The Journal of Animal & Plant Sciences, 22(1): 2012, Page: 224-232
ISSN: 1018-7081

APPROPRIATE CROPPING PATTERN AS AN APPROACH TO ENHANCING IRRIGATION WATER EFFICIENCY IN THE KINGDOM OF SAUDI ARABIA

Khodran H. Alzahrani, Siddig E. Muneer, Alla S. Taha and Mirza B. Baig

Department of Agricultural Extension and Rural Sociology, Faculty of Food and Agricultural Sciences, King Saud University, Saudi Arabia
Corresponding author e-mail: khodran@ksu.edu.sa

ABSTRACT

Fresh water is one of the most important and scarcest natural resources around the globe. In Saudi Arabia fresh water shortage for different uses represents one of the main challenges hindering development efforts in the country. As such there is a need to pursue a water demand management policy which should include any measure or initiative that will result in reduction of water usage and/or water demand. This study is intended to explore the potential of proper cropping pattern as a water demand management tool to enhance water and food security in Saudi Arabia. Secondary data were obtained from the ministry of Agriculture and Ministry of Electricity and Water. The analyses revealed that existing cropping pattern did not benefit from the relative advantage of different regions in producing different crops. Thus, there is a great potential for enhancing food and water security in Saudi Arabia through altering existing cropping pattern by encouraging production of different crops in the regions that have clear relative advantage in their production i.e. give the highest productivity. For example production of cereals could be concentrated in Jouf and Tabuk areas, while vegetables production in the eastern region and Asser area.

Keywords: cropping pattern, irrigation water, scarcity, food security, demand management, relative advantage, Saudi Arabia.

INTRODUCTION

Water is becoming scarce not only in arid areas but also in all regions of the world. Scarcity of fresh water resources represents one of the major challenges facing the world in general and Kingdom of Saudi Arabia (KSA) in particular. Population growth, high living standards as well as development plans in KSA will cause ever-increasing demands for good quality water in the municipal and industrial sector. At the same time, more irrigation water will also be needed to meet the increasing food and fibre needs of the growing population. Further, more water will be required for environmental concerns such as aquatic life, wildlife, recreation, and scenic values. Thus, increased competition for water can be expected in future, requiring efficient water demand management. Under these circumstances, improved management of water resources is the only key for future sustainable development in the KSA. Where sustainable development and improvement of standards of living require urgent reduction of dependence on non-renewable water resources, leaving these as a strategic reserve for drinking and household uses in the first place (Ministry of Economy and Planning, 2009).

Unlike water resource rich countries, pursuing a policy of water supply management, countries with scarce water resources need to pursue a water demand management policy. Water demand management (WDM) includes any measures/ initiatives that will result in reduction of water usage/demand based on taking action and necessary incentives to achieve efficient water use and increase awareness about water scarcity and the limited nature of water resources (Qunaibet, 2002; Zahrani *et al*, 2005). This can achieve a reduction of water demand by up to 30-50% without any deterioration in the pattern or standard of living (Zahrani *et al*, 2005).

Agriculture is the largest consumer of water with about 85% of freshwater being used for irrigation. Whenever the demand for freshwater increases: the competition between municipal, industrial and agricultural sector increases and it often ends up in reduction of the agricultural sector's share. This phenomenon is expected to continue with lesser freshwater available for agricultural use, intensifying in less developed arid region countries that already suffer from water, food, and health problems. Consequently, irrigated agriculture despite being the largest water-consuming sector faces challenge to produce more food with less water.

Poor water management in the agricultural sector is cited as the most frequent cause of inefficient water use in irrigation schemes (Jensen *et al*., 1990; Azhar *et al*., 2010; Azhar et. al., 2011a). This necessitates that water management in the agriculture sector must be coordinated with, and integrated into, the overall water management in the water-starved countries. Efficiency of irrigation is affected by several factors including water availability, accuracy of the design of the irrigation system, method of irrigation, soil type and properties, and good management of the field (Azhar, 2011). There are a wide range of options available for improving irrigation water use efficiency and productivity at the farm level (Omran, 2008; Azhar and Perera, 2011).

Water demand management (WDM) in the agricultural sector under conditions of water scarcity includes practices and management decisions of multiple natures such as: agronomic, economic, and technical. Its objectives are reduction of irrigation requirements, the adoption of practices leading to water conservation and savings in irrigation, reducing the demand for water at the farm, and increasing yields and income per unit of water used (Azhar et. al., 2011b). Virtual water, i.e. importing commodities having high water requirements and focusing production on other commodities that require less water, is considered a promising option for WDM in the agricultural sector (Bouwer, 2000).

During the past four decades water consumption in KSA increased about five times with the agricultural sector being the main consumer (86.5%) of the total water consumption. Non-renewable water is the principal source of water supply, which is a strategic stock and will be depleted if not handled with great care and used optimally. By 1986 Saudi Arabia's irrigation projects had begun to produce sufficient wheat for most of its needs, and it started to export wheat to the world market; this is argued to be use of non-renewable fossil water, as production of cereals and wheat requires large amounts of water (Allan, 1997). This is an example of the lack of allocative efficiency for high-yielding crops, low technical efficiency as well as not exploiting the trade in virtual water. In view of the foregoing, the present study aimed at identifying the most important aspects of inefficiency in water consumption at the national level, measures for improving water use efficiency at the farm level, and visualization of a model for WDM in the agricultural sector in Saudi Arabia.

Water use Efficiency and National Water Security: Water use efficiency can be achieved through two approaches viz: i) technical or productive efficiency, and ii) allocative or economic efficiency (Allan, 1999). The term water use efficiency captures what farmers, industries, services, communities, national water departments and national governments have to consider for achieving improvements in use of water. The technical efficiency can be achieved by using more efficient technologies such as drip and sprinkler irrigation instead of traditional flood irrigation and by more efficient scheduling of water applications (Azhar, 2011); whereas, allocative efficiency is based on the principal that which activity brings the best return to water?, and is relevant at the farm level when the return to a high value crop such as fruit and out-of-season vegetables for an international or local market would be much more than to a crop such as wheat or rice. In services and industry economic returns to a cubic meter of water can be thousands of times more than that of agriculture.

Another WDM tool is via trade in `Virtual Water' (Allan, 1996). Water-short areas can minimize their use of water by importing commodities that take a lot of water to produce like food and electric power from other areas or countries that have more water. The receiving areas then are not only getting the commodities, but also the water that was necessary to produce them. Since this water is `virtually' embedded in the commodity, it is called virtual water (Allan, 1998). It is probably the easiest way to achieve peaceful solutions to water conflicts.

Creating an enabling environment for improved water use efficiency: The continued depletion of water resources in many parts of the world is a clear indication that options for improving water use efficiency are not being adopted. This is largely because enabling policies are missing. Most, if not all, of the policy measures used to support agriculture currently act as powerful disincentives against sustainability (Pretty, 1995). For example, Saudi Arabia during the last three decades produced sufficient wheat for most of its needs, and started to export wheat to the world market. This was a result of a policy of direct support to producers of wheat.

Improved water use efficiency at farm level: Increasing water productivity is an obvious way to reduce stresses that come from overuse of water in agriculture (Molden *et al*., 2007). Technical efficiency includes improving efficiency by using less water. In developing countries, up to 30% of fresh water supplies are lost due to leakage, and in some major cities losses can run as high as 40% to 70%, and in KSA leakage losses are about 35% (The Global Development Research Centre, 2010). Improving irrigation efficiency means how to take advantage of available irrigation water effectively.

Estimates revealed that about 30% of water is wasted in storage and conveyance, about 44% of the total water available at the source is lost as runoff and drainage, and 13–18% of the initial water resource is lost through transpiration by crops in irrigated agriculture (Qadir, *et al*. 2003). Therefore, improving the efficiency of water use through water use efficiency, water conveyance efficiency, and water application efficiency is the key solution to reduce water demand in the agricultural sector.

There is wide range of options available for improving irrigation water use efficiency and productivity at the farm level (Table 1). Poor management is cited as the most frequent cause of inefficient water use on irrigation schemes (Jensen *et al*., 1990). Indeed, it is clear that few of the options listed in Table 1 will result in a significant increase in efficiency if the overall management is poor.

Many of the water demand management options (Table 1) are available to diffusion and adoption by farmers. For example, demand-based on irrigation scheduling, deficit irrigation and use of treated municipal wastewater for irrigation can be used to reduce water demand for irrigation.

Scheduling of irrigation water include adding irrigation water to the plant on scientific basis that takes into account several factors affecting plant water requirement. It is recognized that the adoption of appropriate irrigation scheduling practices could lead to increased yields and greater profit for farmers, significant water savings, reduced environmental impacts of irrigation and improved sustainability of irrigated agriculture (Smith *et al*., 1996).

Table 1. Options available for improving irrigation efficiency at the farm level

Category	Examples of options available
Water use Efficiency	- Improved crop husbandry. - Introduction of higher yielding varieties. - Adoption of cropping strategies that maximize cropped area during periods of low potential evaporation and periods of high rainfall
Water Conveyance Efficiency	- Laser leveling of flood irrigation schemes to improve irrigation uniformity. - Introduction of more efficient irrigation methods, such as drip/sprinkler irrigation. - Improve uniformity and reduce drainage.
Water Application Efficiency	- Improved maintenance of equipment. - Adoption of demand-based irrigation scheduling systems. - Use of deficit scheduling. - Better use and management of saline and waste water. - Improve the physical properties of soil, supplement soil by natural conditioners, industrial conditioners. - Improved agricultural practices i.e. choosing appropriate sowing date, selection of appropriate agricultural density, good and proper fertilization, weed and pest etc. - Expansion in the use of greenhouses.

Source: (After Wallace and Batchelor, 1997; Omran, 2008)

The use of different WDM tools depends on soil factors, the nature of the plant and most important are the climatic factor. Alderfasi, *et al*. (1999) indicated that there was no significant difference in the amount of production per hectare of wheat in the Central Region of Saudi Arabia when the crop was irrigated one or two irrigations per week. This will result in a significant reduction in the amount of water needed to irrigate wheat. Experiments also showed that tomatoes and cucumbers can be produced in greenhouses with 30% and 40% less water requirements, respectively without significantly reducing the productivity of these two crops (Abdulgader *et al*., 2001).

Much research has focused on improving wheat productivity under drought conditions either by selection of drought-resistance varieties or by improvement of irrigation water management. The use of treated municipal waste water (TMWW) has been encouraged in Saudi Arabia during the last decade to increase the efficient use of water irrigation in crop production. For this reason, field experiments were conducted during the 1994-1995 and 1995-1996 seasons at the Agricultural Experimental Station in Dirab, Riyadh on a calcareous soil. The study concluded that the use of treated municipal waste water (TMWW) as a source of agricultural irrigation led to a significant increase in yield productivity and stability especially in water-limited environments.

Irrigation methods such as drip irrigation can be used effectively to increase the yields, crop quality and water use efficiency of many crops. Further, genetic engineering techniques and election of the plants with genotypes resistant to drought can be used to reduce the amount of irrigation water. It is also possible to increase water-use efficiency by 25–40% through modifying practices that involve tillage and by 15 to 25% through soil nutrient management (Hatfield *et al*., 2001).

METHODOLOGY

Data about the iriigation methods used, areas and total production of the different crops in the different regions in 2009 was obtained from the agricultural statistical year book which is published by Ministry of Agriculture. Productivity of the different crop groups in the different regions and the difference in these crops productvity in the different regions was calculated. The least significant difference test (LSD) was used to examine whether the difference in the productivity of the different crop groups in the different regions is statistically significant.

RESULTS AND DISCUSSION

Since the scarcest agricultural resource in Saudi Arabia is water, the cropping pattern should be based on maximizing return per unit of water. This will enhance both food and water security. Table (2) reveals that the maximum return per unit of water is obtained from vegetables, followed by Dates and lastly wheat. Thus to enhance water security through water demand management in the long run, agricultural development plans should emphasize expansion of vegetables and fruits production and make use of `Virtual Water' (Allan, 1996) by importing cereals for human and animals uses.

Table 2. Estimated returns for some major crops per unit of water

Crop	Rate of Water Consumption (m^3/ha/year)	Average Productivity (tons/ha)	Producer prices (SR/ton)	Returns on water (SR per 1000 m^3 of water)
Wheat	8000	4.88	1000	610
Vegetables (tomatoes, onions, potatoes)	15000	20.5	1500	2050
Dates	26000	6.25	6100	1466

(Source: Ministry of Agriculture, 2009).

On the other hand, in the short run and under the existing cropping pattern water security could be enhanced by benefiting from the comparative advantage of the different areas in producing the crops that give the highest yield. For example, the cereals crops give very high productivity in Jouf, Tabouk and Hail regions amounting to 6.81, 6.40 and 6.26 tons/hectare, respectively compared to the other regions (Table 3). However, it fell to 4.86 tons/hectare in Riyadh region which ranks third in comparative advantage in cereals production. Table (3) indicates that there is no significant difference in cereals productivity in Jouf & Tabuk regions and Tabuk & Hail regions; and the difference between Jouf & Hail is modest and only significant at 0.05 level of significance. On the other hand, cereals productivity in these three regions is significantly higher than in any of the other regions (Table 3). Ironically, under the current cropping pattern Jazan region which has the lowest productivity of cereals (2.2 tons/hectare), has the largest area cultivated with cereals i.e. 27.03% of the cereals total area as shown in Table 8. On the other hand, Tabuk region which ranks second in term of cereals productivity ranks seventh in term of cereals area with only a share of 5.53% of the cereals total area. These figures clearly indicate the potential of enhancing water and/or food security by encouraging cereals production in Jouf, Tabuk and Hail regions.

Regarding vegetables production, the Eastern region gives the highest productivity (39.79 ton/hectare), followed by Tabouk, Asseer, Hail and Quaseem regions (Table 3). While vegetable productivity in the Eastern region is significantly higher than in any other region, the difference of vegetable productivity between Tabouk, Asseer, Hail and Quaseem is not significant (Table 4). It worth mentioning that the Eastern region which ranks 1st in terms of vegetable productivity and Asseer region which ranks 3rd, come in the 6th and 11th rank in terms of cereals productivity respectively, (Table 3). Under the current cropping system, the Eastern region which gives the highest productivity of vegetables, it ranks 5th in term of vegetables cultivated area with only 6.24% of the vegetables total area and Asser which ranks 3rd has only 2.57% of the vegetables total area (Table 8). On the other hand, Riyadh region which ranks 9th in terms of vegetable productivity (Table 3) ranks 1st in terms of vegetables cultivated area (45.62%) of the vegetables total area (Table 8).

As depicted in Table 3, the top five regions that give the highest productivity of fodder crops are Jouf, Tabuk, Hail, Quasseem and Riyadh. The least significant difference test (LSD) has indicated no statistically significant difference in fodder crops productivity between any of these five regions (Table 6). Apart from Riyadh region, the other four regions rank top in productivity of cereal and vegetable crops. Thus, it is intuitive that Riyadh is the region where fodder production should be concentrated. Since fodder crops have high water requirements and are not perishable, its domestic production should be limited and instead be imported to make use of virtual water. Unlike other crops, fodder production under the current cropping pattern seems to be proper where Riyadh region which appears to have the best relative advantage in fodders productions ranks 1st in terms of fodder cultivated area with a share of 48.14% as shown in Table 8.

The six regions that give the highest productivity of vegetables in a descending order are the Eastern, Tabuk, Najran, Baha, Makkah and Asser (table 3). Apart from the eastern region there is no statistically significant difference in the mean productivity of fruits in other five regions (Table 7). Most of these regions, except Baha and Makkah regions, have clear relative advantage (high productivity) in production of other crops; cereals and vegetables. Thus, to enhance food and water security in the country fruit production should be concentrated in Baha and Makkah regions which have less relative advantage in production of other crops. Ironically under the current cropping pattern Baha and Makkah regions which rank 4th and 5th in terms of fruits' productivity, rank 12th and 7th in terms of percentage of the fruit's total area with shares of 1.4% and 6.9%, respectively (Table 8).

Table 3. Average productivity of various crop groups in different regions (tons/hectare)

Cereal		Vegetables		Fodders		Fruits	
Region	**Production**	**Region**	**Prod**	**Region**	**Prod**	**Region**	**Production**
Jouf	6.81	Eastern	39.79	Jouf	18.71	Eastern	12.24
Tabuk	6.40	Tabuk	28.08	Tabuk	18.55	Tabuk	9.41
Hail	6.26	Aseer	27.72	Hail	18.46	Najran	9.19
Riyadh	4.86	Hail	26.81	Qaseem	17.09	Baha	8.28
Qaseem	4.76	Qaseem	25.12	Riyadh	16.94	Makkah	8.20
Eastern	4.33	Jouf	24.47	Eastern	16.34	Aseer	8.19
Northern	4.30	Najran	24.21	Baha	16.12	Hail	6.99
Madenah	3.91	Baha	24.07	Jazan	15.78	Jazan	6.59
Baha	3.27	Riyadh	21.69	Aseer	15.60	Madenah	6.33
Najran	3.25	Madenah	18.02	Madenah	15.40	Riyadh	6.15
Aseer	2.80	Makkah	16.78	Najran	15.03	Northern	6.10
Makkah	2.27	Jazan	13.90	Northern	12.63	Jouf	5.44
Jazan	2.20	Northern	13.48	Makkah	11.23	Qaseem	5.15

Table 4. Differences between mean productivity of cereals in different regions (ton/hectare)

region	Jouf	Tabuk	Hail	Riyadh	Qaseem	Eastern	Northern	Madenah	Baha	Najran	Aseer	Makkah	Jazan
Jouf													
Tabuk	0.411												
Hail	0.547*	0.136											
Riyadh	1.988***	1.577***	1.44***										
Qaseem	2.041***	1.63***	1.494***	0.052									
Eastern	2.478***	2.067***	1.931***	0.49**	0.437								
Northern	2.507***	2.095***	1.96***	0.518**	0.465	0.028							
Madenah	2.902***	2.491***	2.355***	0.914***	0.861**	0.424	0.395						
Baha	3.537***	3.125***	2.99***	1.548***	1.495***	1.058***	1.03***	0.634**					
Najran	3.565***	3.154***	3.018***	1.577***	1.524***	1.087***	1.058***	0.662**	0.028				
Aseer	4.005***	3.594***	3.4558***	2.017***	1.964***	1.527***	1.498***	1.102***	0.468	0.44			
Makkah	4.538***	4.127***	3.991***	2.55***	2.497***	2.06***	2.031***	1.635***	1.001***	0.972***	0.532**		
Jazan	4.605***	4.194***	4.058***	2.617***	2.564***	2.127***	2.098***	1.702***	1.068***	1.04***	0.6*	0.067	

*sig. at 0.05 **sig. at 0.01 ***sig. at ≤ 0.001

Table 5. Differences between mean productivity of vegetables in different regions (ton/hectare)

region	Eastern	Tabuk	Aseer	Hail	Qaseem	Jouf	Najran	Baha	Riyadh	Madenah	Makkah	Jazan	Northern
Eastern													
Tabuk	11.711***												
Aseer	12.072***	0.361											
Hail	12.977***	1.265	0.904										
Qaseem	14.668***	2.957	2.595	1.691									
Jouf	15.317***	3.605*	3.244	2.340	0.648								
Najran	15.581***	3.87*	3.508	2.604	0.912	0.264							
Baha	15.722***	4.011*	3.65*	2.745	1.054	0.405	0.141						
Riyadh	18.094***	6.382***	6.021***	5.117**	3.425	2.777	2.512	2.371					
Madenah	21.770***	10.058***	9.697***	8.792***	7.101***	6.452***	6.188***	6.047***	3.675*				
Makkah	23.004***	11.292***	10.931***	10.027***	8.335***	7.687***	7.422***	7.281***	4.91**	1.234			
Jazan	25.887***	14.175***	13.814***	12.91***	11.218***	10.570***	10.305***	10.164***	7.792***	4.117*	2.882		
Northern	26.310***	14.598***	14.237***	13.332***	11.641***	10.992***	10.728***	10.587***	8.215***	4.540*	3.305	0.422	

*sig. at 0.05 **sig. at 0.01 ***sig. at ≤ 0.001

Table 6. Differences between mean productivity of fodders in different regions (ton/hectare)

region	Jouf	Tabuk	Hail	Qaseem	Riyadh	Eastern	Baha	Jazan	Aseer	Madenah	Najran	Northern	Makkah
Jouf													
Tabuk	0.16												
Hail	0.247	0.087											
Qaseem	1.621	1.461	1.374										
Riyadh	1.768	1.608	1.521	0.147									
Eastern	2.372*	2.212*	2.125*	0.751	0.604								
Baha	2.595*	2.435*	2.348*	0.974	0.827	0.222							
Jazan	2.932**	2.772**	2.685*	1.311	1.164	0.560	0.337						
Aseer	2.962**	2.802**	2.715*	1.341	1.194	0.590	0.367	0.03					
Madenah	3.307***	3.147**	3.06**	1.685	1.538	0.934	0.711	0.374	0.344				
Najran	3.685***	3.527***	3.438**	2.064	1.917	1.312	1.09	0.752	0.722	0.378			
Northern	6.057***	5.915***	5.828***	4.454***	4.307***	3.702***	3.48***	3.142**	3.112**	2.768**	2.39*		
Makkah	7.480***	7.320***	7.232***	5.858***	5.711***	5.107***	4.884***	4.547***	4.517***	4.172***	3.794***	1.404	

*sig. at 0.05 **sig. at 0.01 ***sig. at ≤ 0.001

Table - 7. Differences between mean productivity of fruits in different regions (ton/hectare)

region	Eastern	Tabuk	Najran	Baha	Aseer	Makkah	Hail	Jazan	Madenah	Riyadh	Northern	Jouf	Qaseem
Eastern													
Tabuk	2.830***												
Najran	3.34***	0.51											
Baha	3.955***	1.125*	0.615										
Aseer	4.048***	1.218*	0.708	0.092									
Makkah	4.034***	1.204*	0.694	0.078	0.014								
Hail	5.245***	2.415***	1.905***	1.29*	1.197*	1.211*							
Jazan	5.642***	2.812***	2.302***	1.687**	1.594**	1.608**	0.397						
Madenah	5.91***	3.08***	2.57***	1.954***	1.861***	1.875***	0.664	0.267					
Riyadh	6.087***	3.257***	2.747***	2.131***	2.038***	2.052***	0.841	0.444	0.177				
Northern	6.138***	3.308***	2.798***	2.182***	2.09***	2.104***	0.892	0.495	0.228	0.051			
Jouf	6.798***	3.968***	3.458***	2.842***	2.75***	2.764***	1.552**	1.155	0.888	0.711	0.66		
Qaseem	7.084***	4.254***	3.744***	3.128***	3.035***	3.05***	1.838**	1.441*	1.174*	0.997	0.945	0.285	

*sig. at 0.05 **sig. at 0.01 ***sig. at $\le$ 0.001

Table (8) Area cultivated by main crop groups in different region as percentage of the total area cultivated by respective group

Cereal		Vegetables		Fodders		Fruits	
Region	Area as % of total area	Region	Area as % of total area	Region	Area as % of total area	Region	Area as % of total area
Jazan	27.03993	Riyad	45.6234	Riyadh	48.1388	Riyadh	21.97644
Jouf	20.73435	Qaseem	10.69398	Qaseem	11.38296	Qaseem	18.45267
Hail	12.44049	Makah	10.57783	Madena	1.775302	Jouf	11.28929
Riyadh	10.60948	Hail	9.643971	Jouf	9.439081	Hail	10.0432
Eastern	9.560271	Eastern	6.243853	Hail	7.447733	Madena	9.949947
Qaseem	8.789718	Jouf	3.869391	Jazan	7.159302	Eastern	7.487027
Tabuk	5.532588	Tabuk	3.571529	Tabuk	6.456834	Makkah	6.894504
Makkah	2.71899	Jazan	3.472242	Makkah	2.768252	Tabuk	4.136786
Aseer	2.063731	Aseer	2.581467	Eastern	2.671761	Aseer	3.607823
Najran	0.24306	Madena	1.906127	Najran	1.465656	Najran	2.491355
Baha	0.199863	Najran	1.404071	Aseer	1.15907	Jazan	2.269734
Madenah	0.063579	Baha	0.341885	Baha	0.131255	Baha	1.384504
Northern	0.003955	Northern	0.07025	Norther	0.004001	Northern	0.016726
Total	100	Total	100	Total	100	Total	100

Conclusion: These results indicate that there is a great potential for enhancing food and water security in Saudi Arabia through altering the existing cropping pattern by encouraging production of different crops in regions that have clear relative advantage in their production (i.e. give the highest productivity). For example production of cereals could be concentrated in Jouf and Tabuk areas, while vegetables production in the eastern region and Asser area. This is particularly possible at the present time since different regions and parts of the country are well connected with a network of highways which makes it possible to transport agricultural products from its area of production to any local market in a very short time. Nevertheless, this study did not take into consideration the total area suitable for agricultural production and the country's total demand for different crops which are factors that deserve close attention when deciding on the final optimum cropping pattern. Thus, the results of this study should be looked at as providing signals for potential of enhancing food and water security in the country by reconsidering the existing cropping pattern, but a detailed socioeconomic and farming system study is needed to work out the details of optimum farming system.

Acknowledgement: The authors are grateful to the King Saud University, Deanship of Scientific Research, College of Food and Agricultural Sciences, Research Center, for extending all possible assistance, cooperation and needed support towards the completion of the project.

REFERENCES

Abdulgader, A. M., A. A. Ali, A. Alwathig, and K. Ownginiko (2001). The effect of different quantities of irrigation water on productivity of Tomato and Cucumber produced in Green Houses in Saudi Arabia. A technical and economic study. Proceedings of the Arabian Gulf Water 5th Conference held in Doha (Qatar): March 24 – 28, 2001: pp 339 – 350.

Alderfasi, A. A., M. S. AL-Sewailem, F. A. AL-Yahya, K.A. Kamel, and A. Aleter (2002). Effect of irrigation with treated municipal waste water on wheat production under drought stress conditions. J. King Saud Univ., Agric. Sci., 14(1):57-73.

Alderfasi, A. A., M. O. Ghandorah, and K. A. Moustafa. (1999). Evaluation of some wheat genotypes under drought stress in arid region of Saudi Arabia. Alex. J. Agric. Res. 44(3):209 217.

Allan, J. A., (1999). Productive efficiency and allocative efficiency: why better water management may not solve the problem. Agricultural Water Management 40, 71-75

Allan, J. A., (1998). Watersheds and problemsheds: explaining the absence of armed conflict over water in the Middle East. Middle East Review of International Affairs 2 (1).

Allan, J. A. (1996). Policy responses to the closure of water resources: regional and global issues. In: Howsam, P., Carter, R.C. (Eds.), Water policy: allocation and management in practice. E&FN Spon, London, pp. 3-12

Allan, J. A. (1997). Virtual water: a long term solution for water short Middle Eastern economies? In: Proceedings of the Paper Presentation at the 1997 British Association Festival of Sciences, University of Leeds, Water and Development Session, 9 September 1997. Available at http://www2.soas.ac.uk/geography/waterissues/.

Azhar, A. H., M. N. Bhutta, and M. Latif. (2010). Reclamation of irrigated agriculture through tile at Fourth Drainage Project, Faisalabad. The J. Anim. Plant Sci. 20 (3):211-216.

Azhar, A. H. (2011). Irrigation Analytical Report: Field Visit of Diamer Basha Dam (DBD) Project Area – Chilas. Land Acquisition & Resettlement (LA&R), WAPDA, Lahore – Pakistan pp 45.

Azhar, A. H. and B. J. C. Perera (2011). Planning and Operation of Irrigation Systems – Judicial use of Limited Water Resources for Enhanced Water Productivity. VDM Verlag Dr. Muller GmbH & Co. KG, Germany, USA, UK., ISBN: 978-3-

Azhar, A. H., M. M. Alam, and M. Latif (2011a). Subsurface Drainage Impacts on Cropping Intensity in Pakistan. The J. Anim. Plant Sci. 21(1): 97-103.

Azhar, A. H., C.M. Ashraf, and M. Ahmad (2011b). Modern Irrigation Techniques and Technologies – Efficient Utilisation of Scarce Water Resources. VDM Verlag Dr. Muller GmbH & Co. KG, Germany, USA, UK., ISBN: 978-3-639-36459-0, pp153.

Bouwer, H. (2000a). Integrated water management: emerging issues and challenges. Agric. Water Manage. 45, 217–228.

Hatfield, J. L., T. J. Sauer, and J. H. Prueger (2001). Managing soils to achieve greater water use efficiency. Agron. J. 93, 271–280.

Molden, D., D. Binb, R. Loevec, R. Barkera, and T. P. Tuongd (2007). Agricultural water productivity and savings: policy lessons from two diverse sites in China, Water Policy Vol. 9 No S1 pp 29–44

Ministry of Agriculture (2009). Agricultural Statistical Yearbook. Riyadh (Saudi Arabia). Ministry of Agriculture.

Ministry of Economy and Planning (2005). The 8th Development Plan. Riyadh (Saudi Arabia), Ministry of Economy and Planning.

Ministry of Economy and Planning (2009). Achievements of the 8th development plan. Riyadh (Saudi Arabia), Ministry of Economy and Planning.

Omran, A. A. M. (2008). Water requirements for irrigation and rationalization. King Saud University Press.

Pretty, J. N. (1995). Regenerating agriculture: policies and practice for sustainability and self-reliance, Earthscan, London.

Qunaibet, M. H. (2002). Agriculture and Water in Saudi Arabia. A paper presented to: The future vision of the Saudi Economy Symposium. Riyadh (Saudi Arabia). Ministry of Economy and Planning.

Jensen, M. E., W. R. Rangeley, and P. J. Dieleman (1990). Irrigation trends in world agriculture. In: Stewart, B.A., Nielsen, D.R. (Eds.), Irrigation of Agricultural Crops. Agronomy Monograph 30, ASA, Wisconsin, USA, pp. 31-67.

Qadir, M., T. M. Boers, S. Schubert, A. Ghafoor, and G. Murtaza (2003). Review: Agricultural water management in water-starved countries: challenges and opportunities. Agricultural Water Management 62: 165–185

Smith, M., L.S. Pereira, J. Beregena, B. Itier, J. Goussard, R. Ragab, R.L. Tollefson, and P.V. Hoffwegen (Eds.) (1996). Irrigation Scheduling: From Theory to Practice. FAO Water Report 8, ICID and FAO, Rome.

The Global Development Research Centre (2010). Urban water resources management. http:// gdrc. org/ uem/ water

Wallace, J.S., and C.H. Batchelor (1997). Managing water resources for crop production. Phil. Trans, R. Soc. London. B 352: 937- 947.

Zahrani, K.H., E.M. Alshfei, S. Algahtani and A. Alhamid (2005). Changing the household water consumption pattern as an approach for water demand management. Riyadh (Saudi Arabia): King Saud University, Scientific Research Deanship.