AT FARM LEVEL UNDER PUBLIC AND CIVIL CANAL IRRIGATION SYSTEMS IN PESHAWAR VALLEY

Rabnawaz[1], Muhammad Jamal Khan[2], Tahir Sarwar[2], Muhammad Jamal Khan[3]

ABSTRACT

Agriculture consumes more water than any other human activity. In Pakistan, the contribution of irrigated agriculture is more than 90%, thus the sustainable water supply to meet the food and fibre demand of the ever increasing population is a big challenge. Increase in crop water productivity (CWP) is one of the most important options for sustainable use of water resources in semi-arid environment. A field study was conducted during *Rabi* 2010-11 and *Kharif* 2011 crop seasons to compare the CWP of main crops (sugarcane, wheat, maize and tomato) under public and civil canal irrigation systems in Peshawar Valley. For this purpose, 18 farms were selected under public canal system and 13 under civil canal systems. Results revealed that average CWP of wheat, maize, sugarcane and tomato was 0.96, 1.11, 3.31, 3.61 kg m^{-3} under public and 0.90, 0.77, 2.36, 2.98 kg m^{-3}, respectively. In public canal system, the average CWP of the selected crops was 7, 40, 44 and 21% higher than civil canal system, respectively. Low CWP in civil canal system was mainly attributed to over irrigation (because of high water allowance).

Quantitative analysis of the yield per unit volume of water applied was carried out using dummy-regression model. The difference in means for maize, sugarcane and tomato crop was found highly significant while in case of wheat it was non-significant. This study concludes that the public system remained more productive with high CWP at farm level for all the major crops. However, there is a great potential for increasing CWP under civil system by rationalizing the water allowance.

Keywords: Crop Water Productivity, Public Canal System, Civil Canal System, *Rabi*, *Kharif*

1. INTRODUCTION

Although, the issue of water scarcity is rarely talked about in Pakistan's politics, but it constitutes one of the biggest challenges to the country's survival with a projected population of 263 million by the year 2050. Water demand in the country for domestic, industry and environment is rapidly increasing resulting in stress on sustainable water supply to the irrigated agriculture, which contributes more than 90% of the total crop production. Annual per capita water availability in the country is < 1000 m^3, thus placing it in the list of water scarce countaries (Raheel, 2013).

Pakistan is blessed with many natural gifts and one of them is the surface irrigation system. Khyber Pakhtunkhwa (KP) has comparatively more potential to provide more water per unit area than any other systems in the country. Better rainfall with enough water has lead the development of extensive irrigation systems in the province. Out of two major irrigation systems in the province, the first is "public canal systems" where the principal management is the responsibility of Irrigation Department with farmers playing a subsidiary role at tertiary level. Second type is "civil canal systems" which is operated and maintained by the farmers with the government providing periodic

1 On Farm Water Management Department, Govt. of Khyber Pakhtunkhwa, Peshawar

2 Department of Water Management, The University of Agriculture, Peshawar

3 Department of Soil and Environmental Sciences, The University of Agriculture, Peshawar, *Corresponding author: Rabnawaz, Address:On Farm Water Management Department, Govt. of Khyber Pakhtunkhwa, Peshawar, Telephone: +92-91-9216257; Fax: +92-91-9216984, E-mail: drabnawaz97@gmail.com

technical or logistic support. Civil system is a combination of inundation canals taking-off from Kabul and Indus rivers were dug way back in the Mughal's era. The two systems commanding agriculture lands with similar cropping conditions in Peshawar valley have with different water allowance.

Crop water productivity (CWP) is a one of the indicator to compare the performance two systems with different water allowance and more or less same out put. CWP is defined as the physical mass of production or the economic value of production measured against gross inflows, net inflow, depleted water, process depleted water, or available water (Brauman, 2013). According to Liu et al., (2007) and Igbadun et al., (2006),CWP is a useful indicator for determining the impact of irrigation scheduling decisions. Deficit irrigation is a key strategy for increasing water productivity in water scarce areas. In crease in CWP is one of the pathway to get more crop per drop inarid and semiarid regions. MOREOVER, improvements in farm management practices-crop technology, timeliness of input use, and efficient use of water result in to enhancement of CWP (DEHGHANISANIJet al., 2008)**.**A study was conducted in winter (*Rabi*) and summer(*Kharif*) cropping season of2010-2011 with the objective to compare the CWP of Public and Civil Canal systems.

2. MATERIALS AND METHODS

Description of Study Area: The research area is located in district Peshawar basin (>5500 km^2) situated at the southern margin of the Himalaya with Federally Administered Tribal Areas (FATA), the Khyber Agency in the West, Mohmand Agency in north-west, Frontier Region (Semi-Tribal regions) and Kohat district in the south. The two settled districts of Charsadda and Nowshera are situated to its North and North-East, respectively.Peshawar lies between 33° 44′ and 34° 15′ north latitude and 71° 22′ and 71° 42′ east longitude. It consists of fine alluvial deposits with tracts of a rich, light and porous soil, composed of a pretty even mixture of clay and sand. Peshawarlies 358 meters above mean sea level with semi-arid climate having very hot summers (May to September) and mild winters (November to March). Unlike other parts of the province, Peshawar is not a monsoon region but still rainfall is received both in winter as well as summer (Nasreen, 2006).

The basin is irrigated by the Kabul River and its tributaries originating from *Unai Pass* in the *Paghman* Mountains near Kabul and reaches Warsak Dam, Peshawar. At the downstream end of Warsak Dam, the Moghul Emperor, Aurangzeb Alamgir, constructed inundation canals in late 1600s known as the Kabul River Canal System (KRC) as the first major system of the province. KP Irrigation department is the only institution either completely or partially regulating these irrigation systems in the province. Like other systems of the province, KRC is also a rigid supply-based system with a mixture of public as well as civil canals. In Public system, the the canals are operated/regulated completely by the Irrigation department. Civil canal system supplying water to30% of the total irrigated land in the province is managed by the community and exempted from *Abiana*(water charges).In the British era, written rules were introduced for operation and maintenance of this system called "*Kuliat and Rawajat-e-Aabpashi*" which are still used effectively. In Peshawar valley, Kabul River Canal (Public) and Joe-Sheikh Canal (Civil) are the two major canals(Table 1).Wheat-sugarcane in winter (*Rabi*) season and maize-sugarcane with tomato in summer (*Kharif*) season is the cropping pattern under both the systems despite enough water allowance. In order to compare the CWP of two systems, major crops in the command area i.e. wheat, maize, sugarcane and tomato were selected for which a multi-stage sampling scheme was adopted. KRC (public) and JSC (civil) providing a good chance of carrying out such a comparative study, were selected (Figure 1). Keeping the size of the above canals in view, three watercourses were selected at head, middle and tail regions of each system. Two farms (farmer's fields) each at head, middle and tail regions were also selected randomly, except civil canal where it

was not possible to select farms at the head region due to small land holdings. Hence, total 31 farms were selected on both the systems.

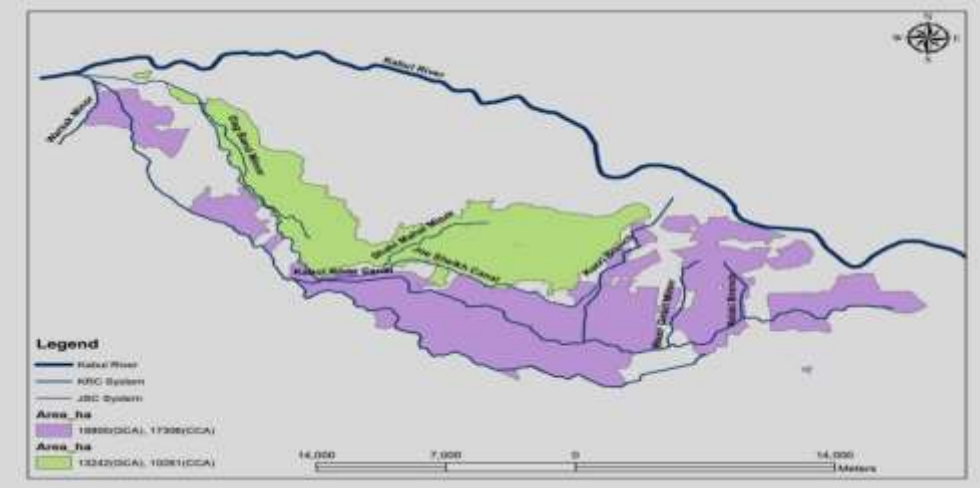

Figure 1: Digitized map of KRC & JSC

Crop Water Productivity: CWP of selected crops was determined in physical terms forboth public and civil canal systems using following equation(Igbadun et al*.,* 2006):

$$CWP = Yield \div SWA \quad \text{(Eq. 1)}$$

Where;
CWP = Crop water productivity ((kg m^{-3})
Yield = Crop yield (kg)
SWA = Seasonal water applied (m^3)

Yield: Crop produced in each of the selected field was actually measured upon harvesting. For this purpose, steel rings (1-2 m^2) prepared from the local market were used. Three samples from each selected field of all the crops were collected and yield was measured by weighing each sample on electronic scale. In case of wheat and maize, the grain and straw weight was measured separately.

Seasonal Water Applied (SWA): SWA to the selected crops during the whole growing seasonwas measured. Irrigation water supply (in each turn) to a field was measured through cut-throat flume. Rainfall data for the study period was obtained from Agricultural Research Station (ARS), Peshawar, effective rainfall (P_{eff}) was calculated by dependable rainfall method usingCropwat program. Accordingly, SWA to each crop was calculated using following expression (Igbadun et al.,2006):

$$SWA = (Q \times T \times N) + Peff \quad \text{(Eq. 2)}$$

where
SWA = Seasonal water applied (m^3)
Q = Discharge measured at farm level through a flume (m^3s^{-1})
T = Time per irrigation (s)
N = Total Number of irrigations
P_{eff} = Effective rainfall (m^3)

In order to test the significance of difference in mean CWP of two irrigation systems, dummy variables regression model was used through a computer software EViews6 (Gujarati, 2003).

$$CWP_i = \beta_0 + \beta_1 D_i + v_i \quad \text{(Eq. 3)}$$

Where;
CWP_i : Crop water productivity (kg m^{-3}) of i^{th} irrigation system
β_0 and β_1: Parameters (β_0 is benchmark category and shows CWP of civilsystem).
D_i : Dummy variable having the value of "1" if belongs to public irrigation system and 0 otherwise.
v_i : Error term

3. RESULTS AND DISCUSSION

The CWP values of wheat ranged from 0.83-1.06 kg m^{-3}under public and from 0.83-0.96 kg m^{-3} under civil system (Table2). Mean CWP of wheat under public system was 7% higher than civil system. Mean CWP of wheat under civil and public system was 0.90 kg m^{-3} and 0.96 kg m^{-3}, respectively. Regression results show that the difference in CWP of the two systems was not significant. DEHGHANISANIJet al., (2009) found CWP values of 0.50-1.80 kg m^{-3} for wheat crop and recommended 1.50 kg m^{-3} as an optimum level. Afshar (2004), Jehangir et al., (2007), Montazar and Kosri (2007), Ashraf et al., (2010), Cai et al., (2010) and Karrou (2012) observed CWP of 1.50, 1.48, 1.62,0.73, 0.94 and 1.53 kg m^{-3}, respectively. Singh (2005), Igbadun et al., (2006), Qureshi (2009) and Aiken et al., (2013) reported the CWP range of 1.22-1.56 kg m^{-3},0.40-0.55 kg m^{-3}, 0.45-0.85 kg m^{-3} and 0.28-0.62 kg m^{-3}, respectively. CWP of wheat in the present study was found slightly on lower side in both the systems; however, it was within the acceptable limits. There is still a huge gap between the actual and potential CWP.

CWP of maize ranged from 1.03-1.23 kg m^{-3}under public systems and 0.65-0.92 kg m^{-3} in civil system (Table 3). In public systemic of maize was 44% higher than the civil system. Mean CWP of maize under civil and public system was 0.77 kg m^{-3} and 1.11 kg m^{-3}. Regression results showed significant difference in CWP of maize between the twosystems. Igbadun et al., (2006) and Karrou (2012) reported CWP of 1.20-1.50 kg m^{-3} and 1.53-1.99 kg m^{-3} for maize. DEHGHANISANIJet al., (2009) reported CWP range of 0.30-2.30 kg m^{-3} and recommended optimum CWP value of 1.70 kg m^{-3} for maize crop. Afshar (2004), Montazar and Kosri (2007), Ashraf et al., (2010) determined the CWP of 1.70, 1.30 and 2.01 kg m^{-3}, respectively. In the resent study, CWP figures under public system were within the acceptable range while in case of civil system, it was quite low mainly due to excessive application of water and low crop yield.

For sugarcane, the CWP varied from 3.13-3.50 kg m^{-3} in public system and2.22-2.50 kg m^{-3}under civil system (Table4). In case of sugarcane, the CWP of public system was recorded 40% higher than the civil system. Mean CWP under civil and public system was 2.36 kg m^{-3} and 3.31 kg $m^{-}3$. Regression results showed significant difference in CWP of sugarcane between the two systems.Singh et al.(2005) obtained mean CWP of 7.1 kg m^{-3} for sugarcane while Ashraf et al., (2010) reported CWP value of 2.01 kg m^{-3}. In the present study, low crop yield and excessive water application were the major factors for low CWP values in civil canal system.

CWP of tomato ranged from 3.10-3.91 kg m^{-3} under public system and 2.75-3.53 kg m^{-3} in civil system (Table 5).Average CWP of civil and public system was 2.98kg m^{-3} and 3.61 kg m^{-3}, respectively. The average CWP of public system was found 21% higher than the civil system. Regression results showed significant difference in CWP of sugarcane between the two the systems.Rashidi (2008) reported CWP of 2.58-11.88 kg m^{-3}, while Montazar and Kosari (2007) reported CWP 6.77 kg m^{-3} for tomato crop. The findings of this study are in agreement with the previous studies.

4. SWA-YIELD RESPONSE

Overall 32% more water was applied to wheat crop under civil system as compared to public system. Maximum yield was obtained at410-450 mm water depth (Figure2) and further application resulted in yield decrease. However, the average SWA in both the systems was found less than the optimal range. Shahnaz et al., (2013) reported relatively higher yields of wheat under public system. Khan *et al*. (2004) reported a significant increase in wheat yield by applying 3rd irrigation during the month of March. In the present study, no irrigation was applied in March due to canal closure and the farmers had to rely on rainfall.

Similarly, maize crop was irrigated 3-4 times in the whole season, including pre-sowing application and 47% more water was applied to maize crop under civil system as compared to public system. In public system, average depth of water applied was less while under civil system, it was higher than the optimal range (Figure 3). A positive relationship was observed between the SWA and maize yield.Optimal range of 500-525 mm was observed as further application resulted in yield decrease.

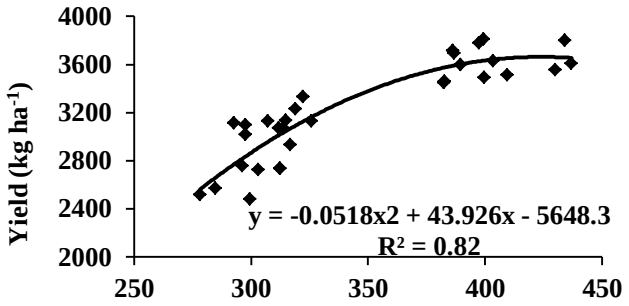

Figure 2. Yield-SW relationship (wheat)

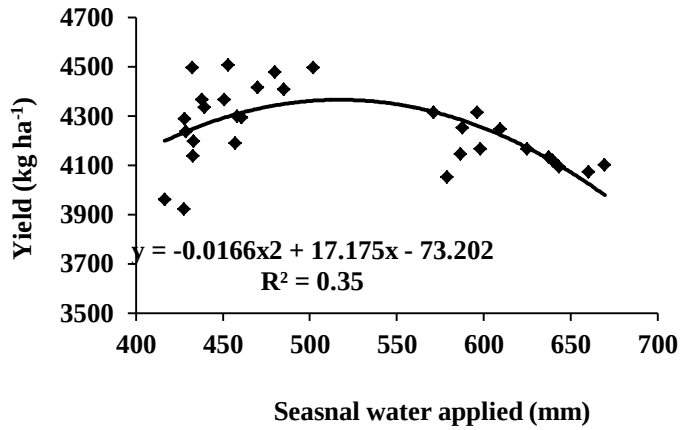

Figure 3. Yield-SWA relationship (maize)

Sugarcane was given 16-18 irrigations during the growing season where 43% more water was applied under civil system as compared to the public system. Alinear relationship was observed between the yield and SWA (Figure 4). Irrigation at critical stage may have resulted in yield increase and thus CWP.

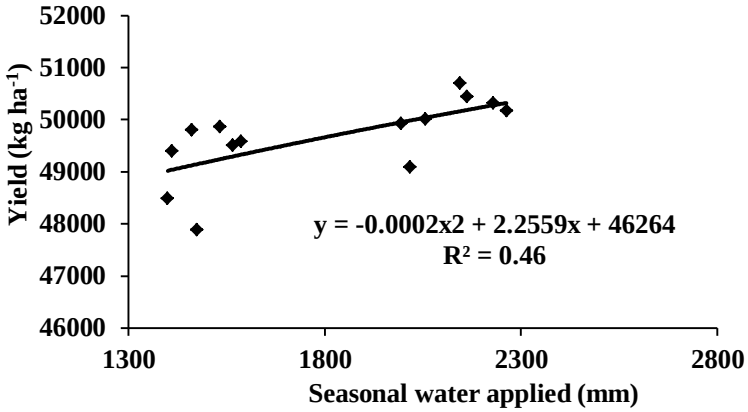

Figure 4. Yield-SWA relationship (sugarcane)

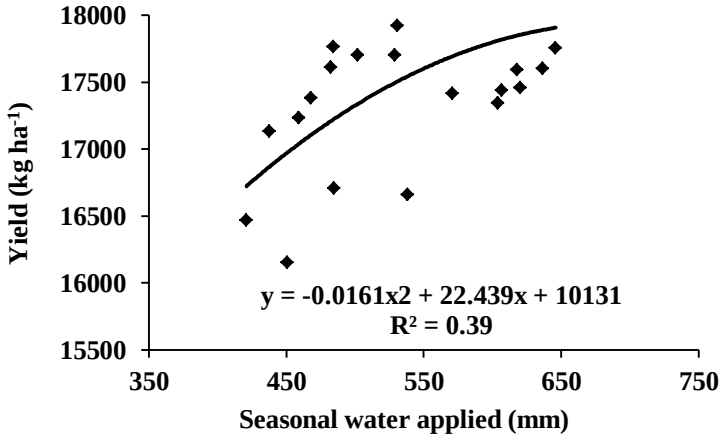

Figure 5. Yield-SWA relationship (tomato)

Tomato crop was irrigated 7-9 times in the growing season and the total volume of water applied under civil system was 26% higher than the public system. A positive relationship was observed between SWA and yield.In this study, optimumal yield was found at about 650 mm SWA. According to Jensen et al. (2010), total water need of tomato after transplantation is 400-600 mm thus supporting the results of this study.

In the above relationships, it has been noticed that the curvilinear relationship is stronger for maize than other crops. Hence, farmers cultivating maize have to be more careful in using excessive water allowance under civil system. CWP can be improved by educating farmers on irrigation scheduling in order to avoid unwanted water stress on plants as well as excessive water application.

Lower CWP values of civil system are mainly due to over irrigation and relatively lower yields, hence, there is enough scope to enhance the CWP. According to Rasiuba (2007), the yield increases linearly with increase in water supply until it reaches a plateau with maximum yield and it is likely that further application of water can result in to decline in CWP. In order to sensitize the farmers regarding efficient use of available water, the productive applied water and yield relationship is a good concept. In case of excessive water, farmers can irrigate crop to the point where marginal CWP is equal to zero. Any further application of irrigation water beyond point of zero marginal CWP is a waste of water because no further yield increase can be expected but possibly a yield decrease. Abbas et al., (2006)observed that irrigation water is not applied according to the crop demand at different growth stages and an integrated management plan is required to regulate irrigation needs according to crop

demand in both the systems. Moreover, there is critical water shortage during low discharge or canal closure period and wastage of water as surface runoff during forced irrigation turns and monsoon rains. As both the systems are supply based (rigid), the farmers have only two choices either to irrigate his field or miss his turn. Therefore, water is applied to the crop irrespective of its demand, resulting in to decline in to yield as well as CWP.

5. CONCLUSIONS

In the present study, CWP of all the selected crops under civil canal system was found low as compared to public canal system. However, the difference in CWP of two systems was significant for maize, sugarcane and tomato and non-significant for wheat crop. This difference is mainly attributed to the amount of water applied under two systems. No significant increase in the crop yield was observed despite frequent water application under civil system. The farmers in most of the cases apply water within a regime where the yield response to irrigation is positive. In certain situations, farmers' water application regime corresponds to a regime where response of yield and CWP to the irrigation is either positive or negative. There is ample scope for improving CWP in irrigated agriculture through water regulation, however, the farmers will go for this option only if there is sufficient land that can be brought under command to utilize the saved water.This study concludes that the public system remained more productive with high CWPat farm level for all the major crops.Hwever, there is a great potential for increasing CWP under civil system by rationalizing the water allowance.

6. ACKNOWLEDGEMENTS

I express my gratitude to everyone who supported me throughout the course of this study. I am indebted to the Higher Education Commission (HEC) Government of Pakistan for their financial assistance for the current research which enabled me to successfully complete my research work.

7. REFERENCES

Abbas, A., M. Saeed and M. Hussain. 2006. Existing irrigation practices and their improvement for enhancing water productivity. Pak. J. Water Res. 10(1).

Afshar H. 2004. Assessment of different deficit irrigation methods on yield and water productivity. Agri. Eng. Res. Institute, Research Report-33.

Aiken, R.M., D. M. O'Brien, B. L. Olson and L. Murray. 2013. Replacing fallow with continuous cropping reduces crop water productivity of semiarid wheat". Agron. J. 105:199–207.

Ashraf, M., N. Ahmed and M.M. Saeed. 2010. Evaluation of the existing water productivity in the lower bari doab canal command-a case study. Pak. J. Agric. Sci., 47(4):389-397.

Brauman K.A., S. Siebert and J. A Foley. 2013. Improvements in crop water productivity increase water sustainability and food security-a global analysis. Environ. Res. Lett. 8 024030.7.

Cai, X. and M.W. Rosegrant. 2010. An assessment of crop water productivity in the Indus and Ganges river basins: Current status and scope for improvement, IWMI, Sri Lanka.

Dehghanisanij H., M. M. Nakhjavani, A.Z. Tahiri and H. Anyoji. 2009. Assessment of wheat and maize water productivities and production function for cropping system decisions in arid and semiarid regions. Irrigation and drainage, 58(1):105-115.

Gujarati, D.N. 2003. Basic Econometrics. 4th Ed. McGraw-Hill/Irwin. New York, NY. 297-339.

Igbadun H.E., H.F. Mahoo, A.K.P.R., Tarimo and B.A. Salim. 2006. Crop water productivity of an irrigated maize crop in Mkoji Sub catchment of the Great Ruaha River Basin, Tanzania. Agric. Water Mgt. 85(1-2):141-150.

Jehangir, W.A., I. Masih, S. Ahmed, M.A. Gill, M. Ahmad, R.A. Mann, M.R. Chaudhary, A.S. Qureshi and H. Turral. 2007. Sustaining crop water productivity in rice-wheat systems of South Asia: a case study from Punjab, Pakistan. IWMI, Sri Lanka, Working Paper 115; 45.

Jensen, C.R.; Battilani, A.; Plauborg, F.; Psarras, G.; Chartzoulakis, K.; Janowiak, F.; Stikic, R.; Jovanovic, Z.; Li, G.; Qi, X.; Liu, F.; Jacobsen, S.; Andersen, M. N. 2010. Deficit irrigation based on drought tolerance and root signalling in potatoes and tomatoes. Agri. Water Mgt., V.98, 403-413.

Karrou, M., T. Oweis, R. Abou El Enein and M. Sherif. 2012. Yield and water productivity of maize and wheat under deficit and raised bed irrigation practices in Egypt. African J. Agric. Res., 7(11):1755-1760.

Kijne, J.W., R.Barker and D. Molden. 2003. Improving water productivity in agriculture: Editors' Overview. CAB Int. IWMI, Colombo, Sri Lanka.

Khan, R.M., M.Tahir and M. A. Ali. 2004. Effect of application time of last irrigation on wheat (Triticum aestivum L.). Yield Pak. J. life soc. sci., 2(1): 59-61.

Liu, J., J.R. Willium., A.J.B. Zehnder and H. Yang.2007. GEPIC-modelling wheat yield and crop productivity with high resolution on a global scale. Agric. Sys-94:478-493.

Montazar, A. and H. Kosari. 2007. Water productivity analysis of some irrigated crops in Iran. Bari: CIHEAM, Options Méditerranéennes: Série B. Etudes et Recherches; n. 56(1):109-120.

Nasreen, S. 2006. Monitoring of surface water groundwater air and soil in Peshawar basin against time the 3rd dimension. A Thesis-Excellence in Geology, Uni. of Peshawar.

Qureshi, A.S. T. Oweis, P. Karimi, J. Porehemmat. 2009. Water productivity of irrigated wheat and maize in the Karkheh River Basin of Iran. Irr. and Drainage, 59(3):264–276.

Raheel M. 2013. Pakistan's Biggest Challenge: The impending water crisis. American Pakistan Foundation.

Rashidi, M., and M. Gholami. 2008. Review of Crop Water Productivity Values for Tomato, Potato, Melon, Watermelon and Cantaloupe in Iran. Intl. J. of Agric. & Biology. 1560–8530.

Rasiuba, T.C. 2007. Water Budget, Water budget water use efficiency in agriculture in Olifants Catchment. Thesis (MSc), Johannesburg, South Africa: Uni. of the Witwatersrand.

Shahnaz, A. Arifullah, A.F. Chishti and M.J Khan. 2013. Public and private irrigation water resource management: Sugarcane crop water productivity and profitability compared". Sarhad J. Agric. 24(4):732-736.

Singh, R. 2005. Water productivity analysis from field to regional scale. Doctoral thesis, Wageningen University, Wageningen, The Netherlands.