Turk J Agric For
28 (2004) 321-331

Comparison of Irrigation Performance Based on the Basin, Crop Pattern, and Scheme Sizes Using External Indicators

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Received: 22.01.2004

Abstract: A comparative assessment allows screening of irrigation systems based on the key issues relative to performance and indicates where improvements should be made, such as in type of management, infrastructure, crop pattern and intensity, and system size. The objective of this study was to assess the performance of 239 irrigation schemes (57 DSI-operated and 182 transferred to Irrigation Associations) based on the basin, crop pattern, and scheme sizes using 6 external indicators for 2001. The basins that grow mostly orchard and industrial crops have higher output per unit land and water than that of the basins that mostly grow cereals. ANOVA test results indicated that the differences in all the indicators except for the relative water supply among the crops in all schemes were statistically significant (P = 0.05). However, the differences in all the indicators except for the irrigation ratio among the size groups of all schemes were not statistically significant. Although more water than demanded (approximately 2.5 times the demand) is applied to the schemes, water is not used efficiently because output per unit land and water is relatively low, 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, basin, crop pattern, scheme size

Sulama Performansının Dışsal Göstergeler Kullanılarak Havza, Bitki Deseni ve Proje Büyüklüğü Bazında Karşılaştırılması

Özet: Karşılaştırma değerlendirmesi, performans ile ilgili temel faktörlere göre sulama sistemlerinin sınıflandırılmasına olanak sağlar ve yönetim, altyapı, bitki deseni ve yoğunluğu ve sistemin büyüklüğü gibi faktörlerin hangisinde geliştirme yapılması gerektiğini belirlemeyi sağlar. Bu çalışmanın amacı, 2001 yılı için dışsal göstergeleri kullanarak 239 adet (57'si DSI ve 182'si sulama birlikleri tarafından işletilen) sulama şebekesinin performansını havza, bitki deseni ve proje büyüklüğü bazında değerlendirmektir. Ağırlıklı olarak meyve-sebze ve endüstrüyel bitkilerin yetiştiği havzaların birim alan ve su başına üretimleri ağırlıklı olarak tahıl bitkilerinin yetiştiği havzalara göre daha yüksek bulunmuştur. ANOVA test sonuçları bütün şebekelerdeki bitkilerin su temin oranı hariç altı göstergesi arasında istatistiksel olarak önemli bir fark olduğunu göstermiştir (P = 0.05). Bununla birlikte, bütün şebekelerin büyüklük guruplarının sulama oranı hariç altı göstergesi arasında istatistiksel olarak önemli bir farkın olmadığı görülmüştür. Şebekelere ihtiyaçtan daha fazla su (yaklaşık iki kat daha fazla) verilmesine rağmen, su etkili bir şekilde kullanılamamıştır, çünkü, uygun olmayan bitki deseni ve yoğunluğu, sulama altyapısı, verilerin güvenilirliği, yönetici ve çiftçilerin eğitim durumları ve yönetim yapısı gibi tahmini faktörler yüzünden birim alan ve suya karşı elde edilen üretim değeri kısmen düşüktür.

Anahtar Sözcükler: Sulama şebekesi, karşılaştırma göstergeleri, havza, bitki deseni, şebeke büyüklüğü

Introduction

Water is an essential source for adequate production of agricultural crops all over the world, but it is a limiting factor for agricultural production in most parts of Turkey due to inadequate rainfall and the increasing population. Applying water to crops through irrigation increases yields and production in agriculture; however, inappropriate management of irrigation schemes might lead to environmental problems such as a high water table and poor drainage and thus salinization and pollution in addition to low quality irrigation water. This implies that optimal management of water in agriculture is very important for the sustainability of agricultural production.

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Assessing the performance of irrigated agriculture is necessary in order to evaluate the impact of agricultural and hydrological interventions. The performance of many irrigation systems is significantly below their potential due to a number of shortcomings, such as poor design, construction and operation and maintenance. The evaluation of irrigation water use efficiency has been studied by many researchers (Bos and Nugteren, 1974; Levine, 1982; Bos et al., 1994; Molden et al., 1998).

The performance has been assessed for individual schemes, schemes in a basin, or schemes at national level for specific types such as those DSI-operated and transferred to Irrigation Associations (IAs) in Turkey. The DSI is the primary government institution responsible for water resource development in Turkey. Değirmenci (2001b) assessed the performance of the Bursa-Uluabat irrigation project for 1992-98 using 7 external indicators developed by the International Water Management Institute (IWMI). The performances of the right bank of Eskişehir (Benli and Beyribey, 1998), the Mersin Irrigation Association (Bulut and Çakmak, 2001) and Bursa Groundwater Irrigation Scheme (Yazgan and Değirmenci, 2002) were assessed using several external indicators. Çakmak (2001), Çakmak (2002), Çakmak and Beyribey (2003), and Murray-Rust and Svendsen (2001) evaluated the performance of Konya IAs, schemes located in the basins of Kızılırmak, Sakarya, and Gediz, respectively, using several external indicators including the IWMI's indicators. In a national study conducted by Değirmenci (2001a), the IWMI's 6 indicators were applied to 158 transferred schemes to assess their performance. Molden et al. (1998) assessed the performance of 18 irrigation schemes in 11 different countries using the IWMI's 9 external indicators. Sakthivadivel et al. (1999) demonstrated 4 typical applications of these indicators: cross-system comparison, temporal variations in performance in one system, spatial variations within one system, and comparing performance by system type to 40 irrigation schemes from 13 countries.

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 assessments of a specific project over time because they consider elements common to all systems. The information on irrigation water management on a detailed scale like at country level is not common due to the lack of data, or reliability and accessibility of the data (Molden et al., 1998).

Gathering the comparative performance indicators for a greater variety and number of irrigation systems (developing a topology) allows the comparison of irrigation systems with similar settings. In addition, it allows us to identify different aspects that lead to better performance. A comparative study helps us to distinguish between irrigation schemes to emphasize key issues relative to their performance (Sakthivadivel et al., 1999). Merdun and Değirmenci (2004) assessed the performance of 57 DSI-operated and 182 transferred schemes based on the system type (diversion, pumping, or diversion and pumping), climatic conditions (semi-arid or semi-humid) and management type (DSI-operated or transferred) using the IWMI's 6 performance indicators for 2001. Further segregation and comparison of these schemes based on other factors such as the basin, crop pattern, and scheme size will help us to determine the problem and develop solutions for improving the performance of the schemes.

Therefore, the objective of this study was to assess the performance of 239 schemes (57 DSI-operated and 182 transferred to IAs) based on the basin, crop pattern, and scheme sizes using the IWMI's 6 performance indicators for the same year.

Materials and Methods

Performance Indicators

In this study, all irrigation schemes developed and operated by the DSI and transferred to IAs were used as material. Fifty-seven of these schemes were developed and are still being operated by the DSI, whereas 182 of them were transferred to IAs. Six external indicators developed by the IWMI were applied to the 239 schemes to assess their performance for 2001. Then the schemes were segregated based on the crop pattern and scheme sizes as in Table 1. Similarly, the schemes were segregated based on the basin as indicated in the Evaluation Reports of Irrigation Schemes operated by the DSI and transferred for 2001 (DSI, 2001a). Even though Turkey is hydrologically divided into 26 drainage basins, the schemes located in 25 basins were assessed in this

Table 1. The number of schemes for a given size group and crop grown.

	Crop Pattern					
	Wheat	Sugar beet	Cotton	Corn	Orchards	Rice
Number of Schemes	56	62	39	33	40	9
	Scheme Sizes (ha)					
	<1000	1000-5000	5000-10,000	10,000-20,000	>20,000	
Number of Schemes	24	126	51	26	12	

study because there is no scheme in the Doğu Karadeniz Basin. A large data set composed of water supply, crop types, crop water requirement, and irrigated and command areas was compiled from the Irrigation Project Evaluation Reports, whereas the crop pattern, and unit yield and price data were obtained from the Product Count Result Reports (DSI, 2001a and 2001b). This data set was then used to calculate 6 irrigation performance indicators: output per unit command, output per unit cropped land, output per unit water supply, output per unit water consumed, irrigation ratio, and relative water supply. 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. The relative water supply indicates how well irrigation supply and demand are matched. A value over 1 would suggest 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. The optimum value of the relative water supply is 1. These indicators are calculated as follows (Molden et al., 1998):

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

$$\text{Output per unit cropped land}\left(\frac{\$}{ha}\right)=\frac{SGVP}{\text{Irrigated cropped land}} \quad (2)$$

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

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

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

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

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 land 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. These indicators allow one to compare the performance of fundementally different systems by standardizing the gross value of agricultural production.

The Standardized Gross Value of Production (SGVP) was developed for cross-system comparisons regardless of where they are or what kinds of crop are grown. It is calculated as follows (Moden et al., 1998):

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

where A_i is the area cropped with crop i (ha), Y_i is the yield of crop i ($kg.ha^{-1}$), 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 predominantly locally grown and internationally traded.

Analysis of the Data

Descriptive statistical parameters such as minimum, maximum, mean, and plus and minus standard deviations, were calculated for each of the 6 indicators for crop pattern and scheme size. In addition, the analysis of variance (ANOVA) was performed using SPSS software (Norusis, 1990) to determine whether differences among the crops and scheme sizes for the 6 indicators are significant or not.

Results and Discussion

Output per unit command

The mean values of the basins for the 6 indicators are plotted in Figures 1-6. The output per unit command of the basins varies between US$107 and US$3065 per hectare with a variation ratio of 1 to 29 (Figure 1). The basins with low values (less than US$1000 ha^{-1}) are those that mostly grow crops such as cereals. The basins with high values (greater than US$1000) include orchards, industrial crops (cotton, corn, and sugarbeet), and some cereals. Molden et al. (1998) also stated that systems including orchards, industrial crops, and some cereals had high values of output per unit command. Moreover, ANOVA test results showed that the differences in output per unit command among the crops in all schemes were statistically significant [$F(5,233) = 13.808$, $P = 0.000 < P = 0.05$] and the mean value of wheat is the smallest, as shown in Table 2. However, ANOVA test results indicated that the differences in output per unit command among the scheme sizes in all schemes were not statistically significant [$F(4,234) = 0.078$, $P = 0.989 > P = 0.05$], as shown in Table 3.

These results indicated that the cropping pattern and cropping intensity with large area and high yield and local price led to high output per unit command. In addition, system type, climatic conditions, and management type might indirectly affect these differences in output per unit command. Output per unit command was determined to be 1840, 679-2888, 477-3626, 195-5391, 1070-1583, 144-8349, 2629, and 67-2001US$.ha^{-1} in the studies conducted by Kloezen and Garces-Restrepo (1998), Molden et al. (1998), Sakthivadivel et al. (1999),

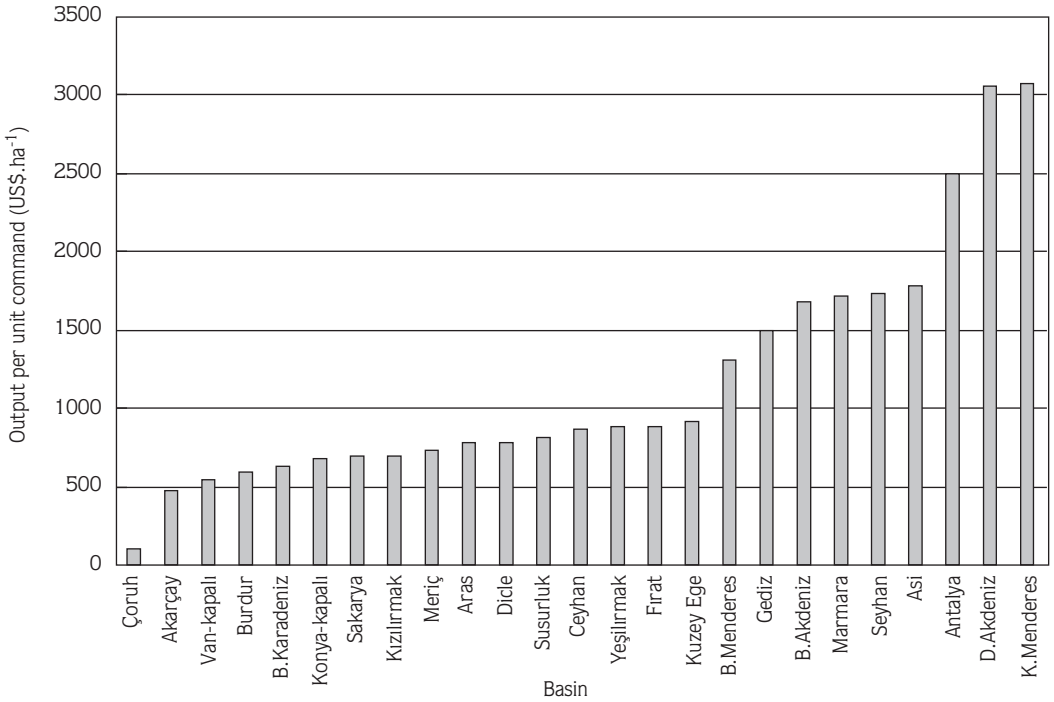

Figure 1. Output per unit command.

Table 2. Descriptive statistics and ANOVA test results for crop pattern.

Crop pattern	Output/unit command				Output/cropped land			
	Min.	Max.	Mean	SD±	Min.	Max.	Mean	SD±
Wheat	50	45799	696	8-1383	202	4579	1303	482-2125
Sug.beet	16	5860	942	0-1935	65	9763	2219	339-4099
Cotton	107	3004	740	174-1305	610	5201	2053	991-3116
Corn	269	3764	1189	472-1905	849	6007	1835	972-2698
Orchard	73	9078	2492	96-4889	987	9575	4322	1980-6664
Rice	254	1943	1007	454-1560	573	2757	2195	1477-2914
	F(5,233)=13.808, P=0.000				F(5,233)=23.136, P=0.000			
Crop pattern	Output/water supply				Output/water consumed			
	Min.	Max.	Mean	SD±	Min.	Max.	Mean	SD±
Wheat	0.01	1.68	0.21	0.00-0.48	0.05	1.77	0.42	0.13-0.71
Sug.beet	0.01	1.58	0.25	0.00-0.56	0.01	2.66	0.57	0.01-1.13
Cotton	0.04	1.37	0.26	0.02-0.50	0.14	1.72	0.56	0.21-0.91
Corn	0.07	0.56	0.18	0.08-0.29	0.14	1.81	0.39	0.13-0.66
Orchard	0.05	1.79	0.47	0.12-0.82	0.17	2.42	0.91	0.44-1.37
Rice	0.07	0.33	0.16	0.07-0.26	0.07	0.51	0.34	0.22-0.46
	F(5,233)=6.552, P=0.000				F(5,233)=10.266, P=0.000			
Crop pattern	Irrigation ratio				Relative water supply			
	Min.	Max.	Mean	SD±	Min.	Max.	Mean	SD±
Wheat	4	100	53	26-80	0.19	7.29	2.92	1.32-4.52
Sug.beet	3	92	46	21-71	1.14	6.12	2.68	1.58-3.79
Cotton	12	98	36	17-54	0.49	9.76	2.81	1.29-4.33
Corn	23	134	64	38-90	1.04	4.45	2.34	1.38-3.31
Orchard	1	110	52	25-79	0.71	5.14	2.36	1.27-3.45
Rice	10	157	57	11-103	0.82	4.90	2.59	1.03-4.14
	F(5,233)=6.665, P=0.000				F(5,233)=1.424, P=0.216			

Note: ANOVA test results for the 6 indicators of the irrigation schemes: F(5,1428)=14.032, P=0.000.

Çakmak (2001), Değirmenci (2001a), Değirmenci (2001b), Yazgan and Değirmenci (2002), and Çakmak and Beyribey (2003), respectively.

Output per unit cropped land

Output per unit cropped land, shown in Figure 2, can be divided into 2 classes of basins. The basins producing cereals have an output per unit cropped land around or less than US$2000, whereas the basins producing non-cereal crops such as orchard and industrial crops (cotton and corn) have an output per unit cropped land around or greater than US$3000. The output per unit cropped land of the basins varies between US$621 and US$7213 per hectare with a variation ratio of 1 to 12 (Figure 2). Molden et al. (1998) found a similar result. Additionally, ANOVA test results revealed that the differences in the output per unit cropped land among the crops in all schemes were statistically significant [$F(5,233) = 23.136$, $P = 0.000 < P = 0.05$] and the mean value of wheat is the smallest, as shown in Table 2. However, even though the ANOVA test results indicated that the differences in the output per unit cropped land among the scheme sizes in all schemes were not statistically significant [$F(4,234) = 1.197$, $P = 0.313 > P = 0.05$], the smaller schemes had higher mean values of output per unit cropped land, as tabulated in Table 3. These results indicate that the cropping pattern and intensity

Table 3. Descriptive statistics and ANOVA test results for scheme size.

Scheme size (ha)	Output/unit command				Output/cropped land			
	Min.	Max.	Mean	SD±	Min.	Max.	Mean	SD±
<1	16	9078	1271	0-3185	567	9492	2677	652-4701
1-5	47	8420	1108	0-2427	65	9575	2362	615-4110
5-10	50	8090	1129	0-2411	202	9458	2007	522-3491
10-20	107	5860	1121	0-2258	448	9763	2053	146-3961
>20	356	1795	1177	767-1588	660	3276	1674	993-2355
	F(4,234)=0.078, P=0.989				F(4,234)=1.197, P=0.313			
Scheme size (ha)	Output/water supply				Output/water consumed			
	Min.	Max.	Mean	SD±	Min.	Max.	Mean	SD±
<1*	0.02	1.27	0.27	0.00-0.54	0.11	1.83	0.69	0.18-1.20
1-5	0.01	1.79	0.30	0.00-0.62	0.01	2.66	0.59	0.15-1.03
5-10	0.01	1.04	0.21	0.03-0.39	0.05	1.43	0.45	0.19-0.72
10-20	0.04	0.85	0.25	0.05-0.45	0.11	1.85	0.51	0.05-0.97
>20	0.08	0.56	0.23	0.10-0.36	0.21	0.72	0.36	0.21-0.52
	F(4,234)=1.048, P=0.383				F(4,234)=2.323, P=0.057			
Scheme size (ha)	Irrigation ratio				Relative water supply			
	Min.	Max.	Mean	SD±	Min.	Max.	Mean	SD±
<1*	3	100	41	12-70	0.65	7.29	3.09	1.46-4.72
1-5	1	157	47	20-73	0.19	9.76	2.69	1.31-4.06
5-10	4	134	52	23-82	0.49	5.94	2.70	1.54-3.86
10-20	13	103	54	32-76	0.75	5.72	2.47	1.04-3.90
>20	53	99	72	55-90	1.08	3.28	1.76	1.17-2.36
	F(4,234)=3.512, P=0.008				F(4,234)=2.121, P=0.079			

*divided by 1000
Note: ANOVA test results for the 6 indicators of the irrigation schemes: F(4,1429)=0.430, P=0.787.

with large area and high yield and local price produce high output per unit cropped land. The smaller schemes seem to be better managed than the larger schemes.

Output per unit cropped land was 105-1800, 2900-4000, 1317-2585, 384-3626, 359-6197, 2857-4415, 190-14843, 4198, and 354-8659US$.ha^{-1} in the studies realized by Kloezen and Garces-Restrepo (1998), Molden et al. (1998), Girgin et al. (1999), Sakthivadivel et al. (1999), Çakmak (2001), Değirmenci (2001a), Değirmenci (2001b), Yazgan and Değirmenci (2002), and Çakmak and Beyribey (2003), respectively.

Output per unit water supply

Output per unit water supply of the basins (Figure 3) varied between 0.04 and 0.56 US$.m^{-3} and can be grouped into 2 classes. The cereal-producing basins resulted in a gross value of output per unit volume of water around or less than US$0.2, whereas the basins with orchards, industrial crops, and vegetables yielded an output per unit water supply around or greater than US$0.3. The ANOVA test results indicated that the differences in output per unit water supply among the crops in all schemes were statistically significant [F(5,233) = 6.552, P = 0.000 < P = 0.05] and the mean

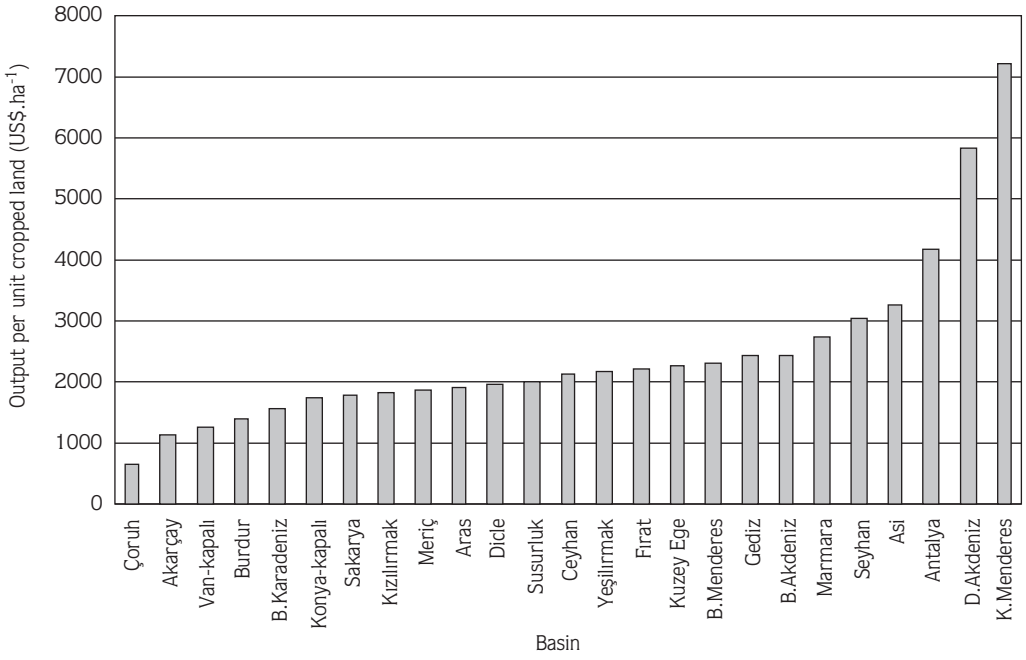

Figure 2. Output per unit cropped land.

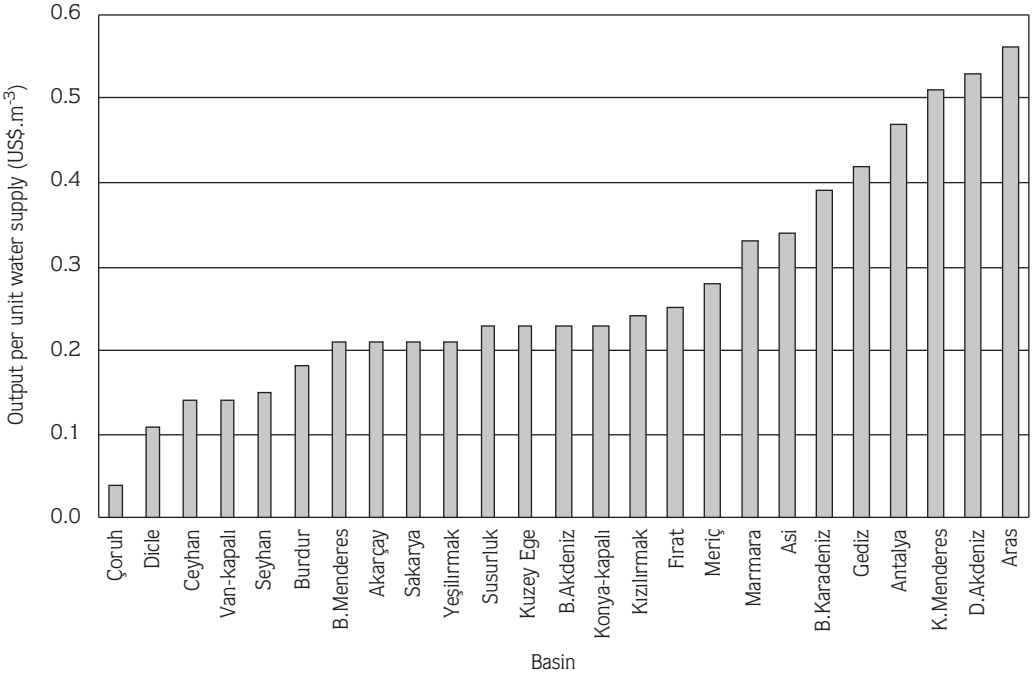

Figure 3. Output per unit water supply.

value of the orchard was the highest, as presented in Table 2. However, the ANOVA test results revealed that the differences in output per unit water supply among the scheme sizes in all schemes were not statistically significant [$F(4,234) = 1.048$, $P = 0.383 > P = 0.05$], as given in Table 3. The results indicated that the cropping

pattern and intensity produced high output per unit cropped land, water supply. In addition, climatic conditions might cause differences in output per unit water supply. Output per unit water supply tends to be higher in humid regions, where irrigation needs are generally lower.

Output per unit water supply was calculated to be 0.11-0.12, 0.00-0.16, 0.04-0.63, 0.18-0.41, 0.04-0.63, 0.02-1.29, 0.31-0.50, 0.02-1.84, and 0.02-0.67US$.m^{-3} by Vermillion and Garces-Restrepo (1996), Kloezen and Garces-Restrepo (1998), Molden et al. (1998), Girgin et al. (1999), Sakthivadivel et al. (1999), Çakmak (2001), Değirmenci (2001a), Değirmenci (2001b), and Çakmak and Beyribey (2003), respectively.

Output per unit water consumed

Output per unit water consumed in the basins (Figure 4) varied between 0.14 and 1.47 US$.m^{-3} and can be grouped into 2 classes: the basins having a gross value of output per unit water consumed less than US$0.6, and greater than US$0.6. The ANOVA test results pointed out that the differences in output per unit water consumed among the crops in all schemes were statistically significant [F(5,233) = 10.266, P = 0.000 < P = 0.05] and the mean value of the orchard was the highest, as demonstrated in Table 2. However, although the ANOVA test results revealed that the differences in output per unit water consumed among the scheme sizes were not statistically significant [F(4,234) = 2.323, P = 0.057 > P = 0.05], the smaller schemes had higher mean values of output per unit cropped land, water consumed as shown in Table 3. These results indicated that the cropping pattern and intensity produced differences in output per unit water consumed.

Output per unit water consumed was determined to be 0.00-0.41, 0.03-0.91, 0.17-0.35, 0.05-0.62, 0.07-2.25, 0.58-1.09, 0.04-3.02, and 0.08-2.54US$.m^{-3} reported by Kloezen and Garces-Restrepo (1998), Molden et al. (1998), Girgin et al. (1999), Sakthivadivel et al. (1999), Çakmak (2001), Değirmenci (2001a), Değirmenci (2001b), and Çakmak and Beyribey (2003), respectively.

Irrigation Ratio

The irrigation ratio of the basins varied between 17 and 92% with a mean of 49% (Figure 5). The ANOVA test results indicated that the differences in the irrigation ratio among the crops in all schemes were statistically significant [F(5,233) = 6.665, P = 0.000 < P = 0.05], as presented in Table 2. Similarly, the differences in the

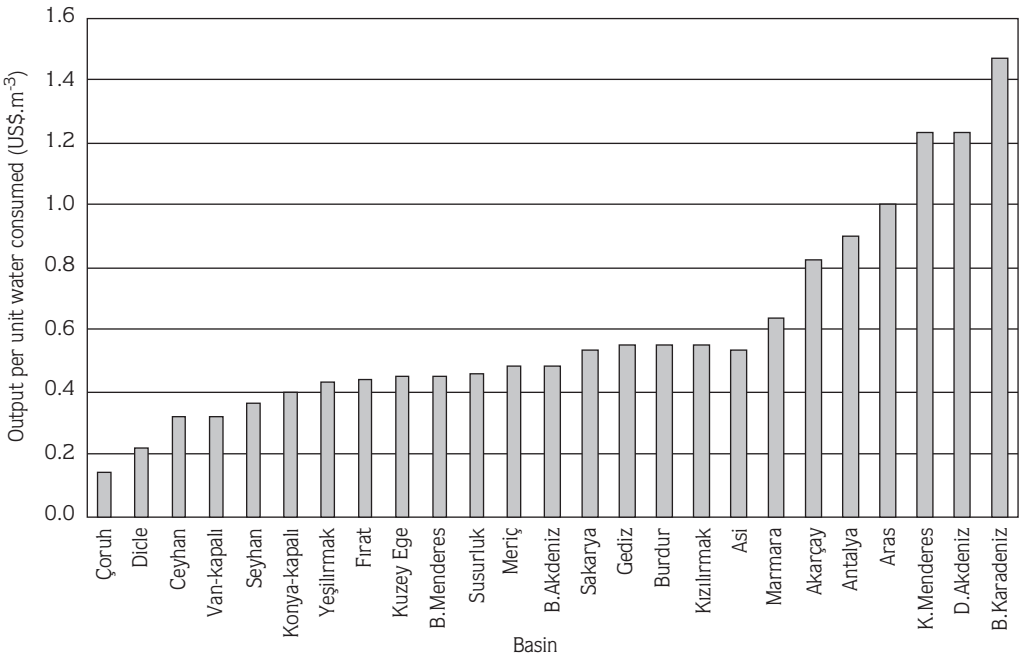

Figure 4. Output per unit water consumed.

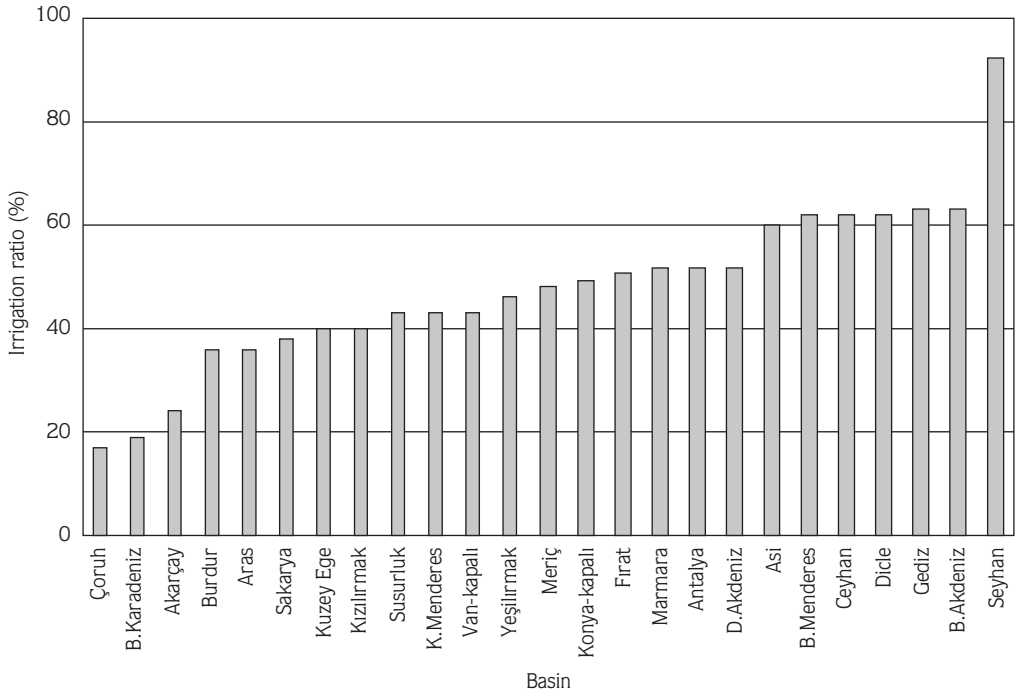

Figure 5. Irrigation ratio.

irrigation ratio among the scheme sizes in all schemes were statistically significant [$F(4,234) = 3.512$, $P = 0.008 < P = 0.05$] and the larger schemes had higher irrigation ratios, as shown in Table 3. Management type compared to the system type and climatic conditions might cause differences in the irrigation ratio as the IAs are more conscious about the efficient use of water than the DSI, as reported by Merdun and Değirmenci (2004). The other possible reasons for the low irrigation ratio might be insufficient infrastructure and water resources, operation and maintenance activities, increases in input prices, poor farmer training, and irrigation water fees.

The irrigation ratio was 32-117, 44-100, 24-105, 36-104, 4-100, 57-81, and 15-94% reported in the studies by Erözel and Alibiglouei (1991), Beyribey et al. (1997a), Beyribey et al. (1997b), Çakmak (2001), Değirmenci (2001b), Yazgan and Değirmenci (2002), and Çakmak and Beyribey (2003), respectively.

Relative water supply

The relative water supply of the basins varied between 1.41 and 4.04 (Figure 6), indicating that the water supply was greater than the demand in all basins. This indicates that irrigation water is not supplied uniformly and efficiently to the basins. Levine (1982) stated that water supplied more than 2.5 times the net requirement was an indication of inappropriate water management. The ANOVA test results indicated that the differences in the relative water supply among the crops in all schemes were not statistically significant [$F(5,233) = 1.424$, $P = 0.216 > P = 0.05$], as shown in Table 2. Similarly, the differences in the relative water supply among the scheme sizes in all schemes were not statistically significant [$F(4,234) = 2.121$, $P = 0.079 > P = 0.05$], but the smaller schemes had higher mean values of relative water supply, as shown in Table 3. The management type might cause differences in the relative water supply.

The relative water supply was determined to be 1.40-1.80, 0.60-1.79, 0.58-2.41, 0.80-4.10, 0.30-7.83, 1.20-1.48, 0.91-7.15, 0.60-1.09, 1.88, and 1.30-8.40 in the studies by Vermillion and Garces-Restrepo (1996), Beyribey et al. (1997a), Beyribey et al. (1997b), Molden et al. (1998), Çakmak (2001), Değirmenci (2001a), Değirmenci (2001b), Yazgan and Değirmenci (2002), Bandara (2003), and Çakmak and Beyribey (2003), respectively.

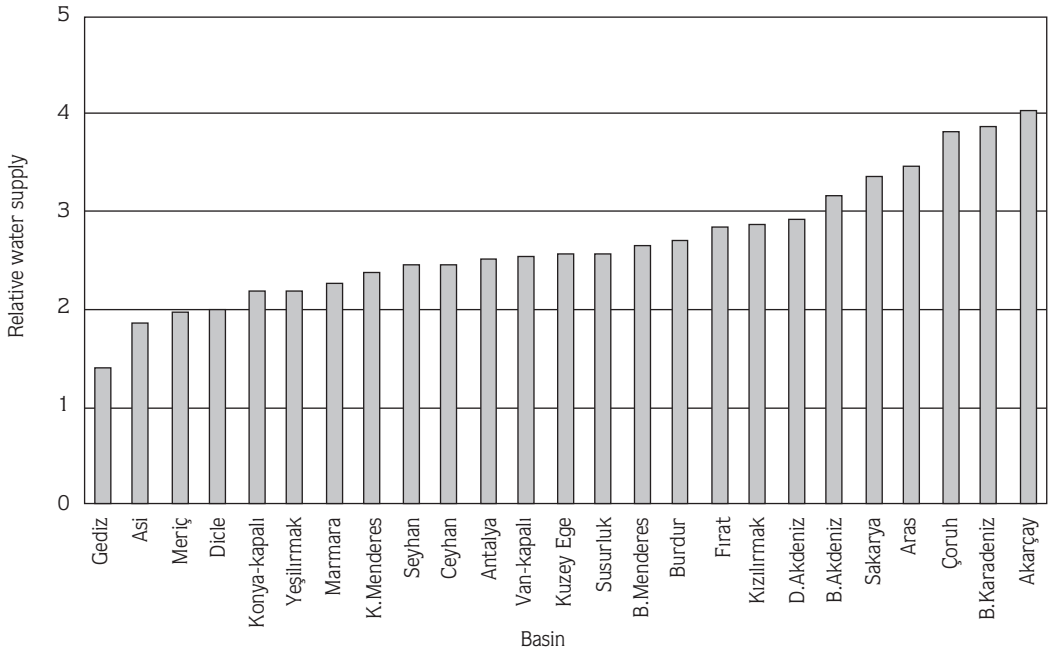

Figure 6. Relative water supply.

Conclusion

In this study, a comparison of 239 irrigation schemes (57 DSI-operated and 182 transferred to IAs) was made based on the basin, crop pattern, and scheme size using 6 external indicators for 2001 in order to determine the key parameters that affect the performance of the schemes.

When considering output per unit land and water, output was higher in the basins in which orchard and industrial crops, and some cereals were dominantly grown compared to the basins where some cereals were commonly grown. This indicates that the variability in output per unit land and water might be due to variations in crop pattern and intensity in addition to the diverted water supply. A statistically significant difference was found among the indicators for crops in all schemes in favor of orchards and industrial crops. Molden et al. (1998) found a similar result. However, the differences among the indicators for different size schemes were not statistically significant even though the smaller schemes had better performance.

The main objective of irrigation is to apply water to the root zone at the required time, amount, and quality. Although more water than required is applied to all schemes, output per unit land and water is relatively low. This indicates that the performance of the schemes is not at the expected level, possibly because of inadequate water resources, insufficient irrigation facilities, inappropriate management, high water table, salinity and alkalinity, inadequate maintenance and repair activities, inadequate rainfall, and socio-economic and other factors (DSI, 2001a). This is a clear indication of a great need to develop and implement effective water management.

Irrigation schemes can be further screened based on water resources (stream or groundwater), conveyance system (open channel or pressured system), the extent of the delivery system (the ratio of the length of the primary, secondary or tertiary channels to their service areas) in the farm, marketing situation, the number of personnel and their education level, and the age of the schemes. Then similar schemes can be compared or evaluated among themselves in order to emphasize key issues relative to performance and to better understand key factors affecting performance.

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