishment of these technologies on the basis of financial support provided by government and authorities. 2. Concentrating on agriculture management in farmlands (accurate irrigation, minimizing the amount of irrigation, protection of the soil and water, diversity of cultivation, revitalization of low lands, pests management, planting adapted species for little watering). 3. Paying attention to the procedures in management of water resources (increase water productivity, make water sustainable in quality and quantity, make modifications in economic structure of water, expand public awareness, and development of technologies). 4. Concentrating on new techniques invented for optimization of the precipitation falls on dry farming lands. 5. Changing the farmers' attitudes towards using water resources by delegating the propagation of the knowledge to promoters. 6. Concentrating on water-related needs of crops and conducting pertinent researchers on the aspects of waste of water.

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