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Topology of Performance Indicators of All Irrigation Schemes in Turkey

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Abstract: The increasing competition among the limited land and water resources leads to the development, monitoring and evaluation of these resources in irrigated agriculture. The objectives of this study were to make cross-system comparison and comparative performance analysis of irrigation schemes based on the system type, climate and management type using the International Water Management Institute (IWMI)'s six performance indicators for the year 2001. Statistical analyses were conducted to determine if statistically significant difference existed between the system types, climatic conditions and management types for each and all of six indicators. ANOVA test results indicated that statistically significant difference at p=0.05 level (p<0.05) was determined between the system types, climates and management types for most of six indicators. In addition, the differences between the system types and climates for all of six indicators were statistically significant, whereas the difference between the management types was not. The mean values of the pumping in system type and semi-humid in climatic conditions were higher than that of the others, whereas no clear difference in the means of the management types was determined. Although more water than the requirement was used for all schemes, water was not used efficiently possibly due to inappropriate crop pattern and intensity, irrigation infrastructure, reliability of the data, education level of the managers and farmers and structure of the administration.

Key words: Irrigation scheme, comparative indicators, system type, management type, climate

INTRODUCTION

The increasing competition among the limited land and water resources leads to the development, monitoring and evaluation of these resources in irrigated agriculture. The information on irrigation water management in a detailed scale like in country level is not common due to the lack of data, or reliability and accessibility of the data. The evaluation of irrigation water use efficiency has been concern of many researchers (Bos and Nugteren, 1974; Levine, 1982; Bos *et al*., 1994; Molden *et al*., 1998), but the performance of irrigated agriculture with limited land and water resources has not been satisfactorily monitored and evaluated because we have not been able to compare irrigation systems relative to each other (Sakthivadivel *et al*., 1999). Therefore, assessing the performance of irrigated agriculture is necessary in order to evaluate the impact of agricultural and hydrological interventions.

The performance of irrigation schemes is evaluated for a variety of reasons such as improving system operations, assessing progress against strategic goals, assessing the general health of a system, assessing impacts of interferences, diagnosing restrictions and comparing the performance of a system with others or with the same system over time (Molden *et al*., 1998).

The comparative performance indicators allow for comparison between countries and regions, different infrastructures (fixed or flexible), system (diversion or pumping) and management (agency, farmer, or joint) types, distribution procedures (supply versus demand), climatic conditions (wet or dry) and performance assessment of a specific project over time because they consider common elements to all systems (Molden *et al*., 1998).

Using the comparative performance indicators developed by the International Water Management Institute (IWMI), the performances of irrigation schemes of 13 Water User Associations (WUAs)-operated (Çakmak, 1997) and 213 public-operated in 21 different regions in the city of Konya (Beyribey, 1997), Bursa-Uluabat (Değirmenci, 2001a), 158 WUAs-operated (Değirmenci, 2001b), 7 WUAs-operated in Konya (Çakmak, 2001), Sakarya Basin (Çakmak and Beyribey, 2003) were evaluated in Turkey. Molden *et al.* (1998)

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assessed the performance of 18 irrigation schemes in 11 different countries using 9 external comparative indicators developed by the IWMI. Sakthivadivel *et al.* (1999) demonstrated four typical applications of these indicators; cross-system comparison, temporal variations in performance at one system, spatial variations within one system and comparing performance by system type to 40 irrigation schemes from 13 countries.

A number of researchers have evaluated the performance of particular irrigation systems with various indicators (Abernethy, 1986; Seckler *et al.*, 1988; Molden and Gates, 1990; Sakthivadivel *et al.*, 1993; Sarma and Rao, 1997; Molden *et al.*, 1998; Bandara, 2003). The performance of the irrigation systems depends upon several factors such as infrastructure design, system and management types, climatic conditions, price, availability of inputs and socioeconomic conditions (Sakthivadivel *et al.*, 1999). However, in most of these studies, the performances of schemes were evaluated using the limited number of these parameters (factors). In addition, the comparative performance indicators were applied to an individual or regional schemes, or schemes from several countries. Extensive assessment of all schemes in a country using all these parameters helps the managers and researchers to better compare them and develop sound management tools.

Therefore, the objectives of this study are to make: a) cross-system comparison of all irrigation schemes in Turkey, b) comparison of the schemes based on the system type, c) comparison of the schemes based on the climatic conditions and d) comparison of the schemes based on the management type using the IWMI's six performance indicators for the year 2001. To achieve the objectives, we compiled a large data set that compromise of water supply, crop types, crop water requirement and irrigated and command areas from the evaluation report of the Irrigation Schemes operated by SHW and transferred refer to the state Hydraulic works and the schemes transferred to the WUAs, respectively. Whereas the data of crop pattern and unit yield and price was obtained from the Product Count Result Reports of the Irrigation Schemes operated by SHW and transferred refer to the state Hydraulic works and the schemes transferred to the WUAs, respectively (Anonymous, 2001a and 2001b). SHW and transferred refer to the state Hydraulic works and the schemes transferred to the WUAs, respectively. This data set was then used to calculate six irrigation performance indicators: Output per unit command, output per unit cropped area, output per unit water supply, output per unit water consumed, irrigation intensity and relative water supply.

MATERIALS AND METHODS

The study area: Irrigation schemes in this study were developed and operated by the General Directorate of the SHW, but the transfer of the schemes to the WUAs started in 1992. The total of 239 schemes (57 and 182 were operated by the SHW and WUAs, respectively) was evaluated in this study. The locations of the studied irrigation schemes are presented on the map of Turkey in Fig. 1.

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 developed. The irrigation areas developed by the SHW, GDRS (General Directorate of Rural Services) and farmers are about 50, 27.7 and 22.3%, respectively, (Tekinel, 2001).

The total potential water is 186 billion m^3 in 26 drainage basins in Turkey and 95 billion m^3 of this amount is usable. However, the total surface and groundwater which is consumable technically and economically is 110 billion m^3. Ninety five, 3 and 12 billion m^3 of this amount are provided by the rivers emerged in the country; the rivers emerged out of the country and groundwater, respectively (Çakmak and Beyribey, 2003).

Turkey is located in a sub-tropical region and mainly under semi-humid and semi-arid climate. The ranges of the annual mean temperature are 18-20, 14-15 and 4-19°C in the southern, western and middle and eastern part of the country, respectively. In general, summer is warm and dry, whereas winter is cold and rainy (Degirmenci, 1996). The annual mean precipitation, total precipitation, total runoff

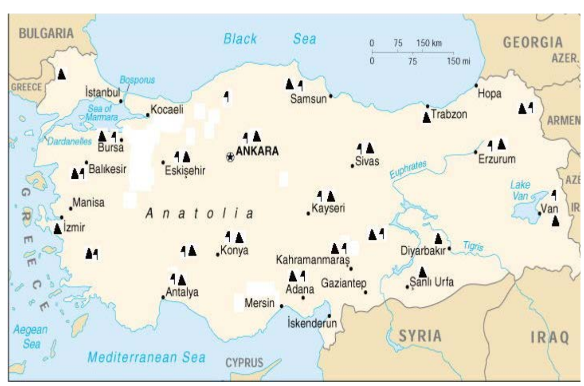

Fig. 1: Map of Turkey showing the locations of the SHW (flag) and WUAs (triangle)-operated irrigation schemes. There is more than one scheme in each marked point

and total usable potential are 643 mm, 501 km^3, 186 km^3 and 110 km^3, respectively (Tekinel, 2001).

A variety of crops are grown in the study area, but common ones are wheat, sugar beet, fruit, vegetable, corn, cotton, tobacco and olive.

Performance indicators: Six external indicators developed by the IWMI were used for the comparative performance evaluation of the 239 irrigation schemes (Eqs. 1-6). The first four indicators relate the output (crop production) to unit land and water. These indicators allow to comparing the performance of fundamentally different systems by standardizing the gross value of agricultural production. In the areas where water is scarce, the Standardized Gross Value of Production (SGVP) per unit water consumed is especially significant, whereas in the areas in which the land is the limited source, output per unit of command or cropped area is more important. The relative water supply 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):

$$\text{Out put per unit command} \left(\frac{\$}{\text{ha}}\right) = \frac{\text{SGVP}}{\text{Command area}} \quad (1)$$

$$\text{Out put per cropped area} \left(\frac{\$}{\text{ha}}\right) = \frac{\text{SGVP}}{\text{Irrigated cropped area}} \quad (2)$$

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

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

$$\text{Irrigation intensity} = \frac{\text{Irrigated cropped area}}{\text{Command area}} \quad (5)$$

$$\text{Relative water supply} = \frac{\text{Total water supply}}{\text{Crop-water demand (ET)}} \quad (6)$$

where, SGVP is the output of the irrigated area in terms of gross or net 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 where they are or what kind of crops is grown. It can be calculated as (Molden *et al.*, 1998):

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

where A_i is the area cropped with crop I (ha), Y_i is the yield of crop I (kg da^{-1}), P_i is the local price of crop I (\$ kg^{-1}), P_b is the local price of the base crop (the predominant locally grown, internationally-traded crop) (\$ kg^{-1}) and P_{world} is the value of the base crop traded at world prices (\$ kg^{-1}). Wheat was considered as the base crop because it was predominant locally grown and internationally traded.

The data on water supply, crop water requirement and irrigated and command areas for the schemes was obtained from the Irrigation Project Evaluation Reports, whereas the data of crop pattern and unit yield and price was obtained from Product Count Result Reports of the irrigation schemes operated by SHW and transferred (Anonymous, 2001a and 2001b).

Analysis of the data: Descriptive statistical parameters such as minimum, maximum, mean, plus and minus standard deviations were calculated for each of six indicators of system type, climatic conditions and management type. In addition, the analysis of variance (ANOVA) test was made using SPSS software (Norusis, 1990) to determine if statistically significant difference existed between the system types, climatic conditions and management types for each and all of six indicators.

RESULTS AND DISCUSSION

Cross-system comparison

SGVP per unit command: The minimum, maximum and mean values of the SGVP per unit command are 16, 9078 and US\$ 1134, respectively (Table 1). The systems with the low values (less than \$ 2000 ha^{-1}) are those that mostly grow crops such as cereals with small area and low yield and local price. The systems with the high values (\$ 2000 and greater) include orchards, industrial crops (sugarbeet, cotton and sunflower) and some cereals. The vast majority of the scheme which have high values of the SGVP per unit command are operated by the WUAs. These results indicate that the reasons for the high SGVP per unit command are the cropping pattern and intensity and the WUAs are successful in managing this. Molden *et al.* (1998) also investigated that the systems including orchards, industrial crops and some cereals had the high values of the SGVP per unit command. The SGVP per unit command was determined as in the range of 1070-1583, 144-8349, 679-2888, 2629, 67-2001, 1840, 195-5391 and 477-3626 US$ ha^{-1} in the studies of Değirmenci (2001a), Değirmenci (2001b), Molden *et al.* (1998), Yazgan and Degirmenci (2002), Çakmak and Beyribey (2003), Kloezen and Garces-Restrepo (1998), Çakmak (2001) and Sakthivadivel *et al.* (1999), respectively.

SGVP per unit cropped land: The minimum, maximum and mean values of the SGVP per unit cropped land are 65, 9763 and US$ 2250, respectively (Table 1). The SGVP per unit cropped land can be divided into two classes of irrigation systems. Irrigation systems producing cereals have the SGVP per unit cropped land around or less than $ 3500, whereas the systems producing non-cereal crops such as orchards, industrial crops (sugarbeet, cotton and sunflower) have the SGVP per unit cropped land between US$ 3500 and $ 10000. Therefore, non-cereal irrigation systems produce more value than the cereal irrigation systems by 0-300%. Most of the schemes with high SGVP per unit cropped area are operated by the WUAs. The SGVP per unit cropped land was found as in the range of 2857-4415, 190-14843, 2900-4000, 105-1800, 4198, 354-8659, 1317-2585, 359-6197, 384-3626 and 384-3434 US$ ha^{-1} in the studies of Değirmenci (2001a), Değirmenci (2001b), Molden *et al.* (1998), Kloezen and Garces-Restrepo (1998), Yazgan and Degirmenci (2002), Çakmak and Beyribey (2003), Girgin *et al.* (1999a), Çakmak (2001) and Sakthivadivel *et al.* (1999), respectively.

SGVP per unit irrigation supply: The range and mean of the SGVP per unit irrigation supply are 0.01-1.79 and 0.27 US$ m^{-3}, respectively (Table 1). Cereal-producing systems give a gross value of output per unit volume of irrigation water varying between $ 0.01 and $ 0.4. However, systems growing orchards, industrial crops (sugarbeet, cotton and sunflower), vegetables and some cereals produce a SGVP per unit volume of irrigation water between $ 0.4 and $ 1.8. The SGVP per unit volume of irrigation water is higher in semi-humid regions where irrigation requirement is generally lower. In addition, the vast majority of the schemes with high SGVP per unit irrigation supply are operated by the WUAs. These results indicate that the reasons for the high SGVP per unit irrigation supply are the cropping pattern and intensity, climatic conditions and management type. The SGVP per unit irrigation supply was calculated as in the range of 0.31-0.50, 0.02-1.84, 0.04-0.63, 0.00-0.16, 0.11-0.12, 0.02-0.67, 0.18-0.41, 0.02-1.29 and 0.04-0.63 US$ m^{-3} in the studies of Değirmenci (2001a), Değirmenci (2001b), Molden *et al.* (1998), Kloezen and Garces-Restrepo (1998), Vermillion and Garces-Restrepo (1996), Çakmak and Beyribey (2003), Girgin *et al.* (1999a), Çakmak (2001) and Sakthivadivel *et al.* (1999), respectively.

SGVP per unit water consumed: The range and mean of the SGVP per unit water consumed are 0.01-2.66 and 0.55 US$ m^{-3}, respectively (Table 1). The SGVP per unit water consumed can also be grouped into two main classes. Cereal-based systems give a gross value of output per unit water consumed varying between $ 0.01 and $ 0.7. However, systems growing orchards, industrial crops (sugarbeet, cotton and sunflower) and vegetables produce a SGVP per unit water consumed between $ 0.7 and $ 2.66. The SGVP per unit volume of irrigation water is higher in the schemes located in the semi-humid regions and operated by the WUAs. These results indicate that the reasons for the high SGVP per unit irrigation supply are the cropping pattern and intensity, climatic conditions and management type. The SGVP per unit water consumed was determined as 0.58-1.09, 0.04-3.02, 0.03-0.91, 0.00-0.41, 0.08-2.54, 0.17-0.35, 0.07-2.25 and 0.05-0.62 US$ m^{-3} in the studies of Değirmenci (2001a), Değirmenci (2001b), Molden *et al.* (1998), Kloezen and Garces-Restrepo (1998), Çakmak and Beyribey (2003), Girgin *et al.* (1999a), Çakmak (2001) and Sakthivadivel *et al.* (1999), respectively.

Irrigation intensity: The range and mean of the irrigation intensity are 1-157 and 49%, respectively (Table 1). Majority of the schemes have irrigation intensity between 20 and 90%, but the mean intensity of WUAs-operated schemes is higher than that of the SHW-operated schemes. This indicates that the WUAs are successful in irrigation of the projected area. The most important reason of the low irrigation intensity might be the lack of infrastructure, water and operation and maintenance activities, water delivery, irrigation method and not making irrigation because of enough precipitation in the related year. The irrigation intensity was found as 32-117, 4-100, 44-100, 24-105, 57-81, 15-94, 36-104 and 25-96% in the studies of Erözel and Alibiglouei (1991), Değirmenci (2001b), Beyribey *et al.* (1997a), Beyribey *et al.* (1997b), Yazgan and Degirmenci (2002), Çakmak and Beyribey (2003) and Çakmak (2001) and Değirmenci and Yazgan (2002), respectively.

Relative water supply: The minimum, maximum and mean of the relative water supply are 0.19, 9.76 and 2.66, respectively (Table 1). The relative water supply indicates how well irrigation supply and demand are matched, a value over one would suggest too much water is being supplied, possibly causing water-logging and negatively impacting yields; a value less than one indicates that

Table 1: The output per unit cropped area, command area, irrigation supply and water consumed; irrigation intensity; and relative water supply

Columns

1	2	3	4	5	6	7	8	9	10
Hasanağa	Diversion	SH	SHW	2293	599	0.18	0.53	26	2.97
Demirtaş	Diversion	SH	SHW	2593	1254	0.48	0.62	48	1.31
Söğüt	Diversion	SH	SHW	1370	244	0.08	0.41	18	4.91
Ayrancİ	Diversion	SA	SHW	2373	73	0.26	0.59	3	2.25
Gebere	Diversion	SA	SHW	5072	2253	0.48	1.27	44	2.64
Düzce	Diversion	SH	SHW	3789	821	0.52	1.85	22	3.52
Güldürcek	Diversion	SA	SHW	1293	55	0.09	0.36	4	4.24
Eleşkirt	Diversion	SH	SHW	393	138	0.10	0.21	35	2.11
Göynük	Diversion	H	SHW	2357	574	0.10	0.53	24	5.27
Gayt	Diversion	H	SHW	1440	539	0.08	0.43	37	5.22
Yazİhan	Diversion	SA	SHW	988	924	0.08	0.19	93	2.39
Ayvacİk	Diversion	SA	SHW	2780	435	0.24	0.98	16	4.00
Zamantİ	Diversion	SA	SHW	2007	865	0.29	0.69	43	2.34
Tahtaköprü	Diversion	SA	SHW	3968	314	0.16	1.13	8	7.29
Varsak	Diversion	SH	SHW	3518	1170	0.16	0.59	33	3.74
Ahlat	Diversion	H	SHW	2790	1478	0.32	0.82	53	2.52
Bulanİk	Diversion	H	SHW	1697	779	0.24	0.39	46	1.59
Malazgirt	Diversion	H	SHW	1681	500	0.11	0.39	30	3.60
Erciş	Diversion	SA	SHW	1036	1017	0.08	0.30	98	3.83
Gemerek	Diversion	SA	SHW	1617	489	0.15	0.49	30	3.33
Divriği	Diversion	SA	SHW	1355	388	0.19	0.52	29	2.82
Karaova	Diversion	H	SHW	1905	267	0.12	0.44	14	3.54
Germeçtepe	Diversion	SH	SHW	3583	976	0.68	1.37	27	2.02
Kİrcalar	Diversion	SH	SHW	2609	709	0.51	0.82	27	1.60
Kars	Diversion	SH	SHW	1706	206	0.14	1.36	12	9.76
Akyaka	Diversion	SH	SHW	1910	942	0.41	0.65	49	1.61
Arpaçay	Diversion	SH	SHW	3397	785	1.37	1.22	23	0.89
Gökçeada	Diversion	SH	SHW	2801	948	0.22	0.52	34	2.42
Bursa	Diversion	SH	WUAs	3135	1899	0.47	0.96	61	2.04
M.Kemalpaşa	Diversion	SH	WUAs	2239	1372	0.33	0.57	61	1.73
İzmit	Diversion	SH	WUAs	1921	491	0.34	0.58	26	1.74
Bergama	Diversion	SH	WUAs	2754	1418	0.31	0.53	51	1.70
Seferihisar	Diversion	SH	WUAs	7213	3065	0.51	1.23	43	2.38
Ahmetli	Diversion	SH	WUAs	3276	1795	0.56	0.72	55	1.28
Sarİgöl	Diversion	SH	WUAs	2601	1396	0.30	0.60	54	1.96
Eskişehir	Diversion	SA	WUAs	780	361	0.04	0.25	46	5.72
İnönü	Diversion	SA	WUAs	1877	779	0.23	0.50	42	2.16
Yaralİ	Diversion	SA	WUAs	1002	993	0.08	0.31	99	3.69
Cihanbeyli	Diversion	SA	WUAs	754	443	0.09	0.21	59	2.25
Gevrekli	Diversion	SA	WUAs	1568	902	0.63	0.31	57	0.49
Akİncİ	Diversion	SA	WUAs	1869	420	0.14	0.50	23	3.46
Kİzİlİrmak	Diversion	SA	WUAs	2199	663	0.07	0.29	30	4.10
Alaca	Diversion	SA	WUAs	1350	342	0.21	0.35	25	1.65
Kesiksuyu	Diversion	SH	WUAs	1520	900	0.19	0.37	59	1.96
Karaisalİ	Diversion	SH	WUAs	1311	687	0.15	0.25	52	1.72
Hacİbeyli	Diversion	SH	WUAs	576	274	0.07	0.14	48	2.11
Hassa	Diversion	SH	WUAs	2123	827	0.20	0.39	39	1.91
Kİrİkhan	Diversion	SH	WUAs	1640	888	0.13	0.35	54	2.69
Anamur	Diversion	SH	WUAs	4908	2245	0.27	0.95	46	3.52
Bozyazİ	Diversion	SH	WUAs	3961	2559	0.45	0.83	65	1.85
Yuvarlaklİ	Diversion	SH	WUAs	1725	894	0.15	0.67	52	4.45
Sabunsuyu	Diversion	SH	WUAs	1030	630	0.09	0.22	61	2.34
Savrun	Diversion	SH	WUAs	1227	1005	0.13	0.26	82	2.04
Gediksaray	Diversion	SA	WUAs	1065	266	0.09	0.20	25	2.16
Gümüşhacİköy	Diversion	SA	WUAs	1044	262	0.37	0.41	25	1.13
Uluköy	Diversion	SA	WUAs	1066	663	0.18	0.25	62	1.41
Bafra	Diversion	SH	WUAs	1312	441	0.32	0.54	34	1.67
Bedirkale	Diversion	SA	WUAs	1801	516	0.26	0.39	29	1.53
Artova	Diversion	SA	WUAs	827	127	0.11	0.17	15	1.52
Niksar	Diversion	SA	WUAs	2227	1723	0.16	0.49	77	3.03
Zile	Diversion	SA	WUAs	1691	490	0.19	0.36	29	1.85
Patnos	Diversion	SA	WUAs	938	655	1.68	0.31	70	0.19
Aşağİ Pasinler	Diversion	SH	WUAs	3215	1253	0.81	1.49	39	1.85
Akçadağ	Diversion	SA	WUAs	1056	879	0.16	0.26	83	1.64
Suçatİ	Diversion	SA	WUAs	1068	510	0.38	0.27	48	0.71

Table 1: Continued

Columns									
1	2	3	4	5	6	7	8	9	10
Sultansuyu	Diversion	SA	WUAs	987	351	0.08	0.17	36	2.14
Doğanşehir	Diversion	SA	WUAs	979	944	0.12	0.31	96	2.68
Polat	Diversion	SA	WUAs	702	422	0.10	0.22	60	2.19
Garzan-Kozluk	Diversion	SH	WUAs	849	459	0.13	0.14	54	1.04
Gözegöl	Diversion	SH	WUAs	1284	401	0.10	0.21	31	2.12
Devegeçidi	Diversion	SA	WUAs	1223	1298	0.11	0.28	106	2.56
Çİnar-Göksu	Diversion	SA	WUAs	1306	491	0.10	0.23	38	2.31
Batman	Diversion	SH	WUAs	1551	1261	0.14	0.27	81	1.96
Derik-Dumluca	Diversion	SH	WUAs	641	466	0.05	0.22	73	4.14
Nusaybin	Diversion	SH	WUAs	1533	1393	0.08	0.27	91	3.29
Yeni Karpuzlu	Diversion	SH	WUAs	573	901	0.08	0.07	157	0.82
Keşan	Diversion	SH	WUAs	2669	254	0.24	0.36	10	1.46
Kayalİköy	Diversion	SH	WUAs	1660	888	0.22	0.37	53	1.73
Hayrabolu	Diversion	SH	WUAs	2590	783	0.33	0.51	30	1.54
Sarİz	Diversion	SA	WUAs	2142	700	0.29	0.85	33	2.96
Ağcaşar	Diversion	SA	WUAs	1121	526	0.46	0.35	47	0.75
Kovalİ	Diversion	SA	WUAs	2183	1995	0.43	0.57	91	1.31
Yalİntaş	Diversion	SA	WUAs	875	677	0.30	0.33	77	1.08
Sekili	Diversion	SH	WUAs	654	137	0.05	0.29	21	5.74
Fehimli	Diversion	SH	WUAs	1752	601	0.10	0.42	34	4.38
Uzunlu	Diversion	SH	WUAs	1769	741	0.26	0.44	42	1.66
Yahyasaray	Diversion	SH	WUAs	1354	482	0.13	0.34	36	2.60
Paşaköy	Diversion	SH	WUAs	1198	408	0.16	0.37	34	2.32
Yerköy-Y.Mahaalle	Diversion	SH	WUAs	1018	540	0.16	0.37	53	2.36
Kİrkgözler-Yeniköy	Diversion	SH	WUAs	1460	790	0.16	0.25	54	1.50
Boğaçay	Diversion	SH	WUAs	4083	3463	0.35	0.63	85	1.81
Gazipaşa	Diversion	SH	WUAs	7629	1242	1.58	2.66	16	1.68
Korkuteli	Diversion	SH	WUAs	3930	2653	0.44	0.78	68	1.78
Hacİhİdİr	Diversion	SH	WUAs	1728	706	0.08	0.24	41	3.00
Karasu	Diversion	H	WUAs	2397	320	0.17	0.49	13	2.91
Arİncİk	Diversion	H	WUAs	808	110	0.04	0.17	14	3.89
Gürpİnar	Diversion	SA	WUAs	448	126	0.10	0.11	28	1.05
Muradiye	Diversion	SA	WUAs	202	50	0.01	0.05	25	3.99
Seyitler	Diversion	SH	WUAs	1503	515	0.16	0.58	34	3.57
Gölhisar	Diversion	SA	WUAs	1742	1232	0.20	0.48	71	2.46
Karamanlİ	Diversion	SA	WUAs	625	371	0.11	0.25	59	2.34
Uluborlu	Diversion	SH	WUAs	9575	8033	1.79	2.42	84	1.35
Yalvaç	Diversion	SH	WUAs	5357	1193	1.01	1.37	22	1.36
Yİldİzİrmağİ	Diversion	SA	WUAs	1510	484	0.23	0.48	32	2.10
Yapİaltİn	Diversion	SA	WUAs	1944	598	0.17	0.57	31	3.41
Gazibey	Diversion	SA	WUAs	1347	289	0.13	0.41	21	3.25
Suşehri	Diversion	SA	WUAs	1171	622	0.14	0.27	53	1.85
Hancağİz	Diversion	SH	WUAs	622	149	0.06	0.36	24	5.94
Andİrİn	Diversion	SH	WUAs	1344	1174	0.08	0.28	87	3.51
Karpuzlu	Diversion	SH	WUAs	1059	281	0.07	0.23	27	3.25
Söke	Diversion	SH	WUAs	1426	1411	0.17	0.28	99	1.62
Akçay	Diversion	SH	WUAs	2943	2206	0.26	0.53	75	2.06
Sultanhisar	Diversion	SH	WUAs	1572	197	0.05	0.25	13	5.14
Çürüksu	Diversion	SH	WUAs	2085	2033	0.20	0.45	98	2.24
Kelekçi	Diversion	SH	WUAs	746	658	0.06	0.20	88	3.28
Acİpayam	Diversion	SH	WUAs	773	613	0.04	0.23	79	5.63
Çal	Diversion	SH	WUAs	3419	1186	0.18	0.74	35	4.04
Irgİllİ	Diversion	SH	WUAs	1338	761	0.09	0.27	57	3.06
Işİklİ	Diversion	SH	WUAs	1578	1196	0.16	0.32	76	1.94
Sarayköy	Diversion	SH	WUAs	2807	3764	0.20	0.57	134	2.83
Fethiye	Diversion	H	WUAs	1749	1042	0.10	0.44	60	4.36
Yk. Akçay	Diversion	H	WUAs	1356	390	0.07	0.27	29	3.79
Iğdİr	Diversion	SH	WUAs	1281	720	0.08	0.27	56	3.28
Gönen	Diversion	SH	WUAs	1967	1943	0.12	0.28	99	2.41
Uluabat	Pumping	SH	SHW	1654	546	0.14	0.40	33	2.90
Orhangazi	Pumping	SH	SHW	2218	504	0.16	0.48	23	3.05
Karaağaç	Pumping	SA	SHW	3799	646	0.28	1.08	17	3.80
Darİdere	Pumping	SA	SHW	1797	51	0.17	0.66	3	4.00
Kalecik	Pumping	SA	SHW	1297	724	0.11	0.28	56	2.56
Gökçeören	Pumping	SA	SHW	825	211	0.10	0.19	26	1.86

Table 1: Continued

Columns									
1	2	3	4	5	6	7	8	9	10
Kumbaba	Pumping	SA	SHW	672	280	0.13	0.18	42	1.36
Aydİncİk	Pumping	SH	SHW	3306	1309	0.15	0.68	40	4.58
Erdemli	Pumping	SH	SHW	9492	9078	0.56	1.83	96	3.30
Uluova	Pumping	SA	SHW	1869	1775	0.24	0.40	95	1.65
Eyüpbağlarİ	Pumping	SA	SHW	3317	724	0.18	0.53	22	2.91
Taşhan	Pumping	SA	SHW	2340	468	0.15	0.59	20	3.94
Sarİhİdİr	Pumping	SA	SHW	2044	1413	0.20	0.71	69	3.57
Beşkonak	Pumping	SH	SHW	567	16	0.02	0.11	3	6.12
Barla	Pumping	SH	SHW	5522	1639	0.47	1.36	30	2.91
Gelendost	Pumping	SH	SHW	3265	1912	0.38	0.66	59	1.75
Senirkent	Pumping	SH	SHW	2649	1126	0.18	0.64	43	3.53
Boyalİca	Pumping	SH	WUAs	3944	2752	0.44	0.85	70	1.93
İznik	Pumping	SH	WUAs	3924	1659	0.36	0.87	42	2.40
Karacabey	Pumping	SH	WUAs	2432	1243	0.48	0.55	51	1.14
Keramet	Pumping	SH	WUAs	4675	5128	0.82	0.94	110	1.14
Dineksaray	Pumping	SA	WUAs	1541	1060	0.24	0.45	69	1.85
Ilgİn	Pumping	SA	WUAs	666	301	0.59	0.29	45	0.49
Misis	Pumping	SH	WUAs	1906	1263	0.10	0.43	66	4.23
Samandağ	Pumping	SH	WUAs	5118	4033	0.76	0.95	79	1.24
Mersin Bah.	Pumping	SH	WUAs	4246	3248	0.37	0.67	76	1.82
Mut	Pumping	SH	WUAs	6353	80	0.49	1.24	1	2.51
Palu-Kovancİlar	Pumping	SA	WUAs	2198	344	0.09	0.46	16	5.33
Kirişhane	Pumping	SH	WUAs	2757	673	0.08	0.37	24	4.90
Küplü	Pumping	SH	WUAs	2363	544	0.75	1.29	23	1.73
Çİplaklİ	Pumping	SH	WUAs	1431	333	0.19	0.25	23	1.36
Mursal	Pumping	SH	WUAs	1200	866	0.34	0.22	72	0.65
Akçakale	Pumping	SA	WUAs	1374	673	0.17	0.25	49	1.46
Ceylanpİnar	Pumping	SA	WUAs	1808	1506	0.20	0.44	83	2.14
Eber-Akşehir	Pumping	SH	WUAs	2885	140	0.20	1.16	5	5.73
Atabey	Pumping	SH	WUAs	4938	1313	0.27	1.22	27	4.45
Şarkİkaraağaç	Pumping	SH	WUAs	1378	181	0.06	0.33	13	5.07
Hoyran	Pumping	SH	WUAs	3523	1395	0.21	0.93	40	4.42
Kalealtİ	Pumping	SH	WUAs	1347	1056	0.15	0.36	78	2.44
Baklan	Pumping	SH	WUAs	2467	1299	0.30	0.58	53	1.96
Gümüşsu	Pumping	SH	WUAs	4006	3004	0.93	0.85	75	0.92
Sütlaç	Pumping	SH	WUAs	2181	596	0.16	0.44	27	2.75
Pamukkale	Pumping	SH	WUAs	1629	1444	0.16	0.32	89	1.98
Kütahya	D and P	SH	SHW	1360	323	0.11	0.35	24	3.28
Tavşanlİ	D and P	SH	SHW	1541	274	0.16	0.42	18	2.68
Bolu	D and P	SH	SHW	2691	443	0.26	1.09	16	4.23
Daphan	D and P	SH	SHW	449	72	0.11	0.20	16	1.85
Erkenek	D and P	SA	SHW	1254	1223	0.10	0.40	98	4.06
Van	D and P	SA	SHW	1718	398	0.24	0.48	23	2.03
Koçköprü	D and P	SA	SHW	610	195	0.08	0.15	32	1.85
Karataş	D and P	SH	SHW	428	94	0.15	0.19	22	1.31
Yİlanlİ	D and P	SH	SHW	4350	1484	0.53	0.93	34	1.75
Yenİşarbademli	D and P	SH	SHW	1334	351	0.07	0.28	26	3.76
Göksun	D and P	SH	SHW	932	462	0.17	0.31	50	1.81
Karaçomak	D and P	SH	SHW	5079	2013	0.85	1.72	40	2.02
Menemen	D and P	SH	WUAs	1701	1397	0.35	0.38	82	1.08
Alaşehir	D and P	SH	WUAs	2793	1724	0.65	0.63	62	0.96
Salihli	D and P	SH	WUAs	1849	1151	0.23	0.41	62	1.79
Çifteler	D and P	SA	WUAs	1820	1245	0.17	0.58	68	3.49
Sarİcakaya	D and P	SA	WUAs	1867	476	0.09	0.51	26	5.35
Seyitgazi	D and P	SA	WUAs	912	323	0.17	0.34	35	2.01
Çavdarhisar	D and P	SH	WUAs	1059	185	0.07	0.34	17	4.81
Pamukova	D and P	SH	WUAs	2739	1018	0.21	0.73	37	3.42
Uluİrmak	D and P	SA	WUAs	688	449	0.13	0.21	65	1.62
Karaman	D and P	SA	WUAs	696	439	0.19	0.21	63	1.10
Çumra	D and P	SA	WUAs	660	356	0.15	0.21	54	1.43
İvriz	D and P	SA	WUAs	1180	1006	0.24	0.38	85	1.60
Asartepe	D and P	SA	WUAs	5201	2306	0.58	0.87	44	1.50
Köprüköy	D and P	SA	WUAs	1013	474	0.07	0.26	47	3.86
Ceyhan	D and P	SH	WUAs	1089	967	0.13	0.22	89	1.73
Kozan	D and P	SH	WUAs	2440	1477	0.17	0.46	61	2.69

Table 1: Continued

Columns									
1	2	3	4	5	6	7	8	9	10
Seyhan	D and P	SH	WUAs	1874	1733	0.15	0.36	92	2.45
Yarseli	D and P	SH	WUAs	1888	1303	0.23	0.40	69	1.76
Berdan	D and P	SH	WUAs	9763	5860	0.85	1.85	60	2.18
Silifke	D and P	SH	WUAs	2589	1834	0.08	0.38	71	4.72
Haruniye	D and P	SH	WUAs	1217	396	0.13	0.25	33	1.95
Amasya	D and P	SA	WUAs	2716	1383	0.26	0.62	51	2.35
Suluova	D and P	SA	WUAs	1013	797	0.25	0.31	79	1.25
Yerkozlu	D and P	SA	WUAs	2845	1572	0.47	0.61	55	1.31
Tokat	D and P	SA	WUAs	3045	2029	0.15	0.76	67	4.93
Erbaa	D and P	SA	WUAs	1615	1027	0.13	0.33	64	2.55
Erzincan	D and P	SA	WUAs	1630	934	0.13	0.53	57	4.13
Tercan	D and P	SA	WUAs	5096	946	0.28	1.23	19	4.43
Malatya	D and P	SA	WUAs	5285	3501	1.04	0.90	66	0.86
Altİnyazİ-Karasaz	D and P	SH	WUAs	2755	1125	0.26	0.41	41	1.59
Sarİmsaklİ	D and P	SA	WUAs	1680	1654	0.22	0.55	98	2.45
Çoğun-Güzler	D and P	SA	WUAs	1341	811	0.12	0.48	60	4.07
Aksu	D and P	SH	WUAs	2251	1530	0.17	0.47	68	2.82
Alanya	D and P	SH	WUAs	7784	6100	0.57	1.28	78	2.24
Finike	D and P	SH	WUAs	9458	8090	0.83	1.43	86	1.72
Manavgat	D and P	SH	WUAs	2273	1007	0.21	0.57	44	2.70
Alara	D and P	SH	WUAs	6007	3018	0.46	1.81	50	3.95
Köprüçay	D and P	SH	WUAs	1537	1081	0.09	0.31	70	3.28
Ş.Urfa-Harran	D and P	SA	WUAs	1620	1353	0.16	0.25	84	1.57
Selevir	D and P	SH	WUAs	2356	776	0.26	0.72	33	2.81
Karakuyu	D and P	SH	WUAs	2566	681	0.25	0.72	27	2.93
Çİldİrİm	D and P	SH	WUAs	1955	872	0.16	0.54	45	3.33
Örenler	D and P	SH	WUAs	3357	698	0.23	0.90	21	3.84
Boğazova	D and P	SH	WUAs	9508	8420	1.32	1.85	89	1.41
Keysun	D and P	SH	WUAs	986	269	0.11	0.19	27	1.77
Çelikhan	D and P	SH	WUAs	4579	4579	1.27	1.77	100	1.39
K.Maraş S.S.	D and P	SH	WUAs	1664	941	0.24	0.32	57	1.34
Aydİn	D and P	SH	WUAs	1873	1703	0.27	0.39	91	1.42
Topçam	D and P	SH	WUAs	1106	523	0.10	0.24	47	2.29
Nazilli	D and P	SH	WUAs	1333	1377	0.11	0.25	103	2.26
Kestep	D and P	H	WUAs	1690	648	0.11	0.41	38	3.79
Masat	D and P	SH	WUAs	621	107	0.04	0.14	17	3.83
Balİkesir	D and P	SH	WUAs	1257	427	0.10	0.26	34	2.65
Kepsut	D and P	SH	WUAs	2527	681	0.13	0.55	27	4.32
Pamukçu	D and P	SH	WUAs	1807	575	0.08	0.37	32	4.46
Bigadiç	D and P	SH	WUAs	2006	1617	0.34	0.42	81	1.26
Savaştepe	D and P	SH	WUAs	2483	1023	0.32	0.56	41	1.78
Sİndİrgİ	D and P	SH	WUAs	65	47	0.01	0.01	73	1.20
Çanakkale	D and P	SH	WUAs	2804	327	0.19	0.55	12	2.96
Bayramiç	D and P	SH	WUAs	1192	340	0.06	0.26	29	4.21
			Min	65	16	0.01	0.01	1	0.19
			Mean	2250	1134	0.27	0.55	49	2.66
			Max	9763	9078	1.79	2.66	157	9.76
			SD+	3960	2460	0.54	0.96	76	4.01
			SD	1711	1326	0.28	0.41	27	1.35
			SD-	539	-192	-0.01	0.14	22	1.31

Column 1: System name, Column 2: Type of system (D and P is the diversion and pumping), Column 3: Climate (SH: Semi-humid, SA: Semi-arid, H: Humid), Column 4: Type of management (SHW and WUAs are the schemes operated by the State Hydraulic Work department and Water User Associations) Column 5: Output per unit cropped area, US\$ha^{-1}, Column 6: Output per unit command area, US\$ha^{-1}, Column 7: Output per unit irrigation supply, US\$m^{-3} Column 8: Output per unit water consumed, US\$ m^{-3}, Column 9: Irrigation intensity, %, Column 10: Relative water supply

crops are not getting enough water. The optimum value of the relative water supply is one.

The irrigation water less than the requirement is applied to 11 schemes in which 10 and 1 are operated by the WUAs and SHW, respectively; whereas 228 schemes receive water more than the requirement. This indicates that irrigation water is not used uniformly and efficiently by both management types. Levine (1982) stated that water supplied more than 2.5 times of the net requirement was an indication of inappropriate water management. Since planned water delivery is not available in the irrigation schemes, the large amount of water in the canal is wasted; as a result, this increases the relative water supply. The relative water supply was determined as 1.20-1.48, 0.91-7.15, 0.60-1.79, 0.58-2.41, 0.80-4.10, 0.60-1.09, 1.30-8.40, 1.40-1.80, 0.30-7.83 and 1.88 in the studies of

Table 2: Descriptive statistics and ANOVA test result

	Output/cropped area			Output/unit command			Output/water supplied			Output/water consumed			Irrigation intensity			Relative water supply		
	Div[a]	Pum[b]	D and P[c]	Div	Pum	D and P	Div	Pum	D and P	Div	Pum	D and P	Div	Pum	D and P	Div	Pum	D and P
Type of system																		
n[d]	124	44	72	124	44	72	124.00	44.00	72.00	124.00	44.00	72.00	124	44	72	124.00	44.00	72.00
Min.	202	567	65	50	16	47	0.01	0.02	0.01	0.05	0.11	0.01	3	1	12	0.19	0.49	0.86
Max.	9575	9492	9763	8033	9078	8420	1.79	0.93	1.32	2.66	1.83	1.85	157	110	103	9.76	6.12	5.35
Mean	1970	2766	2423	923	1362	1362	0.26	0.29	0.27	0.51	0.64	0.57	49	46	53	2.66	2.79	2.58
SD-	562	1022	362	13	255	273	0.04	0.07	0.00	0.10	0.26	0.13	21	17	28	1.24	1.34	1.41
SD+	3378	4509	4484	1859	2978	2996	0.55	0.51	0.54	0.92	1.02	1.00	76	75	77	4.09	4.24	3.75
	$F_{(2,237)}$=3.827, P=0.023			$F_{(2,237)}$=3.316, P=0.038			$F_{(2,237)}$=0.204, P=0.816			$F_{(2,237)}$=1.486, P=0.228			$F_{(2,237)}$=0.66, P=0.51			$F_{(2,237)}$=0.404, P=0.668		

	Output/cropped area		Output/unit command		Output/water supplied		Output/water consumed		Irrigation intensity		Relative water supply	
	Semi-humid	Semi-arid	Semi-humid	Semi-arid	Semi-humid	Semi-arid	Semi-humid	Semi-arid	Semi-humid	Semi-arid	Semi-humid	Semi-arid
Climate												
n	145	83	145	83	145.00	83.00	145.00	83.00	145	83	145.00	83.00
Min.	65	202	16	50	0.01	0.01	0.01	0.05	1	3	0.65	0.19
Max.	9763	5285	9078	3501	1.79	1.68	2.66	1.27	157	106	9.76	7.29
Mean	2606	1686	1377	780	0.30	0.22	0.62	0.44	50	50	2.64	2.55
SD-	647	619	217	180	0.00	0.00	0.14	0.18	23	23	1.28	1.23
SD+	4566	2754	2970	1380	0.61	0.45	1.11	0.69	78	76	4.00	3.88
	$F_{(1,226)}$=15.61, P=0.00		$F_{(1,226)}$=10.73, P=0.00		$F_{(1,226)}$=4.11, P=0.04		$F_{(1,226)}$=11.00, P=0.00		$F_{(1,226)}$=0.06, P=0.80		$F_{(1,226)}$=0.22, P=0.635	

	Output/cropped area		Output/unit command		Output/water supplied		Output/water consumed		Irrigation intensity		Relative water supply	
	SHW	WUAs	SHW	WUAs	SHW	WUAs	SHW	WUAs	SHW	WUAs	SHW	WUAs
Type of management												
n	57	182	57	182	57.00	182.00	57.00	182.00	57	182	57.00	182.00
Min.	393	65	16	47	0.02	0.01	0.11	0.01	3	1	0.89	0.19
Max.	9492	9763	9078	8420	1.37	1.79	1.85	2.66	98	157	9.76	5.94
Mean	2328	2225	868	1217	0.25	0.27	0.65	0.52	35	54	3.13	2.51
SD-	775	465	364	130	0.02	0.02	0.22	0.11	11	27	1.57	1.26
SD+	3881	3986	2101	2564	0.48	0.56	1.08	0.93	59	80	4.68	3.77
	$F_{(1,237)}$=0.15, P=0.69		$F_{(1,237)}$=3.02, P=0.08		$F_{(1,237)}$=0.24, P=0.62		$F_{(1,237)}$=4.26, P=0.04		$F_{(1,237)}$=22.44, P=0.00		$F_{(1,237)}$=9.19, P=0.00	

[a]Diversion, [b]Pumping, [c]Diversion and pumping, [d]The number of samples (irrigation scheme),

Note: Anova test results for the six parameters of the system type is $F_{(2,1437)}$=3.500, P=0.030

Anova test results for the six parameters of the climate is $F_{(1,1366)}$=13.135, P=0.000

Anova test results for the six parameters of the management type is $F_{(1,1432)}$=0.334, P=0.563

Değirmenci (2001a), Değirmenci (2001b), Beyribey *et al.* (1997a), Beyribey *et al.* (1997b), Molden *et al.* (1998), Yazgan and Degirmenci (2002), Çakmak and Beyribey (2003), Vermillion and Garces-Restrepo (1996), Çakmak (2001) and Bandara (2003), respectively.

Comparing performance by system type: The irrigation schemes were disaggregated based on the system types as diversion, pumping and diversion and pumping for each of six indicators and statistical analysis results are displayed in Table 2. Although statistically no significant difference at p=0.05 level (p>0.05) was determined among the system types for the output per unit water, irrigation intensity and relative water supply; significant difference was determined among them for the output per unit land and all of six indicators. The pumping and diversion have the highest and lowest mean values for the output per unit land and water. The reason might be due to the fact that people are using water more efficiently because pumping water from river or storage is costly compared to the other systems.

Comparing performance by climate: Drought indices were determined for irrigation schemes using De Morttonne Drought Indices. Turkey is mainly under the two indices; semi-humid and semi-arid. The irrigation schemes were grouped based on the climate as semi-humid and semi-arid for each of six indicators and statistical analysis results are displayed in Table 2. Although statistically no significant difference at p=0.05 level (p>0.05) was determined between the climatic conditions for irrigation intensity and relative water supply, the difference was significant for the output per unit land and water and all of six indicators. The means of all indicators were higher in semi-humid regions than in semi-arid regions. The reason might be due to the fact that irrigation requirement is generally lower in semi-humid regions compared to the semi-arid regions.

Comparing performance by management type: The irrigation schemes were grouped based on the management type as the SHW and WUAs-operated for each of six indicators and statistical analysis results are displayed in Table 2. Statistically no significant difference at p=0.05 level (p>0.05) was determined between the management types for output per unit land, output per unit water supplied and all of six indicators except the output per unit water consumed, irrigation intensity and relative water supply. Although there is statistically no clear difference in the means of the management types for the output per unit land and water, more of the designed area is irrigated by the WUAs with efficient use of water, where irrigation intensity is larger and relative water supply is lower.

In this study, cross-system comparison of all irrigation schemes developed by the SHW department and comparative performance analyses of the schemes based on the system type, climate and management type were made using the IWMI's six performance indicators for the year 2001.

The output per unit land and water can be grouped into two main classes. The systems that mostly grow orchards, industrial crops and some cereals have higher output per land and water than the cereal-producing systems. Although more water than the requirement is used for all schemes, water is not used efficiently because output or production per unit land and water is relatively low. This might be due to the application of inappropriate crop pattern and intensity to the project areas, the lack of infrastructure and the lack of the knowledge and experience of the farmers for an appropriate irrigation practice.

Irrigation schemes should be grouped and evaluated based on their crop patterns and growth-time and marketing situation and then similar schemes should be compared or evaluated among themselves to expand this topological study. In addition, time-series of topological study can be conducted to better understand key determinants of performance.

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