Indian Journal of Science and Technology Vol. 5 No. 2 (Feb 2012) ISSN: 0974- 6846

Evaluation of water delivery and irrigation performances at field level: the case of the Menemen Left Bank irrigation district in Turkey

N. Korkmaz[1] and M. Avci[2]
[1]International Agricultural Research and Training Center, Izmir, Turkey
[2]Dept. of Agricultural Structures and Irrigation, Faculty of Agriculture, University of Ege, Izmir, Turkey
nilkorkmaz@yahoo.com

Abstract

In this study, an evaluation was made of water delivery and irrigation performances in the Menemen Left Bank irrigation district at field level on the basis of farmers' irrigations. Water delivery performance was determined by the indicators of adequacy, efficiency, dependability and equity, and irrigation performance was determined according to the indicators of water application, water storage, uniformity coefficient, and distribution uniformity. These indicators were calculated from the amounts of water which was actually applied and which should have been applied and from soil moisture values for the irrigation seasons of 2005 and 2006. Water delivery performance was found to be fair in the first year and good in the second year with regard to adequacy, good in the first year and fair in the second year for efficiency, fair in the first year and good in the second year for dependability, and poor in the first year and fair in the second year for equity. Two-year averages varied between 50 and 80% for water application efficiency, 54 and 97% for water storage efficiency, 73 and 88% for uniformity coefficient, and 68 and 82% for distribution uniformity. These results showed that irrigation efficiency and uniformity are generally at attainable levels for surface irrigation.

Keywords: Water delivery performance, Irrigation performance, Surface irrigation, Turkey.

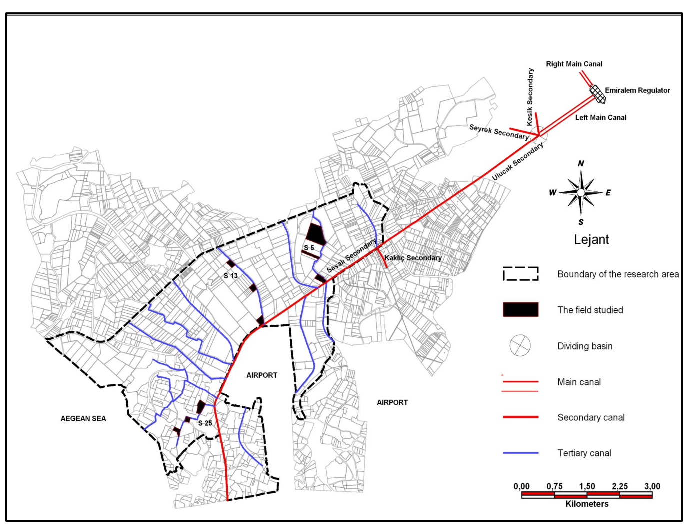
Introduction

Water is a natural resource of strategic importance which directly affects economic and social development. As competition for water increases, the irrigation sector is often blamed for its high and inefficient use of water and is commonly held responsible for urban water shortages. But when competition over water intensifies, irrigation almost always becomes the residual human use after other needs have been met (Molle & Berkoff, 2009). On-farm irrigation, to be efficient in use of water and labour, must be served from a supply that is flexible in frequency, rate, and duration comparable to a domestic system, and operated under the direct control of the irrigator at or near the point of application (Merriam *et al.,* 2007). Irrigated agriculture, in Turkey as in the rest of the world, has an important role in human nutrition and in increasing the economic development of rural areas. Therefore, the irrigated areas are constantly increasing. As important as increasing the irrigated area is the efficient, equitable and dependable delivery of water and the efficient and uniform application to the fields of the water delivered. An important proportion of water losses in irrigation arise from surface flow at field level and uneven delivery of water.

In systems not based on water delivery to fields by volume, it is very difficult to deliver water equitably between fields. According to Solomon (1984), besides the amount of irrigation water delivered to the fields, uniform distribution of this water is also important. Non uniform irrigation results in some parts of the irrigated land receiving less water than necessary and other parts receiving more than is needed. All of this makes it necessary to increase performance in water delivery and irrigation at field level. The Menemen Irrigation System was one of the first irrigation systems in Turkey, and delivers water by means of open canals. The system was operated by the State Hydraulic Works (DSI) until 1995, when it was handed over to water user associations (WUA). A number of studies have been carried out evaluating the system performance and irrigation practices of this system in the study area.

Water transport losses occurring in the system and factors affecting them were examined before the handover (Altuglu, 1966; Sener, 1976; Sener, 1978; Girgin *et al.,* 1999). Some studies have also been carried out on performance evaluation by means of indicators relating to water use, agricultural efficiency, and economic, social and environmental effects (Akkuzu, 2001; Avci *et al.,* 1999; Beyazgul *et al.,* 1999; Karatas, 2006; Korkmaz *et al.,* 2009; Unal *et al.,* 2004a; Unal *et al.,* 2004b). These studies were generally carried out at

Fig.1. The water delivery canals and fields in the study area



system or canal level. The studies of water delivery and irrigation performance at field level have not been performed. In this study, water delivery and irrigation performances at field level in the Menemen Left Bank irrigation district were evaluated on the basis of farmers' irrigations in irrigation seasons of 2005-2006. Water delivery performance was determined according to the indicators of adequacy, efficiency, dependability and equity, while irrigation performance was determined according to the indicators of water application efficiency, water storage efficiency, uniform distribution efficiency and distribution uniformity.

Materials and methods

Irrigation system and study area

The study was performed on the Menemen Left Bank Irrigation System (MLBIS), which is part of the Menemen Irrigation System and serving the Menemen plain. The Menemen plain is located between the latitudes of 38º26'-38º40' north and longitudes 26º40'-27º07' east, in the Gediz Basin in the west of Turkey. The plain was at 10.3 m above sea level, and the texture of the soils was dominantly medium and medium-heavy structure. The main crops in the plain were cotton and cereals (Topraksu, 1971; Topraksu, 1974). The Menemen plain has a Mediterranean climate, with hot dry summers and cool wet winters. According to long-term climatic data, total annual rainfall is 525.3 mm, of which 50% falls in winter, 24.6% in spring, 23.2% in autumn and 2.1% in summer. The average annual temperature is 16.9^{0}C; the average for July, the hottest month, is 27^{0}C, and that for the coldest month, January, is 7.8^{0}C. Average annual relative humidity is 57.5%; the highest, 66.9%, is in December, and the lowest is 46.3%, in July (MTSKAE, 2008).The rainfall catchment area of the Gediz Basin which covers Menemen Plain is 17 000 km^2, and it has a ground water potential of 2.0 km^3/year (Baran *et al.,* 1999). The Lower Gediz Basin irrigation systems, of which the Menemen irrigation system forms a part, obtain their water from the Demirkopru Dam, fed by the Gediz River, and Marmara Lake. Water for the system is obtained from the dam and the lake in the months when crop water consumption is highest (July-Sept) and in other months from the river. This water in the river bed is water from tributaries below the dam. Water from the dam and the lake is diverted to the irrigation systems by means of three regulators, and the Menemen irrigation system is supplied by the Emiralem regulator. Water from this regulator supplies a right bank and a left bank irrigation system, each of which is operated by WUA.

Diversion of water from the main canal to the secondaries and from the secondary canals to the tertiaries is the responsibility of the WUA. Diversion of water from the tertiaries to the fields is under the control of the village irrigation committees (VIC). Water is diverted from the secondary canals to the tertiaries by means of constant-head orifices, and from the tertiaries to the fields by means of siphons. Water diverted to the secondaries, tertiaries and fields is not measured. Because water supplied to the fields is not measured, farmers have no way of knowing how much water has been supplied, and are thus incapable of ensuring completely adequate and equitable delivery. Water charges are based on crop type and land area. MLBIS is made up of one main canal and six secondary canals connected to it. It was constructed in 1944, and irrigates an area of 16585 ha. This study was carried out on nine fields in the 2400 ha area served by the Sasalı secondary canal and the 12 tertiaries connected to it, at the end of the system. These fields were selected from the lands irrigated by three tertiaries, one at the head (S5), one in the middle (S13), and one at the tail (S25). Selection was made to include one field each from the head, middle and end of each tertiary (Fig.1).

On about 70% of the land irrigated by each of the tertiaries selected, cotton was being grown, with first crop maize, melons, watermelons and grain on the rest. In both years of the study, cotton was grown on all fields, except for two fields in 2005 (the field in the middle of S5, where maize was grown as a first crop, and the field at the end of S13, where watermelons were grown as a second crop. Irrigation was by surface irrigation methods (uncontrolled flooding, border, and furrow). Soil characteristics of the fields studied were determined according to Tuzuner *et al.* (1990) and Richards (1954). Observation wells were drilled in the fields, and the water table level was monitored throughout the vegetation season. Areas, soil characteristics and highest water

Table 1. Field of the locations, areas, and soil properties

Tertiary Number		S5			S13			S25		
Field location		Head	Middle	Tail	Head	Middle	Tail	Head	Middle	Tail
Field area (ha)		3.25	5.57	9.05	2.87	2.30	2.20	2.45	1.10	1.10
Sand (%)		27	23	42	46	36	14	32	36	24
Clay (%)		13	41	20	18	29	41	19	16	25
Silt (%)		61	39	38	36	45	49	47	50	61
Texture		SiL	C	L	L	CL	SiC	L	L	SiL
Field capacity (mm)		308	289	317	289	362	360	297	299	348
Wilting point (mm)		129	169	190	138	210	207	149	146	170
Bulk density (g/cm^{-3})		1.36	1.26	1.49	1.47	1.54	1.37	1.37	1.47	1.44
Available water(mm)		179	120	127	151	152	153	148	153	178
Na (%)		4.24	6.29	5.91	11.83	19.46	28.28	18.37	7.71	6.10
Watertable depth (cm)	2005	120	122	124	104	110	100	130	134	117
	2006	123	128	147	100	116	122	140	126	126

Indian Journal of Science and Technology Vol. 5 No. 2 (Feb 2012) ISSN: 0974- 6846

Table 2. Properties of irrigation water

EC (dS/m)	pH	Cations (mel^{-1})				Anions (mel^{-1})				Bor (ppm)	Na (%)
		Na	K	Ca	Mg	CO_3	HCO_3	Cl	SO4		
0.820	7.8	2.49	0.22	2.30	3.10	-	5.90	1.90	0.31	0.2	30.7

table levels in the irrigation seasons of the fields are given in Table 1. It was found that water table levels sometimes rose by up to 100 cm in some of the fields in the study area during the course of the irrigation season. For this reason, effective crop root depth was taken as 80 cm in the calculations. Canal irrigation water used to irrigate the fields was of class S_3A_1 (Table 2).

Amounts of irrigation water diverted and required

In the irrigation seasons, there was no interference in the timing or period of irrigations or the amounts of water which the farmers diverted to their fields. However, at each irrigation, the amount of water diverted and the moisture content of the soil were measured. The amount of irrigation water diverted to the fields by farmers, measured in mm depth (Q_D), was calculated by multiplying the measured flow rate by the duration of irrigation and dividing by the field area. Flow was measured by the use of a Parshall flume. Amount of irrigation water required (Q_R) was the amount of water which made up the actual amount of moisture at the depth of the effective crop root zone before each irrigation to field capacity. Soil moisture before and after irrigations was determined by the neutron scatter method (Carneiro & De Jong, 1985; Bell & McCulloch, 1993). The number of soil moisture measurement points per field was 4, 6 or 8 according to the size of the field, set out in a square pattern. The access tubes where measurements were made were located in the centers of the squares, without disturbing the soil. Calibration of the neutron probe was carried out individually according to the conditions in each field.

Water delivery performance Indicators

Water delivery performance at field level was determined according to the indicators of adequacy, efficiency, dependability and equity. In calculating these indicators, the values of Q_D and Q_R for each irrigation were taken as basic variables; the number of irrigations in one season (T) was taken as the time period; and the number of fields (R) was taken as the sub-region. From the computed performance indicator values, performance was classified as “good”, “fair” or “poor” according to the performance standards (Molden & Gates,1990).

Adequacy (P_A): A fundamental concern of water-delivery systems is to deliver the amount of water required to adequately irrigate crops. Adequacy was calculated using Eq. (1).

$$P_A = 1/T \sum_{T=1}^{T} \left(1/R \sum_{R=1}^{R} p_A \right) \quad (1)$$

where p_A on the right is calculated as Q_D/Q_R. When the amount delivered Q_D exceeded the amount required Q_R, the amount delivered was accepted as adequate without considering the amount of the excess, and the ratio Q_D/Q_R was taken as 1.00. A value of 1.00 or close to 1.00 for P_A showed adequacy of water delivery, while a value less than 0.80 for P_A showed inadequacy of water delivery. Performance was evaluated as good when P_A values were between 0.90 and 1.00, fair when they were between 0.80 and 0.89, and poor when they fell below 0.80.

Efficiency (P_F): Efficiency embodies the ability to conserve water by matching irrigation application with crop water requirements. Efficiency was calculated using Eq. (2)

$$P_F = 1/T \sum_{T=1}^{T} \left(1/R \sum_{R=1}^{R} p_F \right) \quad (2)$$

where p_F on the right of the equation was calculated as Q_R/Q_D. When $Q_R \leq Q_D$, the value of p_F *was* calculated, but otherwise p_F was taken as equal to 1.00. If p_F was equal to or close to 1.00, this meant that water in the system was being used efficiently, but if the value was less than 0.70, it meant that water in the system was not being used efficiently. Performance was said to be good when the value of P_F was between 0.85 and 1.00, fair if it was between 0.70 and 0.84, and poor if it was below 0.70.

Dependability (P_D): Dependability is defined as temporal uniformity of the ratio of the amount of water delivered to that required to irrigate the crops, and was calculated using Eq. (3)

$$P_D = 1/R \sum_{R=1}^{R} CV_T \left(\frac{Q_D}{Q_R} \right) \quad (3)$$

where $CV_T(Q_D/Q_R)$ is the coefficient of temporal variation of the ratio Q_D/Q_R in time-period T. When the value of P_D approaches zero, this shows that water delivery is uniform over the given time period and thus is more dependable. Performance was said to be good when the value of P_D was between 0.00 and 0.10, fair when it was between 0.11 and 0.20, and poor when it was above 0.20.

Equity (P_E): Equity expresses the degree of variability in relative water delivery from point to point over the irrigated area, and was calculated using Eq. (4)

$$P_E = 1/T \sum_{T=1}^{T} CV_R \left(\frac{Q_D}{Q_R} \right) \quad (4)$$

where $CV_R(Q_D/Q_R)$ is the coefficient of spatial variation of the ratio Q_D/Q_R in region R. When P_E approaches zero, this shows that greater equity has been achieved in water delivery. Performance was said to be good when the value of was between 0.00 and 0.10, fair when it was between 0.11 and 0.25, and poor when it was more than 0.25.

Irrigation performance

Irrigation performance was evaluated from irrigation efficiency and uniformity: for irrigation efficiency the

Indian Journal of Science and Technology Vol. 5 No. 2 (Feb 2012) ISSN: 0974- 6846

Table 3. Q_D and Q_R values for each irrigation at the fields for the irrigation seasons (mm)

Tertiary number	Field location	Irrigation number	2005						2006					
			Crop	Date	Q_D	Q_R	Total Q_D	Total Q_R	Crop	Date	Q_D	Q_R	Total Q_D	Total Q_R
S5	$S5_{Head}$	1	Cotton	22 July	160	135	437	382	Cotton	14 July	141	153	462	420
		2		12 Aug	158	138				05 Aug	188	158		
		3		30 Aug	119	109				01 Sep	133	109		
	$S5_{Middle}$	1	Maize	20 June	106	94	564	444	Cotton	20 July	113	110	350	280
		2		02 July	113	89				12 Aug	128	94		
		3		18 July	137	90				30 Aug	109	76		
		4		31 July	119	98								
		5		15 Aug	89	73								
	$S5_{Tail}$	1	Cotton	12 July	89	102	356	399	Cotton	08 July	149	110	534	514
		2		28 July	80	104				25 July	181	138		
		3		17 Aug	98	101				12 Aug	129	128		
		4		31 Aug	89	92				30 Aug	75	138		
S13	$S13_{Head}$	1	Cotton	10 July	75	49	286	165	Cotton	14 July	93	71	358	272
		2		28 July	76	34				01 Aug	103	73		
		3		12 Aug	64	39				17 Aug	95	67		
		4		26 Aug	71	43				06 Sep	67	61		
	$S13_{Middle}$	1	Cotton	08 July	106	102	468	411	Cotton	04 July	129	111	569	493
		2		25 July	110	103				21 July	134	130		
		3		11 Aug	133	121				09 Aug	151	128		
		4		29 Aug	119	85				28 Aug	155	124		
	$S13_{Tail}$	1	Water Melon	01 Aug	28	66	132	371	Cotton	04 July	139	92	479	360
		2		11 Aug	25	72				22 July	123	97		
		3		18 Aug	28	72				09 Aug	104	82		
		4		26 Aug	29	76				27 Aug	113	89		
		5		30 Aug	22	85								
S25	$S25_{Head}$	1	Cotton	07 July	151	121	633	430	Cotton	30 June	146	105	512	406
		2		25 July	142	96				17 July	84	90		
		3		12 Aug	140	102				04 Aug	147	111		
		4		02 Sep	200	111				24 Aug	135	100		
	$S25_{Middle}$	1	Cotton	06 July	138	119	439	346	Cotton	30 June	136	95	634	400
		2		26 July	144	114				18 July	137	109		
		3		14 Aug	157	113				03 Aug	123	103		
		4								23 Aug	238	93		
	$S25_{Tail}$	1	Cotton	06 July	144	119	376	337	Cotton	26 June	144	99	497	414
		2		25 July	107	102				08 July	126	98		
		3		12 Aug	125	116				24 July	116	95		
		4								10 Aug	111	122		

Table 4. Water delivery performance of the system at field level for the irrigation seasons

Seasons	Adequacy (P_A)	Efficiency (P_F)	Dependability (P_D)	Equity (P_E)
2005	0.85	0.85	0.15	0.26
2006	0.98	0.81	0.10	0.23

indicators of water application efficiency (E_a) and storage efficiency (E_s) were used, and the indicators of uniformity coefficient (CU) and distribution uniformity (DU) were used to evaluate uniformity (Merriam & Keller, 1978; Hart *et al.,* 1979; Bos & Nugteren, 1990; Rogers *et al*., 1997; Zerihun *et al.,* 1997).

Water application efficiency (Ea): Water application efficiency shows the ratio of water delivered to the field to that stored in the crop root zone, and was calculated by means of Eq. (5)

$$E_a = 100 \frac{Q_s}{Q_D} \quad (5)$$

where E_a is water application efficiency (%), Q_s is irrigation water stored in the root zone (mm), and Q_D is water delivered to the field (mm), Q_s in the equation was found from the difference between soil moisture values measured before and after irrigation. For surface irrigation methods E_a should be 60-90% in basin irrigation, 60-90% in border irrigation, 50-90% in furrow irrigation, and 60-90% in surge irrigation.

Water storage efficiency (E_S): Water storage efficiency is the ratio of the amount of water stored in the crop root zone to the amount required to be stored, and indicates the extent to which irrigation is adequately carried out. It was calculated by means of Eq. (6)

$$E_S = 100 \frac{Q_S}{Q_R} \quad (6)$$

where E_s is water storage efficiency (%), Q_s is irrigation water stored in the root zone (mm), and Q_R is the amount of water which should have been stored in the root zone before irrigation, or the amount of moisture lacking. A value of E_s equal to or greater than 0.80 indicates that efficiency is very good, a value of 0.80-0.50 is acceptable and a value of below 0.50 indicates an unacceptable level.

Uniformity coefficient (CU): The uniformity coefficient shows the extent to which water collects uniformly in the crop root zone and whether or not the application is uniform. The uniformity coefficient was calculated by means of Eq. (7)

$$CU = 100 \left(1 - \frac{\sum_{i=1}^{n} d_i}{n\overline{Q_S}}\right) \quad (7)$$

where CU is uniformity coefficient (%), d_i is the deviation of the amount of water stored at each measurement point minus the average amount of water stored ($d_i = / Q_{S i} - \overline{Q_S} /$), $Q_{S i}$ is the amount of water stored in the soil at measurement point i (mm), $\overline{Q_S}$ is the average amount of water stored in the soil (mm), and n is the number of measurement points. A value of CU equal to or greater than 0.80 was evaluated as highly efficient, a value of 0.60-0.80 was evaluated as acceptable, and a value below 0.60 was unacceptable.

Distribution uniformity (DU): Distribution uniformity shows how homogeneously water was distributed over the land, and gives information on the degree to which there are problems of water distribution on the plots irrigated. The average percentage of the amount of water applied which was received in the least-watered quarter of the field was calculated by Eq. (8)

$$DU = 100\left[\frac{Q_{lg}}{\overline{Qs}}\right] \quad (8)$$

where DU is distribution uniformity (%), Q_{lg} is the average amount of water in the quarter of the plot which receives the least water (mm), and $\overline{Q_S}$ is the average amount of water stored in the soil during irrigation. A value of DU equal to or greater, than 0.90 indicated high efficiency a value of 0.90-0.70 was acceptable and a value of less than 0.70 was unacceptable.

Results and discussion

Values of Q_D and Q_R in relation to Irrigations

Table 3 shows values of Q_D and Q_R for each irrigation in the irrigation seasons of 2005 and 2006. In both irrigation seasons, total values of Q_D were greater than total Q_R values in all fields except for $S5_{Tail}$ and $S13_{Tail}$ in 2005. In fields planted with cotton, Q_D values varied between 64 and 200 mm and Q_R values varied between 34 and 138 mm at each irrigation. While in 2006 Q_D values were 67-238 mm and Q_R values were 61-153 mm. Ozkara and Sahin (1993) recommended that at each irrigation of cotton irrigated by furrow irrigation on the Menemen Plain 60% (60-80 mm) of the water needed to bring the moisture present in the 0-90 mm layer of the soil to field capacity (Q_R) should be applied. According to this, farmers have been applying more irrigation water than is recommended, and more than the calculated irrigation water requirement.

The total Q_R value for maize in $S5_{Middle}$ was 444 mm, and the Q_D value was 564 mm. Pamuk and Ozgurel (2008) found that the amount of water needed to bring the moisture present in the 0-120 cm layer of the soil to field capacity with maize irrigated by the furrow method in Izmir conditions in two irrigation seasons was 323.2 and 466.6 mm. Comparing these values and the Q_R values obtained in the research with Q_D values, it can be seen that farmers are giving too much water to their fields. The total Q_R value for watermelons in $S13_{Tail}$ was 371 mm, and the Q_D value was 132 mm. It can be said that the crop made up this shortage of water from groundwater which rose to 100 cm in the irrigation season.

Water delivery performance at field level

Temporal Values of Performance Indicators: Average temporal values of pA, pF and CVT for farmers' irrigations in the irrigation seasons are given in Fig. 2.According to p_A values, adequacy in 2005 was classified as bad for $S13_{Tail}$ (0.36), it was classified as fair for $S5_{Tail}$ (0.89), and for the others it was classified as good, while in 2006, adequacy for $S5_{Tail}$ (0.89) was fair, and for all the others it was classified as good [Fig. 2 (a and b)].According to p_F values, efficiency in 2005 was poor for $S13_{Head}$, fair for $S5_{Middle}$ (0.80), $S25_{Head}$ (0.69) and $S25_{Middle}$ (0.79), and good for the others [Fig. 2 (c and d)].

In 2006, efficiency was classified as poor for $S25_{Middle}$ (0.68), good for $S5_{Head}$ (0.89), $S5_{Tail}$ (0.87) and $S13_{Middle}$ (0.87), and fair for all the others. Evaluating p_A and p_F values together, it can be seen that in general sufficient water was supplied to the fields; also, that in 2005 it was used relatively efficiently but in 2006 efficiency was fair: that is, more water was used than was needed. Taking into account the location of the fields, it can be said that in both years adequacy for 3 fields at the end of a tertiary was worse, but that efficiency was better for 4 fields at the end of a tertiary. While performance classes according to the indicator of adequacy did not change in fields at the head and middle of the tertiaries, performance classes according to the indicator of efficiency did show a change.

This can be said to stem from a lack of knowledge on the part of the farmers, and from the fact that water delivered to the fields is not measured. According to CV_T (Q_D/Q_R) values, dependability in 2005 was classified as fair for $S5_{Tail}$ (0.12) and $S13_{Tail}$ (0.19), and good for the others. In 2006, it was poor only for $S5_{Tail}$ (0.25), and good for the others [Fig. 2 (e and f)]. Generally, the indicator of dependability was good for both years, which meant that farmers were able to obtain water for irrigation when they wanted it. It can be said that the fact that this indicator was good is because some fields were irrigated before the time that the farmers had requested.

This as can be seen in Fig. 2, in all fields in the tertiary S25 at the end of the secondary and in fields only at the ends of the other tertiaries, irrigation was done earlier than in fields at the head. This is because farmers are worried that no water will be left in the canal later. Unal *et al.* (2004) found that the rates of confidence of the farmers at the head, middle and tail of tertiary canals in terms of water delivery were 78%, 44% and 33% respectively in a survey study of the same area.

Spatial Values for Performance Indicators

Spatial average values of p_A. p_F and CV_R for farmers' irrigations in the two irrigation seasons are given in Fig. 3. The numbers of irrigations taken into account when calculating these values were as follows: in 2005, three in three fields ($S5_{Head}$. $S25_{Middle}$ and $S25_{Tail}$), four in four fields ($S5_{Tail}$, $S13_{Head}$, $S13_{Middle}$ and $S25_{Head}$) and five in two fields ($S5_{Middle}$, $S13_{Tail}$); in 2006, three in two fields ($S5_{Head}$ and $S5_{Middle}$), and four in the others. According to the spatial values of p_A, adequacy was good in the first (0.92), second (0.90) and third (0.93) irrigations in 2005, fair in the fourth (0.89), and poor in the fifth (0.63); in 2006, all four irrigations were classed as good (0.92-1.00), [Fig. 3 (a and b)]. According to the spatial values of p_F, efficiency in 2005 was good in the first (0.87) and fifth (0.91) irrigations, and fair in the second (0.83), third (0.83) and fourth (0.79) irrigations. In 2006, all four irrigations were classed as fair (0.79-0.82) [Fig. 3 (c and d)]. Generally speaking, adequate water was applied to the fields in the first four irrigations in both years. Efficiency for these four irrigations in 2005 was classed as fair, apart from the first irrigation. At the fifth irrigation, cotton was not irrigated and only maize and second crop water melons were irrigated; adequate water was not applied to the fields, so that as a result efficiency was high. According to CV_R (Q_D/Q_R) values, equity in the first three irrigations of each year was classed as good, and as poor in the others [Fig. 3 (e and f)]. In general, the fact that cotton was irrigated three times, and that after the third irrigation less water was delivered to the canals, had a positive effect on equity.

Average values of performance Indicators

The average values of the indicators of water delivery performance at field level for the two years are given in Table 4. Adequacy of system performance was fair in the first year and good in the second year. Efficiency was good in 2005 and fair in 2006. These indicators show that when water in the system was adequate, farmers did not use it efficiently. Dependability of system performance was fair in the first year and good in the second year. Equity was poor in 2005, and fair in 2006. These indicators show that although water was not delivered from the tertiary canals to the fields at the targeted level of equity, dependability of delivery was closer to the targeted level. The fact that the indicator of equity was low shows that water was not delivered equitably among the fields benefiting from the same tertiary. This is because water delivery from the tertiaries to the fields is carried without any plan.

Irrigation performance

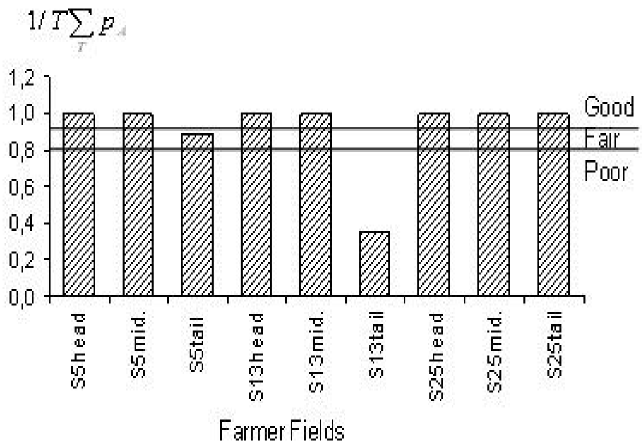
Fig. 4 shows the annual and average values of water application efficiency (E_a), water storage efficiency (E_s), uniformity coefficient (CU) and distribution uniformity (DU) for 35 farmers' irrigations in 2005 and 34 in2006, a total of 69 in the fields under study.

Water application and storage efficiencies

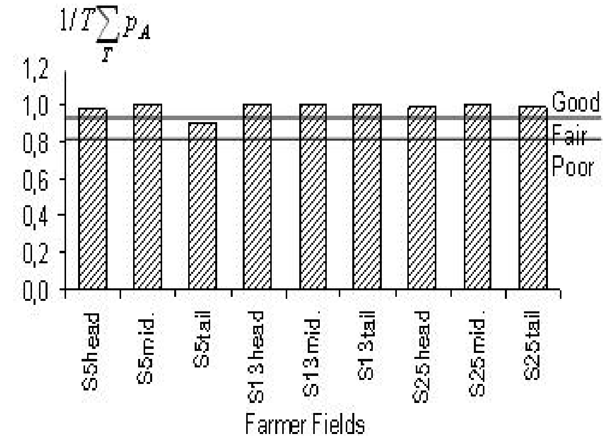
E_a values showed great variation between fields and years. These values varied between 56 and 90% in 2005 and, 44 and 82% in 2006, with an average of 50-80%. The lowest value of E_a in each year was $S13_{Head}$ (56% and 44%), the highest value in 2005 was 90% for $S13_{Tail}$, and in 2006 it was 82% for $S5_{Head}$. The lowest two-year average value of E_a was $S13_{Head}$ (50%), and the highest was $S5_{Head}$ (80%). Over the two years, fields were classed as good for E_a, apart from $S13_{Head}$ (56%) in 2005. $S13_{Head}$ (44%) and $S13_{Tail}$ (56%) in 2006, and the two-year average of $S13_{Head}$ (50%) (Fig. 4a). It can be said that the differences between field water application efficiencies arise from such factors as irrigation when plants have no need of water, the levelling off the field, the texture of the soil, the type of crop, and the irrigation method. Thus, watermelons were sown on ridges in the field $S13_{Tail}$ in 2005, and irrigated by the furrow method, and E_a was determined to be 90%. Cotton was sown in

Indian Journal of Science and Technology Vol. 5 No. 2 (Feb 2012) ISSN: 0974- 6846

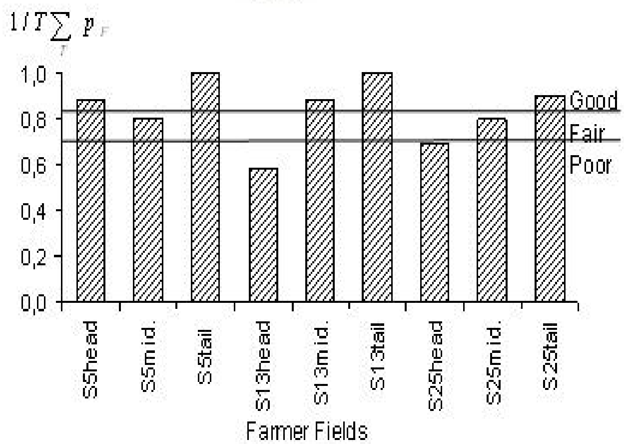
Fig.2. Average temporal values of pA, pF and CVT for the irrigation seasons



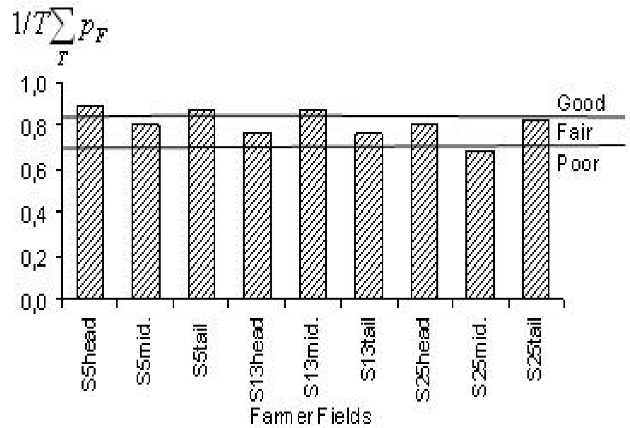
a) p_A for 2005



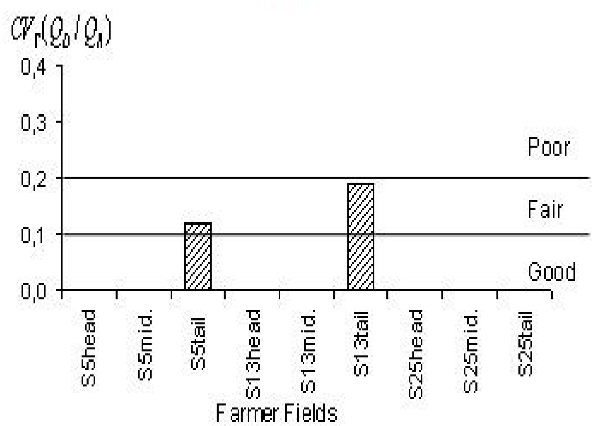
b) p_A for 2006



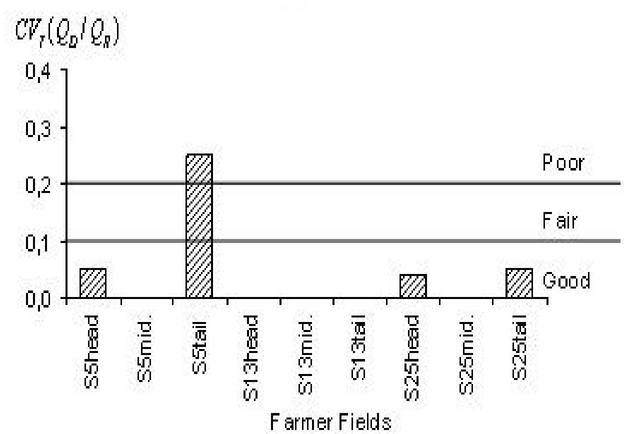
c) p_F for 2005



d) p_F for 2006



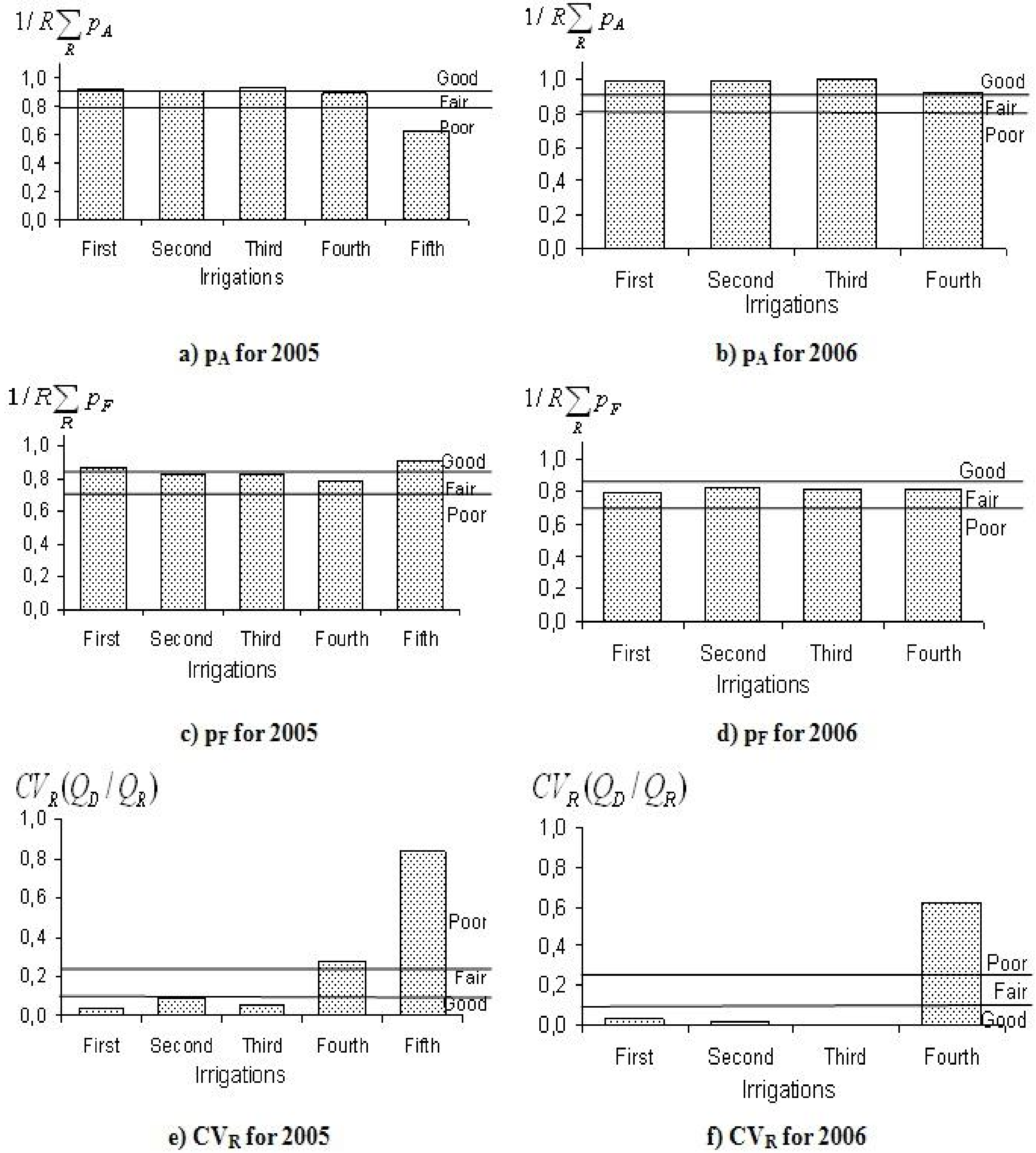
e) CV_T for 2005



f) CV_T for 2006

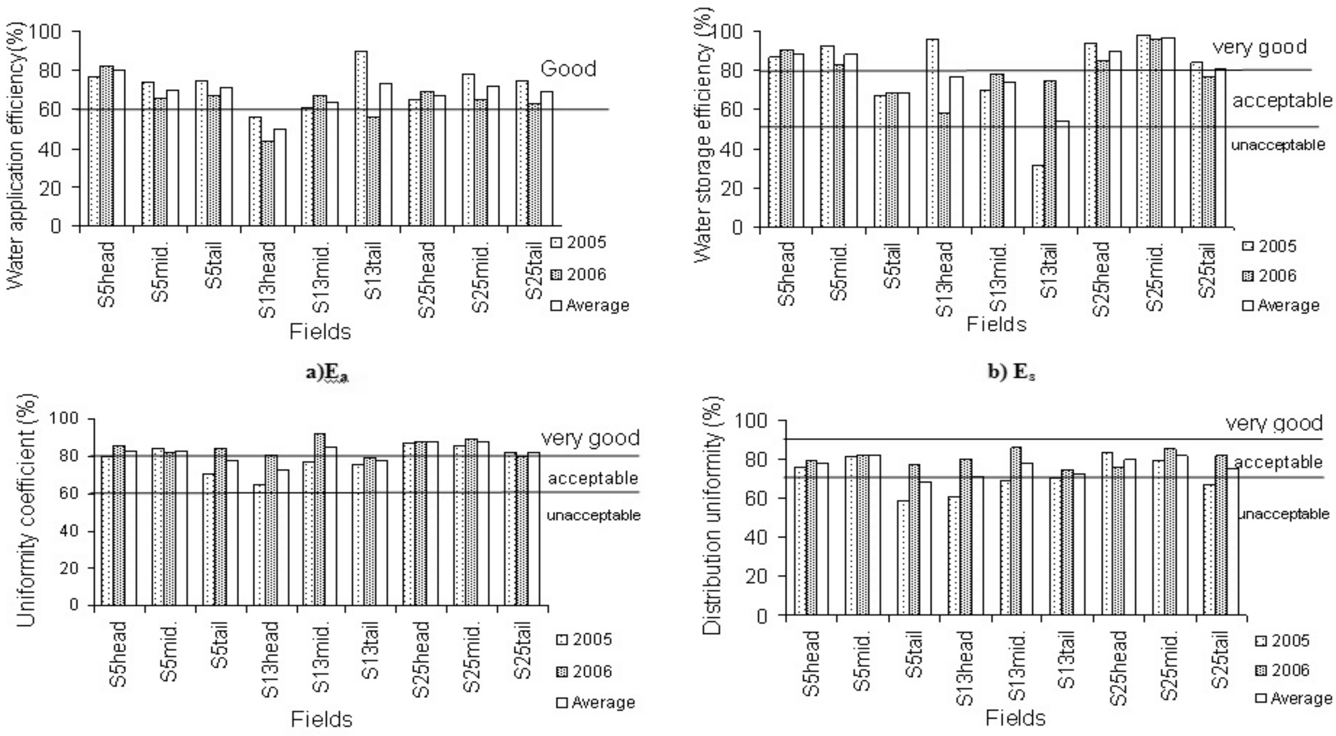
Indian Journal of Science and Technology Vol. 5 No. 2 (Feb 2012) ISSN: 0974- 6846

Fig. 3. Spatial average values of for pA, pF and CVR for the irrigation seasons



Indian Journal of Science and Technology Vol. 5 No. 2 (Feb 2012) ISSN: 0974- 6846

Fig. 4. Irrigation efficiencies and uniformities in the fields for the irrigation seasons



c) CU

d) DU

the same field in 2006 and irrigated by the border method, and E_a was found to be 56%, Es values for 2005 varied between 32 and 98%: the lowest value was 32% for $S13_{Tail}$, and the highest value was 98% for $S25_{Middle}$. In 2006 values ranged from 58-96%: the lowest was 58% for $S13_{Head}$, and the highest was 96% for $S25_{Middle}$. Two-year average values of E_s ranged between 54 and 97%: the lowest was 54% for $S13_{Tail}$, while the highest was 97% for $S25_{Middle}$. For each year separately and for the two-year average. E_s was classified as very good for $S5_{Head}$, $S5_{Middle}$, $S25_{Head}$ and $S25_{Middle}$, moreover $S25_{Tail}$ was except for 2006, and as acceptable for $S5_{Tail}$ and $S13_{Middle}$, and finally $S13_{Tail}$ was an except for 2005 (Fig. 4b).

These results show that water application and storage efficiency in farmers' irrigations in the study area were at attainable levels for surface irrigation. The main reason for this is that because cotton has been grown for many years on the Menemen Plain. The farmers there have ample experience in irrigating cotton. The low efficiency in some fields may be related to such factors as high ground water, salinity, or soil structure. The reason why water application efficiency was high and water storage efficiency was low in $S13_{Tail}$ in 2005, when melons were grown, is that less water than needed was given to that field. In various studies of surface irrigation in Turkey, water application efficiency was determined as 38% in Eskisehir-Cifteler (Ogretir, 1981), 49% in Konya-Alakova (Beyribey, 1989), 52% in Kahramanmaras (Ucan &Yuksel, 2000), and 54% in the Bursa plain (Sener & Yuksel, 2005). Water storage efficiency was found to be 75-80% in irrigation in Eskisehir-Alpu (Oylukan, 1970) and 13% in Konya-Yazlıca (Soganci, 1999). When these values are compared with values from the area of the present study, it can be seen that efficiency of water application and storage is generally higher for irrigation on the Menemen Plain.

Uniformity coefficient and distribution uniformity

CU values in 2005 varied from 65-87%; the lowest value was 65% for $S13_{Head}$, and the highest was 87% for $S25_{Head}$. Values in 2006 ranged between 72% and 92%, the lowest value being 79% for $S13_{Tail}$, and the highest 88% for $S25_{Head}$ and $S25_{Middle}$. Average values over the two years for CU were between 73% and 88%. The lowest was 73% for $S13_{Head}$, and the highest was 88% for $S25_{Head}$ and $S25_{Middle}$. According to the values of each year and the averages of the two years together, CU was classified as very good for $S5_{Head}$, $S5_{Middle}$, $S25_{Head}$, $S25_{Middle}$ and $S25_{Tail}$, and as acceptable for the others (Fig.4c). DU values in 2005 varied from 59-83%: the lowest value was 59% for $S5_{Tail}$, and the highest was 83% for $S25_{Head}$. Values in 2006 ranged between 74% and 85%, the lowest value being 74% for $S13_{Tail}$, and the highest 85% for $S25_{Middle}$. Average values over the two years for DU were between 68% and 82%. The lowest was 68% for $S5_{Tail}$, and the highest was 82% for $S5_{Middle}$ and $S25_{Middle}$.

According to the values of each year and the averages of the two years together, DU was classified as acceptable for $S5_{Head}$, $S5_{Middle}$, $S13_{Middle}$, $S13_{Tail}$, $S25_{Head}$

and $S25_{Middle}$,and as acceptable for the others except 2005 values (Fig. 4d). These results show that the uniformity coefficient was acceptable or very good in farmers' irrigations in the study area, and distribution uniformity was at an acceptable level. It can be said that such factors as leveling the fields and using special machines to raise the border ridges, and the skill which has been gained in water management, affected this. In addition, the fact that water was applied to some fields in excess of needs by farmers helped to create the high level of irrigation uniformity. In another study on irrigation in Konya-Yazlıca, CU values were between 59 and 89%, and DU values were between 49 and 87% (Soganci, 1999). It can be seen that these values are close to those of the research area.

Conclusions

In this study, an evaluation was made of water delivery and irrigation performances at field level in the Menemen Left Bank irrigation district. Water delivery performance was determined according to the indicators of adequacy, efficiency, dependability and equity; irrigation performance was determined according to the indicators of water application, water storage, uniformity coefficient and distribution uniformity. These indicators were calculated from values from two annual irrigation seasons of soil moisture content and of the amounts of irrigation water which was applied and which should have been applied to the fields. The two-year average amount of irrigation water diverted to the fields in the years 2005 and 2006 was 4043 mm, while the required amount was 3422 mm. So the irrigation water lost was 621 mm, which is 15% of the diverted water.

It was found that there was no significant problem with adequacy of water distribution at the field level in relation to the current crop design, but that when the farmers obtained an adequate amount of irrigation water, they did not use it efficiently. And although water was not delivered from the tertiary canals to the fields at the targeted level of equity, it was being supplied at close to the targeted level of dependability. Irrigation efficiency and uniformity in the farmers' irrigations were found to be generally at an attainable level for surface irrigation.

This showed that the farmers' success in preparing the fields for irrigation and water management at field level was at a reasonable level. In order to improve water delivery and irrigation performance in the Menemen irrigation district where surface irrigation is predominant; managerial practices such as that water should be delivered from tertiaries to fields in a planned way, that these plans should be drawn up in consultation with farmers, that water should be charged on the basis of volume, and that farmers should be given training in efficient irrigation are recommended. Among recommended structural practices are that water delivered to fields should be measured, and that systems should be established to monitor soil moisture or estimate evapotranspiration determining the amount of irrigation water to be applied.

References

1. Akkuzu E (2001) Asagı Gediz havzasindaki bazi sulama sistemlerinin performanslarinin degerlendirilmesi uzerine bir arastirma. *Ph.D. Dissertation. Ege Univ. Izmir*. Turkey.
2. Altuglu B (1966) Menemen Ovasi sulama sebekesi sekonder kanallarinda sizma kayiplari. Tarim Bakanligi EgeBolgesi Menemen Sulu Ziraat Aras. Ens. Mud., 21. Izmir. Turkey.
3. Avci M, Akkuzu E, Kilic M and Karatas BS (1999) Sekonder sulama kanali duzeyinde su dagitim esitligi uzerine bir arastirma. Proc..VII Kulturteknik Kongresi. Kulturteknik Dernegi. Ankara. Turkey. 29-33.
4. Baran T, Durnabas I, Ozis U and Gul A (1999) Ege Bolgesinin yerustu su potansiyeli. Proc. Izmir Su Kongresi. Turk Muhendis ve Mimar Odalari Birligi. Ankara. Turkey. 57-73.
5. Bell JP and Mcculloch L (1993) Soil moisture content. Guidebook on nuclear techniques in hydrology. Technical Reports 91. *IAEA.* Vienna.
6. Beyazgul M, Kayam Y, Ozder E and Burto M (1999) Gediz Havzasi sulama sebekelerinde performans degerlendirmesi. Proc. VII Kulturteknik Kongresi. Kulturteknik Dernegi. Ankara. Turkey. 55-67.
7. Beyribey M (1989) Konya-Alakova yeraltisuyu isletmesinde su dagitim ve kullanim etkinligi. Ph. D. Dissertation. Ankara Univ., Ankara. Turkey.
8. Bos MG and Nugteren J (1990) On irrigation efficiencies. 2nd ed., ILRI Publ. no.19. Intl Inst. Land Reclamation & Improv. (ILRI). Wageningen. Netherlands.
9. Carneiro C and De Jong E (1985) In determination of slope the calibration curve of a neutron probe using a volumetric technique. *Soil Sci.* 139(3). 250-254.
10. Girgin A, Gecgel G, Gul S and Ozder E (1999) Menemen sulama sebekesinin sulama birliklerine devri oncesi ve sonrasinda su yonetimine iliskin bazi degerlendirmeler. Proc. VII KulturteknikKongresi. Kulturteknik Dernegi. Ankara. Turkey. pp: 34-45.
11. Hart WE, Peri G and Skogerboe GW (1979) Irrigation performance: an evaluation. ASCE *J. Irrigation & Drainage Div.* 105(3), 275-288.
12. Karatas BS (2006) Cografi bilgi sistemi ve uzaktan algilama teknikleriyle Menemen sulama sistemi performansinin degerlendirilmesi. Ph.D. Dissertation. Ege Univ., Izmir. Turkey.
13. Korkmaz N, Avci M, Unal HB, Asik S and Gunduz M (2009) Evaluation of the water delivery performance of the Menemen left bank irrigation system using variables measured on-site. *ASCE J. Irrigation & Drainage Engg.* 135(5), 633-642.
14. Merriam JL and Keller J (1978) Farm irrigation system evaluation: a guide to management. Utah State Univ., Logan. Utah.

15. Merriam JL, Styles SW and Freeman BJ (2007) Flexible irrigation systems: Concept. design and application. *J. Irrig. Drain. Engg.* 133(1), 2-11.
16. Molle F and Berkoff J (2009) Cities vs. agriculture: A review of intersectoralwater re-allocation. *Nat. Resour. Forum.* 33(1), 6-18.
17. Molden DJ and Gates TK (1990) Performance measures for evaluation of irrigation water delivery systems. *J. Irrig. Drain. Engg.* 116(6), 804-823.
18. MTSKAE (2008) Menemen hidrometeorolojik rasat verileri. *Menemen Toprak ve Su Kaynaklari Arastirma Ens*. Izmir. Turkey. pp: 239.
19. Oylukan S (1970) Eskisehir Alpu Ovasi sulama sebekesinde yapilan sulamalarda sulama tespit testi. Topraksu Genel. Mud. Eskisehir Bolge Topraksu Aras. Ens. Mud., Eskisehir. Turkey. pp: 67.
20. Ogretir K (1981) Cifteler DSİ sulama sebekesinde su iletim kayiplari ve sulanan alanlarda su uygulama randimanlari. *Eskisehir Bolge Topraksu Aras. Ens. Mud. Eskisehir*. Turkey. 164, 57-60.
21. Ozkara MM and Sahin A (1993) Ege Bölgesinde farkli sulama programlarinin Nazilli 84 veNazilli 87 pamuk cesidinin verim ve bazi kalite özelliklerine etkileri. *Koy Hizmetleri Genel Mud. Menemen Arastirma Enstitusu*. Ankara. Turkey. 193, 127.
22. Pamuk Mengü G. Ozgurel M (2008) An evaluation of water-yield relations in maize *(Zea mays L.)* in Turkey. *Pakistan J. Biol. Sci.* 11(4), 517-524.
23. Rogers DH, Lamm FR, Alam M, Trooien TP, Clark GA, Barnes PL and Mankin KR (1997) Efficiencies and water losses of irrigation systems. Irrigation Management Series. Kansas State Univ. Res & Extension Ser. Publi. MF-2243. Manhattan. Kansas.
24. Richards LA (1954) Diagnosis and Improvement of saline and alcaly soil. Agri. Handbook. 60. USA.
25. Sener S (1976) Menemen Ovasi sulama sebekesinde su naklinde meydana gelen kayiplar uzerine arastirmalar. Menemen Bolge Topraksu Aras. Ens. Mud Izmir. Turkey. 47.
26. Sener S (1978) Menemen Ovasi sulama sebekesinde sulama randimanlarinin saptanmasi. Menemen Bolge Topraksu Aras. Ens. Mud Izmir. Turkey. 56.
27. Sener M and Yuksel AN (2005) Hayrabolu sulamasinda su kullanim etkinliginin belirlenmesi. *Tekirdag Ziraat Fak. Dergisi.* 2(2), 166-176. (http:www.trakya.edu) (2008).
28. Soganci A (1999) Konya-Doganhisar Yazlica goleti sulama agi etkinliginin degerlendirilmesi. *Koy Hiz. Gen. Mud. Toprak ve Su Kaynakları Aras.* yilligi 1998. Ankara. Turkey. 108, 204-219.
29. Solomon KH (1984) Yield related interpretation of irrigation uniformity and efficiency measures. *Irrig. Sci.* 5(3), 161-172.
30. Topraksu (1971) Menemen Ovasi temel toprak etudu. Topraksu Genel Md., Ankara. Turkey. 236, 65s.
31. Topraksu (1974) GedizHavzasi topraklari. Topraksu Genel Md., Ankara. Turkey. 302.
32. Tuzuner A, Kurucu N, Gedikoglu I, Borekci M, Sonmez B and Agar A (1990) Toprak ve su analiz laboratuarlari el kitabi. Koy Hizmetleri Genel Mud. Ankara. Turkey.
33. Ucan K and Yuksel AN (2000) Kahramanmaras sulamasinda sulama suyu etkinliginin belirlenmesi. *Fen ve Muh. Dergisi. Kahramanmaras.* Turkey. 3(1), 120-130.
34. Unal HB, Asik S, Avci M, Yayar S and Akkuzu E (2004a) Performance of water delivery system at tertiary canal level: A case study of the menemen left bank Irrigation system. *Agri. Water Managt.* 65, 155-171.
35. Unal HB, Avci M, Asik S, Akkuzu E, Kilic M and Karatas BS (2004b) Farmer response to irrigation water delivery: A case study of the menemen left bank irrigation system. Ege. Univ. Ziraat Fak. Derg., Izmir. Turkey. 41(3), 165-175.
36. Zerihun D, Zhi Wang S, Rimal J, Feyen J and Reddy M (1997) Analysis of surface irrigation performance terms and indices. *Agri. Water Manage.* 34. 25-46.