RAISING WATER PRODUCTIVITY LEVELS AND ENSURING SUSTAINABILITY OF IRRIGATION FOR HIGH WATER USING CROPS

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ABSTRACT

Increasing water demand for industrial and domestic use and for environmental sustainability entails efficient water use in agriculture. On the other hand, irrigation can maximize the crop yield and/or irrigation water use efficiency (IWUE) or water productivity and maximize the farmer's economic returns. Improving water use efficiency or enhancing water productivity in a sustainable manner is crucial to irrigated agriculture and water use. In this study, yields of the crops, IWUE or irrigation water productivity, net returns per unit land area and per unit of water used for some higher water-using crops (cotton, corn, sugar beet, tomatoes and winter wheat) in Turkey were computed and discussed vis-a-vis different amount of irrigation water, irrigation methods and some different climatological regions. According to this study, net return per unit land area and per unit water in the different regions of Turkey were \$ 430-6707/ha and \$ 0.10-1.22/m^3 depending on different crops and region, respectively. Water cost also varied from \$ 0.05/m^3 through \$ 0.20 /m^3 depending on the regions. These figures showed that irrigation water has not been used with the same efficiency in different regions of Turkey. Meanwhile, having the highest water use efficiency does not mean that net returns will be highest for all the crops. The most profitable use of water is somewhere between the amount that provides highest water use efficiency and the amount that provides for maximum yield. Water productivity and/or net return for farmers could be, thus, increased using micro irrigation and appropriate irrigation schedules. Irrigation scheduling ensured higher water prodcutivity is, thus, important in view of the global scale of fresh water crisis. However, ensuring sustainability is closely dependent on other inputs such as nitrogen, crop variety, agronomic practices, climate conditions etc. In this article, irrigation schedules and regimes on higher water productivity and the approaches towards achieving sustainability for higher water-using crops are also discussed.

Keywords: Water productivity, Sustainability, Net return, Irrigation water use efficiency (IWUE).

1. INTRODUCTION

Irrigation is one of the most important inputs to increase crop yields in arid and semi-arid regions. Agriculture makes use of 70% of all water withdrawn from aquifers, streams and lakes. Irrigated agriculture accounts for 20% of the total cultivated land but contributes 40% of the total food produced worldwide (Drechsel et al. 2015). Agricultural sector is, however, the largest consumer of water not only in Turkey but also in the world.

There is increased competition for land, water, energy, and other inputs into food production. 'Sustainable intensification' (SI) as too narrowly focused on production, or even as a contradiction in terms altogether (Campbell et al. 2014). The competing uses for water (domestic, industrial, and environmental) and the increasing demand

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for food due to a rapidly growing world population require an urgent improvement of productivity per unit of water consumed in agriculture (FAO 2002).

Water productivity can be analyzed at the plant level, field level, farm level, system level and basin level, and its value would change with the changing scale of analysis (Molden et al. 2003). Thus, irrigation is a commonly used platform for intensification of sustainability. The best use water resources for agriculture and improving effciency are urgent needs and prerequisities for sustainable food production. Because, improving water use efficiency or enhancing agricultural water productivity is a critical response to sustainability on irrigated agriculture and water use. Crop water productivity is an important index to evaluate water saving and to obtaine higher output or value for each drop of water used (Kang et al. 2009). Considering sustainability or intensification of sustainability, measures to enhance yield to raise water productivity in biomass per unit of water depleted, might increase the cost of production thereby reducing net return per unit of water depleted. Therefore, crop water productivity needs to be assessed in terms of both kilogram of crop per cubic metre of water diverted or depleted; and net or gross present value of the crop produced per cubic metre of water (Kijne et al. 2003).

Three different objectives can be achieved for irrigated agriculture: i) maximizing the crop yield, ii) maximizing the crop water use efficiency (WUE), iii) maximizing the farmer's economic returns (De Pascale et al. 2011).

On the other hand, the authorities stated that there are significantly differences between gross incomes per unit irrigation water in the different regions of Turkey. Beacuse, average gross production per unit water in Western and Southeastern of Turkey are $ 0.27-0.68 and $ 0.13-0.22/m^3, respectively (GAP 2015).

In this article, yields of the crops, irrigation water use efficiency (IWUE), net return per unit land area and net return per unit water for some higher water-used crops (cotton, corn, sugar beet, winter wheat and tomatoes) in Turkey are computed and discussed considering different amount of irrigation water, irrigation mothods and some different climatological regions. Thus, the ways of intensification of sustainability in terms of irrigation for irrigated crops are also given and discussed.

2. METHODS

In this study, the results of researchs carried out in the previous years in the different regions of Turkey were used. Different irrigation scheduling and different amount of irrigation water in these studides were considered. The crops were cotton (Cetin & Bilgel 2002), second crop silage corn (Yolcu 2014), winter wheat (Cetin, 1993) in the Southeastern Anatolia region, sugar beet (Tari et al. 2011) and tomatoes (Cetin & Uygan 2008) in the Central Anatolia region of Turkey.

Irrigation water use efficiency or physical water productivity was computed as the ratio of total biomass or grain yield to water supply seasonal basis, and economic water productivity is defined as the value derived per unit of water used. Thus, the equations (1, 2 and 3) given below are used to compute irrigation water use efficiency, net return per land area and net return per unit water (Sinclair et al. 1984; Kijne et al. 2003; Sharma et al. 2015).

The yields and amount of irrigation water applied were used to compute and analyse irrigation water use efficiency, in another word, water productivity, net return per unit land area and unit irrigation water. Net returns are based on current prices and cost productions. All subsidies which have got crops were included to the net return.

$$IWUE = \frac{Y}{IW} \qquad (1)$$

$$NRA = \frac{NR}{IA} \qquad (2)$$

$$NRW = \frac{NR}{IW} \qquad (3)$$

Where IWUE is irrigation water use efficiency (kg/ha/m^3), Y is crop yield (kg/ha), IW is irrigation water (m^3/ha), NRA is net return per unit land area ($/ha), NR is net return ($/ha), IA is irrigated area (ha), NRW is net return per unit water ($/m^3).

The net income for each treatment according to the amount of irrigation water applied and/or different agronomic treatments was computed by subtracting all the production costs from gross incomes. All calculations were done based on a unit area of 1 ha (Koral & Altun 2000; Inan 2001). Economical analysis and evaluation were computed by using the results of this study based on investment, operation and production costs.

The water cost was estimated and computed from the water user associations, some literatures (Yurdem et al. 1999; Tuzun et al. 2006) and farmers. Thus, it was averaged in order to represent the actual water cost in the study area. Thus, the cost of irrigation water varied from $ 0.05 to 0.20/m^3 for the study regions.

Ensuring sustainability was, thus, considered water saving and economical water productivity.

3. RESULTS AND DISCUSSION

3.1 Irrigation water use efficiencies and economical water productivity

3.2 Tomatoes

According to the calculation and evaluations of the data, the maximum net retrurn was obtained as $ 6707/ha for the treatment (Ab in Table 1) in which the lateral and crop row spacing were 1 m, and based on the percentage of canopy cover for the calculation of the amount of irrigation water applied (Table 1). The water prices were recorded from the farmers used deep-well irrigation water and water user cooperatives, and it was averaged in order to represent the actual water cost in the study area. Thus, the cost of irrigation water was $ 0.20/m^3 for farm conditions. It was high cost of water because the farmers have used deep well water and it included withdrawing and pumping cost of water (Çetin & Uygan 2008).

The financial net returns are both positive and relatively higher. For that reason, use of drip irrigation for tomatoes has rapidly increased because of both increasing in yield of tomatoes by using drip irrigation and subsidizing of drip irrigation systems by the government.

The treatment in which the lateral spacing was 2 m, and used the percentage of canopy cover for amount of irrigation water (Bb) resulted in a net income of $ 5117 /ha, and it was ranked second among the treatments. It is noted that there was a significant difference in terms of net income between the treatment Ab and the others. On the other hand, both the treatment Ab and Bb resulted in significantly more income compared to all the other treatments (Çetin & Uygan, 2008). Considering different treatments, the maximum yield (121.1 t/ha), the maximum net return per unit land area ($ 6707/ha) and maximum net return per unit irrigation water ($ 1.22/m^3) were obtained from the treatment Ab. Additionally, IWUE (22.0 kg/ha/m^3) was also almost the maximum compared to the other treatments.

Table 1. The data on yield, net return and water productivities for tomatoes under the Eskişehir conditions (Adapted from Cetin & Uygan 2008).

Treatments (Amount of irrigation water) (m^3/ha)	Marketable tomatoes yield (kg/ha)	IWUE (kg/ha/m^3)	Net return per land area ($/ha)	Net return per unit water ($/m^3)
Aa (6600)	100.6	15.2	2975	0.45
Ab (5510)	121.1	22.0	6707	1.22
Ac (4890)	96.3	19.7	2631	0.54
Ba (3530)	77.2	21.9	-93	-0.03
Bb (4910)	109.9	22.4	5117	1.04
Bc (4890)	92.6	18.9	2079	0.43

3.3 Winter wheat

According to the result for two-year data (Cetin 1993) the maximum net return per unit land area was 429.4 $/ha (Table 2). In this treatment, the winter wheat was irrigated at the beginning of heading and milk stages except drought conditions. This treatment provided the maximum grain yield. Additionally, the same treatment also provided maximum net return ($ 0.11/m^3) per amount of irrigation water applied.

Table 2. Net return on unit land area and unit irrigation water for winter wheat under the Southeastern Anatolia conditions (Adapted from Cetin 1993).

Irrigation treatments (m^3/ha)	Net return ($/ha)				
	Nitrogen rate (kg N/ha)				
	N0	N60	N120	N180	N240
I_0	-114.6	-69.2	-208.1	-302.3	-434.2
I_1(2227)	-24.4	-50.3	-261.8	-283.3	-436.0
I_2(3876)	-5.7	260.9	208.6	429.4	99.8
I_3(4784)	-43.4	302.9	333.7	422.9	121.0
I_4(4420)	112.3	209.6	392.7	398.8	145.4
Irrigation treatments (m^3/ha)	Net return per unit irrigation water ($/m^3)				
I_1(2227)	-0.01	-0.02	-0.12	-0.13	-0.20
I_2(3876)	0.00	0.07	0.05	0.11	0.03
I_3(4784)	-0.01	0.06	0.07	0.09	0.03
I_4(4420)	0.03	0.05	0.09	0.09	0.03

The farmers applying the same dosage of irrigation water migth obtain different levels of yield due to difference in N fertilizer application. However, the grain yield significantly depends on climatic conditions as well, such as temperatures, distribution of rainfall and relative humidity.

3.4 Cotton

Considering the regression analysis between yield and irrigation water applied for cotton, the yields and amount of irrigation water are given in Table 3. There were siginificant quadratic relationships between applied irrigation water and seed-cotton yield for all methods. In general, drip irrigation produced 21 % more seed-cotton than the furrow method. Hence, drip irrigation resulted in not only higher cotton yield but also considerable water savings. At the same time, the highest IWUE was recorded in drip-irrigated plots. The seed-cotton yields increased as long as the amount of irrigation water increased. The net return of 989 \$/ha per land area could be obtained at the amount of irrigation water of 10000 m^3/ha for furrow irrigation method. Whereas, the same net return was obtained at the amount of irrigation water of 8000 m^3/ha for drip irrigation method. The highest IWUE was computed for drip-irrigated cotton. Consequently, drip irrigation is the most effective method in terms of both obtaining maximum cotton yield and water conservation. Considering for all the circumstances; net return per land area, net return per unit water, IWUE, and water saving drip irrigation was more appropriate for the sustainability. Similarly, Kumar et al. (2008) stated that the yield corresponding to the same amount of “applied water” would be higher under micro irrigation. However, the appropriate amount of water and irrigation method depends on the farmers’ situation, his technical facilities and skills, and price of water (Cetin & Bilgel 2002).

The lower dosage of water applied meant lower water productivity or net return in this study. The farmers who applied higher dosage of irrigation (10000 m^3/ha) had the highest water productivity for furrow irrigation. The water productivity is highest for dosage of irrigation (8000 m^3/ha) for the drip irrigation. It is possible, thus, to achieve the twin-objectives of higher water productivity and higher yield through drip irrigation. The reason of the use of higher amount of irrigation water on providing higher water productivity for both furrow and drip irrigation could be attributed to the arid conditions during growing season. Additionally, lower cost of water might be considered, as the water costs were \$0.05 and 0.075 \$/m^3 for furrow and drip irrigation, respectively.

On the other hand, having the highest water use efficiency does not mean that net returns will be highest. Neither do high water use and maximum production mean maximum net returns. As more water is applied per land area, crop yields generally increase, but each increase in yield is less than for the previous unit of water applied. Thus, the IWUE generally decreases as water use increases (Buller et al. 1988). Targeted agronomic practices such as the choice of appropriate crop/cultivar for a specific environment as well as planting and harvesting times, adequate plant nutrition, soil management, and weed control can significantly contribute to improve IWUE.

3.5 Sugar beet

In this study, the effects of different lateral spacings and different amount of irrigation water on sugar beet yield were aimed (Tari et al. 2011). According to the calculations, the maximum net return per unit land area could be obtained from the treatment in which the lateral spacing was 90 cm and amount of irrigation water of 6600 m^3/ha (Table 4). However, considering water saving and net return per unit irrigation water could be also taken into accounted as a second range application (I_2 in Table 4). Because there were no significant differences in terms of net return per unit area.

Table 3. Comparing furrow and drip irrigation methods on net retun and irrigation water use efficiency for Southeatern Anatolia Region of Turkey (Adapted from Cetin & Bilgel 2002).

Irrigation water (m^3/ha)	Seed-cotton yield (kg/ha)		Irrigation water use efficiency (kg/ha/m^3)		Net return per unit area ($/ha)		Net return per unit water ($/$m^3$)	
	Furrow	Drip	Furrow	Drip	Furrow	Drip	Furrow	Drip
I_1(5000)	2094	3493	0.42	0.70	130.6	412.4	0.026	0.082
I_2(6000)	2473	3953	0.41	0.66	358.8	645.1	0.060	0.108
I_3(7000)	2810	4353	0.40	0.62	558.7	837.4	0.080	0.120
I_4(8000)	3105	4693	0.39	0.59	730.3	989.4	0.091	0.124
I_5(9000)	3358	4973	0.37	0.55	873.7	1100.9	0.097	0.122
I_6(10000)	3569	5193	0.36	0.52	988.8	1172.1	0.099	0.117
I_7(11000)	3738	5353	0.34	0.49	1075.6	1202.8	0.098	0.109
I_8(12000)	3865	5453	0.32	0.45	1134.1	1193.2	0.095	0.099

Table 4. Net return per unit land area and per unit water on sugar beet in Central Anatolia of Turkey (Adapted from Tari et al. 2011).

Irrigation amount of water (m^3/ha)	Sugar beet yield (t/ha)		Irrigation water use efficiency (kg/ha/m^3)		Net return per land area ($/ha)		Net return per unit water ($/$m^3$)	
	Lateral spacing (cm)		Lateral spacing (cm)		Lateral spacing (cm)		Lateral spacing (cm)	
	45	90	45	90	45	90	45	90
I_1(6660)	97.0	98.8	14.6	14.8	2094.8	2365.9	0.31	0.36
I_2(5390)	89.0	92.5	16.5	17.2	1807.9	2179.8	0.34	0.40
I_3(4120)	73.1	73.4	17.7	17.8	1053.1	1235.3	0.26	0.30
I_4(2850)	50.2	52.7	17.6	18.5	-116.8	195.7	-0.04	0.07

3.6 Silage corn

In this study, the different irrigation levels and different N fertigation frequencies on second crop silage corn (Yolcu 2014). All calculations are given in Table 5.

Considering the data from this study, fresh silage corn yield (87.8 t/ha), IWUE (19.6 kg/ha/m^3), net return per land area ($1053.1/ha) and net return per unit irrigation water ($ 0.61/m^3) were maximum at the treatment in which level of irrigation was 100 % Class A pan evaporation and application of one-fifth of the total amount of N fertilizer at the sowing date, with the remaining N applied at each irrigation cycle for 5 days based on 240 kg N/ha. This is an important finding for the feeding of animals, as well as sustainability of water and N use. Consequently, the lower amounts of irrigation water resulted in a significant decline in silage corn yield.

Table 5. The data on net return and IWUE for Southeastern Anatolia Region of Turkey for second crop silage corn (Adapted from Yolcu 2014).

Treatments	Irrigation water (m^3/ha)	Fresh yield (t/ha)	IWUE (kg/ha/m^3)	Net return per unit area ($/ha)	Net return per unit water ($/$m^3$)
I_1N_1	2850	54.9	18.9	-125.8	-0.11
I_1N_2	2850	58.4	20.5	47.7	0.04
I_1N_3	2850	58.6	20.5	52.3	0.05
I_2N_1	3660	64.1	17.5	201.2	0.14
I_2N_2	3660	66.2	18.1	281.9	0.20
I_2N_3	3660	71.8	19.6	498.5	0.35
I_3N_1	4470	69.4	15.5	342.7	0.20
I_3N_2	4470	73.8	16.5	514.6	0.30
I_3N_3	4470	87.8	19.6	1053.1	0.61
I_4N_1	5290	76.2	14.4	541.9	0.27
I_4N_2	5290	82.8	15.7	797.7	0.39
I_4N_3	5290	89.6	16.9	1058.5	0.52

The lower water productivity at high dosage of irrigation could be due to lack of proportional increase in yield, increase in cost of fertilizers which reduces the net returns, and increase in volume of water applied, which increases the value of denominator.

4. CONCLUSION

In this study, net return per unit land area and per unit water in the different regions of Turkey were computed as 430-6707 $/ha and 0.10-1.22 $/$m^3$, respectively. Considering IWUEs, irrigation water have not been used same efficiently in different regions of Turkey. Meanwhile, having the highest water use efficiency does not mean that net returns will be highest for all the crops. The most profitable use of water is somewhere between the amount that provides highest water use efficiency and the amount that provides for maximum yield.

Higher water used crops, such as cotton, silage corn and sugarbeet can be prioritized for water productivity improvement. Thus, the use of micro irrigation system will save significant amount of water compared to traditional method of irrigation such as level borders and furrows. Large-scale adoption of drip irrigation for cotton, corn and sugarbeet can, thus, serve as successful examples for efficient use of water. On the other hand, it could be stated that there are unfair competition between farmers in terms of water cost and prices in the different regions of Turkey. Because the water cost varied from $ 0.05 to $ 0.20 /m^3 according to the regions studied. In addition, the volumetric water tariffs must be considered according to actual water use by growers. This can contribute to ensuring.

As a result, one of the most important ways of ensuring sustainability of irrigated agriculture is to use micro irrigation, and it may help in saving significant amount of water and increase the quality and quantity of produce. Thus, it is possible to achieve the twin-objectives of higher water productivity and higher yield through drip irrigation. Irrigation scheduling ensured higher water prodcutivity and thus, is important in view of the global scale of fresh water crisis. However, ensuring sustainability is closely dependent on ensuring timely availability of other inputs such as nitrogen, crop variety, some agronomic applications, climate conditions etc.

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