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Full Length Research Paper

Assessment of irrigation schemes in Turkey based on management types

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Increasing population and demand for food, combined with finite land and water resources makes developing and monitoring the performance of irrigation systems inevitable in the 21st century. This study presents a comparative performance analysis of irrigation schemes based on their management types (State Hydraulic Works (SHW) and Water User Associations (WUAs)-operated schemes). The assessment used the International Water Management Institute (IWMI)'s six performance indicators for the year 2001. Analysis of variance (ANOVA) test results indicated that the differences in the output per cropped area (OPCA), output per unit water consumed (OPUWC), and irrigation intensity (II) between the two management types were statistically significant, whereas the differences in the output per unit command (OPUC), output per unit irrigation supply (OPUIS), and relative water supply (RWS) between the two management types were not significant. Although the II was higher and RWS was lower in the WUAs-operated schemes comparing with SHW, the other indicators (OPCA, OPUIS and OPWC) were also lower in the WUAs-operated schemes except for OPUC indicator. This suggests that the WUAs-operated schemes are not optimally managed, possibly due to factors such as inappropriate crop pattern and intensity, irrigation infrastructure, lack of an effective monitoring and evaluation system, insufficient awareness among managers and farmers, or unstable administrative structure.

Key Words: Comparative indicators, irrigation project, management types, irrigation management, performance, Turkey.

INTRODUCTION

Increasing competition for finite land and water resources requires these resources to be developed, monitored, and evaluated. Shortage of water, exacerbated by unregulated water use, is a serious global problem (Rey et al., 2007). Water is expected to become a vital subject of discussion in continued national and international efforts (Khairy et al., 2001) to determine precisely what problem occur as a result of water scarcities and accelerating water contamination (Tanriverdi, 2005). Seventeen percent of the agricultural land in the world (280 million ha) is currently irrigated. Thirty-six percent of the total agricultural production is from irrigated agricultural land and 70% of water consumption is attributed to agriculture (Wolff et al., 1995), despite agriculture providing lower social and economic returns compared with industry returns (Perry, 2005). Therefore, water management of irrigated agriculture is very important in meeting the food requirement of the increasing world population (Wolff et al., 1995; Gal et al., 2003; Tanriverdi, 2005; Tanriverdi, 2006). The principal purpose of irrigation projects is to increase agricultural production, and hence, the wealth of people. Nevertheless, in many developing countries including Turkey, the performance of irrigation projects is lower than expected.

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Abbreviations: SHW, State hydraulic works; **WUAs,** water user associations operated schemes; **IWMI,** international water management institute; **ANOVA,** analysis of variance; **OPCA,** output per cropped area; **OPUWC,** output per unit water consumed; **OPUC,** output per unit command; **OPUIS,** output per unit irrigation supply; **RWS,** relative water supply.

Assessing the performance of irrigated agriculture is necessary in evaluating the impact of field-level agricultural and hydrological interventions. The ultimate objective of performance assessment is to achieve effective and efficient performance of the institution by providing relevant feedback to the management at all levels (Bandara, 2003). Therefore, the first performance level of the current irrigation projects needs to be determined and then any problems identified should be addressed.

Comparative performance indicators are helpful to evaluate how well irrigated agriculture is performing at the project, basin, or national level. Comparative performance indicators help policy makers and planners to evaluate productive use of land and water resources, help irrigation managers to set reasonable objectives and measure progress, and allow researchers to compare irrigation systems (Molden et al., 1998). Irrigation managers should have sufficient knowledge to determine better water management options (Visitacion et al., 2009). The accomplishment of irrigation projects depends on several factors, such as infrastructure design, management types, climatic conditions, price, availability of inputs, and socio-economic conditions (Sakthivadivel et al., 1999). Considering these factors, an appropriate indicator group needs to be set up in order to compare the performance of the irrigation schemes. Since 1993, the operation of irrigation systems in Turkey has gradually been transferred from State Hydraulic Works (SHW) to Water User Associations (WUAs). Although some irrigation systems in different areas of the country have been transferred to irrigation cooperatives, municipalities, and village organizations, the government's ultimate goal is to transfer all irrigation systems to WUAs in a participatory approach. SHW in Turkey is a Government organization primarily responsible for the construction of irrigation projects. It is organized into 25 SHW regional directorates. SHW does not only construct but also administered irrigation projects. Although, it provides very useful services to farmers, many argue that the expected success has not been achieved. The financial cost of the SHW to Government has also increased over time. By transferring the responsibility for irrigation systems, the Government ought to ensure the continuity of the irrigation systems, improve performance, reduce operation, management, and administration expenses and to ensure effective use of resources.

The existing literature includes studies on the performances of irrigation systems. Cakmak (1997) used 7 indicators developed by the International Water Management Institute (IWMI) to assess the performance of 13 WUAs where operation had been transferred from SHW in Konya province. Molden et al. (1998) assessed the performance of 18 irrigation projects in 11 different countries using 9 external comparative indicators developed by the IWMI. Sakthivadivel et al. (1999) to examined 40 irrigation projects from 13 countries and demonstrated four typical applications of these indicators: cross-system comparison, temporal variations in performance within one system, spatial variations within one system, and comparing performance by system type. A number of researchers have evaluated the performance of a particular irrigation system using various indicators (Boss and Nugteren, 1974; Levine, 1982; Abernethy, 1986; Seckler et al., 1988; Molden and Gates, 1990; Sakthivadivel et al., 1993; Boss et al., 1994), however, very few of these studies involved comparison of the irrigation schemes based on management types (agency, farmer, or joint). These indicators should be standardized for better comparison of irrigation schemes based on management types, as in the recent studies (Boss et al., 1994).

Even though a small number of studies have compared irrigation systems based on management types all over the world, research on this subject is significantly lacking in Turkey. Therefore, the objective of the present study was the comparative performance analysis of irrigation schemes based on management types (the SHW and WUAs-operated schemes) using the IWMI's six performance indicators for the year 2001. To achieve the objective, a large data set was compiled from the Irrigation Project Evaluation Reports, comprising water supply, crop types, crop water requirement, and irrigated and command areas for the SHW and WUAs-operated irrigation schemes; further data on crop pattern and unit yield and price was obtained from the Product Count Result Reports (Anonymous, 2001a and b). This data set was then used to calculate six irrigation performance indicators: Output per cropped area (OPCA), output per unit command (OPUC), output per unit water supply (OPUWS), output per unit water consumed (OPUWC), irrigation intensity (II), and relative water supply (RWS).

MATERIALS AND METHODS

The study area

The distribution of the SHW and WUAs-operated irrigation projects evaluated in this study is presented on the map of Turkey, shown in Figure 1. The SHW department divided the entire area of Turkey into 25 regions. The intention was to select 2 irrigation projects from each region, one of which is operated by SHW, and the other by WUAs, in order to make a comparison. However, data were only available for 17 SHW-operated, and 22 WUAs-operated irrigation projects. Therefore, our comparison is limited to this available data.

Land, water, climate, and crop resources of the study area

The total, arable, irrigable, and economically irrigable land in Turkey are 78, 28.05, 25.82, and 8.50 million ha, respectively. Approximately 50% (4.5 million ha) of the economically irrigable land has already been irrigated (Tekinel, 2001). Irrigated land value was increased (5.1 million ha) in 2006 and the target irrigated land of SHW is 6.5 million ha in 2030 (Anonymous, 2008). Turkey is located in a sub-tropical region and has a semi-arid climate. The difference of latitude between north and south region of Turkey has

Figure 1. Map of Turkey showing locations of SHW (flag) and WUAs (triangle)-operated irrigation schemes.

a great role on temperature changes. Therefore, the south region is under the influence of sub-tropical climate which is similar to Mediterranean climate. On the other hand, in the north region of Turkey the Black Sea climate which is always rainy in all seasons is observed (Anonymous, 2009). In general, summer is warm and dry, whereas winter is cold and rainy. The average annual precipitation, total precipitation, total runoff, and total usable potential are 643 mm, 501, 186, and 112 km^3, respectively (Degirmenci et al., 2008). A variety of crops are grown in the study area, but common crops are wheat, sugar beet, corn, fruit, vegetable, cotton, tobacco, rice and olive.

Performance indicators

Six external indicators developed by the IWMI were used for the comparative performance analysis of the SHW and WUAs-operated irrigation projects (see Equations 1 - 6). The first four indicators relate the output (crop production) to unit land and water. These indicators allow comparison of the performance of fundamentally different systems by standardizing the gross value of agricultural production. In areas where water is scarce, the Standardized Gross Value of Production (SGVP) per unit water consumed is especially significant, whereas in areas in where land availability is the limiting resource, output per unit of command or cropped area is more important. The relative water supply (RWS) was presented by Levine (1982) and expressed as the ratio of the total water supply to the total crop-water demand. These indicators can be calculated as (Molden et al., 1998):

$$\text{Output per cropped area}\left(\frac{\$}{\text{ha}}\right) = \frac{\text{SGVP}}{\text{Irrigated cropped area}} \quad (1)$$

$$\text{Output per unit command}\left(\frac{\$}{\text{ha}}\right) = \frac{\text{SGVP}}{\text{Command area}} \quad (2)$$

$$\text{Output per unit irrigation supply}\left(\frac{\$}{\text{m}^3}\right) = \frac{\text{SGVP}}{\text{Diverted irrigation supply}} \quad (3)$$

$$\text{Output per unit water consumed}\left(\frac{\$}{\text{m}^3}\right) = \frac{\text{SGVP}}{\text{Volume of water consumed by ET}} \quad (4)$$

$$\text{Relative water supply} = \frac{\text{Crop water demand (ET)}}{\text{Total water supply}} \quad (5)$$

$$\text{Irrigation intensity} = \frac{\text{Irrigated cropped area}}{\text{Command area}} \quad (6)$$

where SGVP is the output of the irrigated area in terms of gross value of production measured at local or world prices, irrigated cropped area is the sum of the areas under crops during the time period of analysis, command area is the nominal or design area to be irrigated, diverted irrigation supply is the volume of surface irrigation water diverted to the command area, plus net removals from groundwater; volume of water consumed by ET is the actual evapotranspiration of crops; and total water supply is the surface diversions plus net groundwater draft plus rainfall. The SGVP was developed for cross-system comparisons regardless of location or what kinds of crops that are grown. It can be calculated as (Molden et al., 1998):

$$\text{SGVP} = \left(\sum_{\text{crops}} A_i Y_i \frac{P_i}{P_b}\right) P_{world} \quad (7)$$

where A_i is the area cropped with crop i (ha); Y_i is the yield of crop i (kg/da); P_i is the local price of crop i (\$/kg); P_b is the local price of the base crop (the predominant locally grown, internationally-traded crop) ($/kg); and P_{world} is the value of the base crop traded at world prices ($/kg). The irrigation project evaluation reports that wheat was considered as the base crop because it was predominant, locally grown and internationally traded.

The data on water supply, crop types, crop water requirement, and irrigated and command areas for the SHW and WUAs-operated irrigation schemes was obtained from the Irrigation Project Evaluation Reports, whereas the data of crop pattern and unit yield and price was obtained from the Product Count Result Reports (Anonymous, 2001a,b). The determination of these values is explained as follows. Planned-distribution of water is available in irrigation projects in Turkey. Farmers report the location and size of their land, and the crops they will plant to the SHW or WUAs before the irrigation season. Irrigation scheduling is prepared based on this report. Employees of the SHW or WUAs check the reports for errors at the beginning of the season. The net irrigated cropped area is determined by making corrections during the collection of the irrigation fees at the end of the irrigation season. In either the SHW or WUAs-operated irrigation schemes, the total amount of water diverted from the source (creek, stream, river, reservoir, regulator, or dam) to the main canal of each irrigation scheme is determined by discharge measuring tools (limnigraph or staff gauge) placed at the diversion point for daily, weekly, monthly, and annual data during the irrigation season. In either the SHW or WUAs-operated irrigation schemes, water consumption or evapotranspiration of all the crops planted in the irrigation season is determined by the Blaney and Criddle method (1950). The reason for using this method is that it requires fewer climatic parameters but produces acceptably reliable results.

Analysis of the data

SPSS software was used to calculate Analysis of variance (ANOVA) (Ozdamar, 1999) to determine if statistically significant differences existed between the SHW and WUAs-operated irrigation schemes in terms of the OPCA, OPUC, OPUWS, OPUWC, II, and RWS. In addition, the standard deviations of the six indicators were calculated.

RESULTS AND DISCUSSION

Output per cropped area (OPCA)

The minimum, maximum, mean, standard deviations and ANOVA test results for the OPCA are presented in Figure 2a. The ranges and means (in parentheses) of the OPCA were 449-5079 US$/ha (2339) for the SHW-operated and 448-4938 $/ha (1568) for the WUAs-operated irrigation projects. A statistically significant difference was found between the two management types ($p = 0.039 < 0.05$). The significant difference in the OPCA between the management types might be due to the differences in the crop pattern and intensity, irrigation infrastructure, applied agricultural system, reliability of the records of the related institutions, education level of the farmers, and structure of the administration. Similar differences might be valid for the OPUC, OPUIS, and OPUWC. Previous studies have reported OPCA values ($/ha) of 105-1800 (Kloezen and Garces-Restrepo, 1998), 384-3626 (Molden et al., 1998), 1317-2585 (Girgin et al., 1999), 384-3434 (Sakthivadivel et al., 1999), 359-6197 (Cakmak, 2001) and 354-8659 $/ha (Cakmak and Beyribey, 2003).

Output per unit command (OPUC)

The ranges and means (in parentheses) of the OPUC were 72-2013 $/ha (725) for the SHW-operated and 107-1795 $/ha (887) for the WUAs-operated irrigation projects (Figure 2A). The difference between the two management types were not statistically significant ($p = 0.329 > 0.05$). The values of the OPUC were high because of the type and intensity of crop grown, especially orchards, industrial crops, and some cereals (Molden et al., 1998; Sakthivadivel et al., 1999). Previous studies have reported OPUC values ($/ha) of 679-2888 (Molden et al., 1998), 1840 (Kloezen and Garces-Restrepo, 1998), 477-3626 (Sakthivadivel et al., 1999), 195-5391 (Cakmak, 2001) and 67-2001 $/ha (Cakmak and Beyribey, 2003).

Output per unit irrigation supply (OPUIS)

The ranges and means (in parentheses) of the OPUIS were 0.01-0.85 $\$/m^3$ (0.23) for the SHW-operated and 0.03-0.56 $\$/m^3$ (0.18) for the WUAs-operated irrigation projects (Figure 2B). The difference between the two management types was not statistically significant ($p = 0.365 > 0.05$). Previous studies have reported OPUIS values ($\$/m^3$) of 0.11-0.12 (Vermillion and Garces-Restrepo, 1996), 0.04-0.63 (Molden et al., 1998), 0.00-0.16 (Kloezen and Garces-Restrepo, 1998), 0.18-0.41 (Girgin et al., 1999), 0.04-0.63 (Sakthivadivel et al., 1999), 0.02-1.29 (Cakmak, 2001) and 0.02-0.67 $\$/m^3$ (Cakmak and Beyribey, 2003).

Output per unit water consumed (OPUWC)

The ranges and means (in parentheses) of the OPUWC were 0.15-1.85 $\$/m^3$ (0.64) for the SHW-operated projects and 0.11-1.22 $\$/m^3$ (0.35) for the WUAs-operated projects (Figure 2C). A statistically significant difference was found between the two management types ($p = 0.018 < 0.05$). Previous studies have reported OPUWC values ($\$/m^3$) of 0.03-0.91 (Molden et al., 1998), 0.00-0.41 (Kloezen and Garces-Restrepo, 1998), 0.17-0.35 (Girgin et al., 1999), 0.05-0.62 (Sakthivadivel et al., 1999) 0.07-2.25 (Cakmak, 2001), and 0.08-2.54 $\$/m^3$ (Cakmak and Beyribey, 2003).

Relative water supply (RWS)

The ranges and means (in parentheses) of the RWS

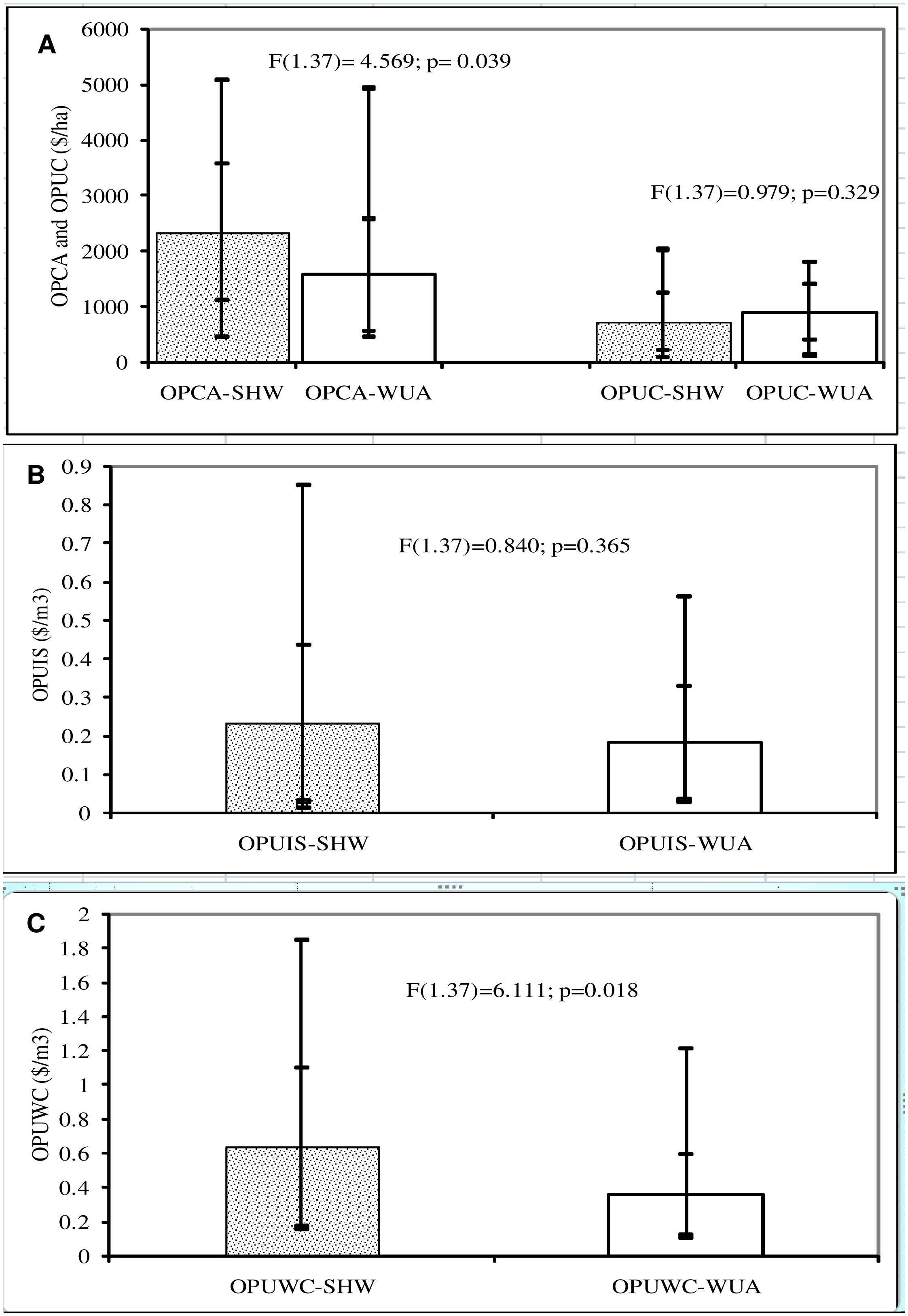

Figure 2. OPCA and OPUC (A), OPUIS (B), and OPUWC (C) values for SHW and WUAsoperated irrigation schemes.

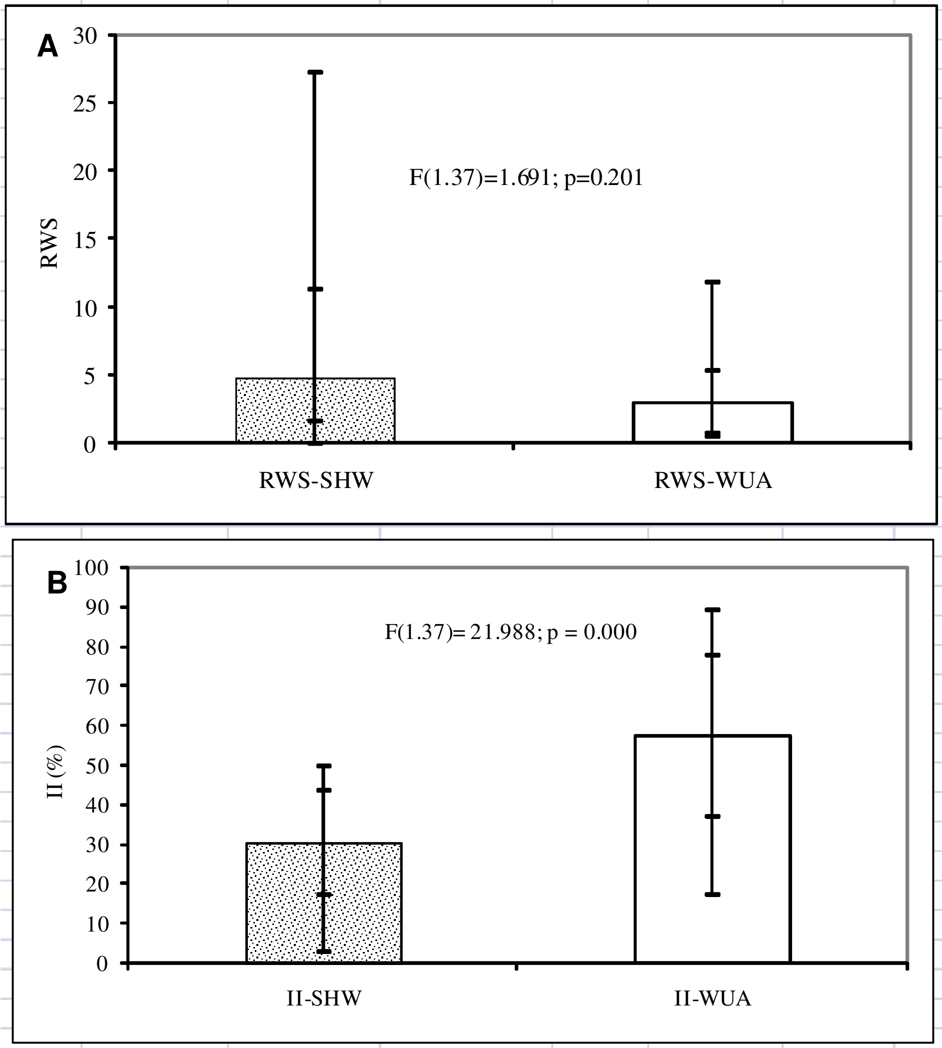

Figure 3. RWS (A) and II (B) values for SHW and WUAs-operated irrigation schemes.

were 1.61-27.23 (4.85) for the SHW-operated and 0.75-11.78 (2.93) for the WUAs-operated irrigation projects (Figure 3). The difference between the two management types was not statistically significant ($p = 0.201 > 0.05$). The RWS indicates that either required water (value = 1), insufficient water (<1), or excess water (value >1) is diverted to the project area. The water over the requirement was diverted to the area of the all projects. Since planned water delivery had not been available in the irrigation projects, a large amount of water in the canal was wasted, as a result, this increased the relative water supply. As the RWS indicates how well irrigation supply and demand are matched, a value one of more than 1 would suggest that too much water is being supplied, possibly causing water-logging and negatively impacting yields, a value less than 1 indicates that crops are not getting enough water (IWMI). The optimum value of the RWS is 1. Levine (1982) stated that a water supply in excess of 2.5 times the net requirement is an indication of inappropriate water management.

Although, more water was used for all projects than the required amount, water was not used effectively because output or production per unit land and water was relatively low. This might be due to the lack of irrigation management or a lack of knowledge and experience of appropriate irrigation practice among farmers. Previous studies have reported RWS values of 1.40-1.80 (Vermillion and Garces-Restrepo, 1996), 0.60-1.79 (Beyribey et al., 1997a), 0.58-2.41 (Beyribey et al., 1997b), 0.80-4.10 (Molden et al., 1998), 0.30-7.83 (Cakmak, 2001), 1.30-

8.40 (Cakmak and Beyribey, 2003) and 1.88 (Bandara, 2003).

Irrigation intensity (II)

The ranges and means (in parentheses) of the II were 3-50% (30) for the SHW-operated and 17-89 (57) for the WUAs-operated irrigation projects (Figure 3B). A statistically significant difference was found between the two management types (p = 0.000 < 0.05). The most important reasons for the low irrigation intensity might be the lack of infrastructure, water, operation and maintenance activities, water delivery, irrigation method, and lack of irrigation due to insufficient irrigation during the preceding year. Previous studies have reported II values (%) of 32-117 (Erozel and Alibiglouei, 1991), 44-100 (Beyribey et al., 1997a), 24-105 (Beyribey et al., 1997b), 36-104 (Cakmak, 2001) and 57-81 (Cakmak and Beyribey, 2003).

Conclusions

Comparative performance analysis of irrigation schemes based on the management types (the SHW and WUAs-operated schemes) was made using the IWMI's six performance indicators for the year 2001. Although, more water was used for all projects than the required amount, water was not used effectively because output or production per unit land and water was relatively low, especially in the WUAs-operated schemes. This might be due to the poor irrigation management due to insufficient knowledge and experience of appropriate irrigation practice among managers and farmers. Application of the inappropriate crop pattern and intensity to the project areas is a common management problem. In addition, irrigation projects should be grouped based on their regions, climatic conditions, crop patterns and growth-time, irrigation systems and methods, marketing situation, and management types. Similar projects should then be compared or evaluated among themselves in order to provide a better comparison between the projects.

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