Journal of Environmental Biology **April 2007,** 28(2) 455-459 (2007)

Effects of irrigation system management turnover on water table depth and salinity of groundwater

Kemal Sulhi Gundogdu* and S. Tulin Akkay Aslan

[1]Agricultural Structures and Irrigation Department, Agricultural Faculty, Uludag University, Bursa-16059, Turkey

(Received: January 1, 2006 ; Revised received: July 4, 2006 ; Accepted: October 8, 2006)

Abstract: *In recent years, management of large, state owned irrigation projects in Turkey have been transferred to water users such as farmers cooperatives or associations in order to reduce the financial burden on the government and to increase irrigation efficiency and farmer participation. Water table depth and groundwater salinity are important factors in irrigation systems, not only for plant growth but for human health as well. The objective of this study was to determine the impact on water table depth and groundwater salinity for transferring management of the Mustafakemalpasa irrigation project (19,370 ha) in north-western Turkey to local, farmer controlled irrigation districts. Maps of water table depth and groundwater salinity were created for the month of July (averaged over several years), the month with the highest amount of applied irrigation water, based on measurements made in 200 wells in the project area before and after transfer of managerial control. Both depth of the water table and salinity decreased after transfer. The area with average water table depth of 100–200 cm was 25.41% of total area before turnover and 79.45% after, and the area with water table depth 200–300 cm was 73.84% before turnover and 20.50% after. Before turnover, the area with average groundwater salinity 1.5–2.0 dS/m was 26.16% of total area, and that with average salinity 2.0–2.5 dS/m was 61.73% of total area; after turnover, average groundwater salinity was 1.5–2.0 dS/m in over all areas. Both changes were the consequence of an increased amount of applied water after transfer of the control of irrigation management from the state to local irrigation districts controlled by farmers. In the short run, the farmers will get benefit from increased irrigation. However, over the long term, if water table depth continues to decrease then secondary salinization could become a major hindrance to irrigation sustainability.*

Key words: *Water table depth, Groundwater salinity, Turnover*

Introduction

Development strategies have undergone a dramatic change in recent years, with the emphasis shifting from the state as the central sector toward greater participation by non governmental organizations. In Turkey, much of the irrigated area was controlled by public enterprises until the beginning of the 1990s, but in the last decade it has been widely argued that the sustainable management of irrigation schemes is not possible under state controlled organizations because they make inefficient use of irrigation water. A privatization process has been initiated involving the transfer of many irrigation schemes to water user associations, cooperatives or municipalities (Yercan, 2003).

The main reason for privatization has been the belief that with farmer control there would be better management of financial resources as well as improved irrigation management, resulting in more efficient use of water resources. It has also been argued that transfer of irrigation management from the state to local farmer organizations would ensure fairer allocation of resources (Meinzen Dick and Zwarteveen, 1997). The main goals of transferring control are to assure the active participation of users in maintenance, operation and management services and to reduce state expenditures (Gundogmus *et al.*, 2001; Anonymous, 2002).

Some studies have evaluated the level of adoption of the irrigation systems by farmers (Maritz, 2001; Yercan, 2003). Others have focused on the effects of transfer in various countries on irrigation efficiency, gross crop production, crop variety, irrigation cost, maintenance and repair expenses, profitability and amount of irrigation water used (Svendsen and Vermillion, 1994; Svendsen *et al.*, 1997; Quintero-Pinto, 1999; Lin, 2002; Topak *et al.*, 2003). Papers and reports have been published on transfer impacts in Indonesia (Vermillion, 2001), Sri Lanka (Samad and Vermillion, 1998), Philippines (Wijayaratna and Vermillion, 1994), Colombia (Vermillion and Garces-Restrepo, 1996), and Turkey (Kiymaz *et al.*, 2003). These studies were generally carried out to determine the effects of turnover of irrigation management on farmers economic and social well being and to characterize changes in irrigation management following turnover.

The objective of this study was to determine the effects of management transfer on depth of water table (DWT) and groundwater salinity (GWS) in the Mustafakemalpasa (MKP) irrigation project area in the northwest of Turkey.

Materials and Methods

MKP, located between 28°22´E, 40°12´N and 28°31´E, 40°02´N, is the largest irrigation project (19,370 ha) in Marmara region (Anonymous, 1997). There are 200 observation wells in this irrigation system which are used to make monthly observations of water table depth (distance between the soil surface and water table) and GWS (Anonymous, 2000). Control of the system was transferred from the state Hydraulic works (DSI) to the MKP water users' association (WUA) in 1997.

The main water source of the MKP irrigation system is the Mustafakemalpasa river. The electrical conductivity of the

***Corresponding author:** E-Mail: kemalg@uludag.edu.tr, Tel.: +90 (224) 442 89 70 / 258, Fax: +90 (224) 442 87 75

Table - 1: Climate data for July, 1994–1996 and 1998–2000

Year	Rainfall (mm)	Average temperature (°C)	Average relative humidity (%)
1994	3.1	24.0	56.4
1995	7.2	23.6	60.4
1996	20.2	23.7	58.7
1998	21.9	24.0	61.7
1999	0.0	24.7	64.9
2000	8.9	24.7	55.3

Table - 3: Crop pattern in Mustafakemalpasa irrigation area, 1994–1996 and 1998–2000 (%)

Crop	1994	1995	1996	1998	1999	2000
Clover	11.4	10.8	6.3	6	5	6.3
Corn	13.1	15.6	17.3	20.6	21.4	22.7
Fruits	2.9	2.7	2.8	2.3	1.7	1.7
Melon	3.4	1.6	2.3	3.4	1.6	5.2
Onion	1.8	1.1	0.6	1.4	1.7	1.2
Pulse	7.3	6.9	4.9	4.7	-	3
Rice	0.9	-	-	0.3	1.4	0.8
Sugarb.	22.7	17.6	10.5	15.3	9.9	13.4
Vegeta.	36.3	43.6	54.9	45.7	56.6	45.5
Others	0.2	0.1	0.4	0.3	0.7	0.2

Table - 5: Minimum water table depths before and after turnover (July)

Water table	1994–1996		1998–2000	
depth (cm)	Area (ha)	%	Area (ha)	%
0–100	6.75	0.04	–	–
100–200	10,888.00	56.21	18,802.00	97.07
200–300	8,474.50	43.75	567.25	2.93
> 300	–	–	–	–

river water ranges from 0.48 to 0.72 dS/m and the corresponding range in sodium adsorption ratio is from 0.65 to 2.00. (Anonymous, 2000)

Water is diverted to the irrigation area by means of a dam which diverts water into two main canals, one on each bank of the river. There are drainage canals parallel to the irrigation system and the drainage water is removed from the project area through pumping stations.

The soils in MKP are alluvial in character. Lake Uluabat and the Mustafakemalpasa river played an important role in their formation (Anonymous, 1967; Anonymous, 1981).

Data for DWT and GWS from 1994 to 2000 were obtained from the Archives of the State Hydraulic Works (DSI), Bursa, Turkey. Data for DWT were monthly, whereas GWS data were collected only in July, when irrigation demand in the MKP area is at its peak. Therefore, July observations for the three years before (1994-96) and after (1998-2000) turnover of irrigation management were evaluated.

Table - 2: Water delivered to the network and discharged from irrigation network in July, 1994–1996 and 1998–2000

Year	Water delivered to irrigation network (hm^3)	Water discharged from irrigation network (hm^3)	Irrigation efficiency (%)
1994	14.739	0.999	68
1995	19.830	4.548	56
1996	26.718	5.261	50
1998	22.483	5.658	65
1999	26.740	4.438	52
2000	26.161	4.249	51

Table - 4: Water consumption of crops produced in Mustafakemalpasa irrigation project area as calculated from average climatic data using the Blaney-Criddle equation

Crop	Water consumption in July (mm)
Clover	173.20
Corn	143.87
Fruits	164.15
Melon	108.88
Onion	121.08
Pulse	138.50
Rice	164.66
Sugar beet	156.14
Vegetables	144.51

DWT and GWS maps for this study were drawn for considered years by an iterative finite difference interpolation technique (Hutchinson, 1993; Wahba, 1998). The Grid module of the ArcInfo 7.1.2 program (ESRI, Redlands, California, USA) was used to prepare the maps with 50x50 m grid cells (Anonymous, 1994). To determine the variation in DWT and GWS after turnover of irrigation management, ArcInfo Grid MEAN, MIN, MAX, and STD functions were applied to the maps. These functions use multiple input grids to determine mean, minimum, maximum, and standard deviation, respectively, on a cell by cell basis (Anonymous, 1994).

Consequently, mean and minimum DWT and standard deviation maps were created using the DWT maps for the years before turnover of irrigation management. The same process was repeated for DWT maps for the years after turnover of irrigation management. As the minimum value of DWT is a restrictive factor in crop production, minimum DWT maps were created.

A similar process was applied for analysis of the GWS maps. Because the maximum value of GWS is a restrictive factor in crop production, maximum GWS maps were created. The maps were partitioned based on their grid values and the area of each partition was calculated. Additionally, analysis of variance (ANOVA) was done using all data from before and after turnover of irrigation management.

Table - 6: Average water table depths before and after turnover (July)

Water table	1994–1996		1998–2000	
depth (cm)	Area (ha)	%	Area (ha)	%
0–100	–	–	–	–
100–200	4,921.75	25.41	15,388.00	79.45
200–300	14,303.75	73.84	3,970.75	20.50
> 300	143.75	0.75	10.50	0.05

Table - 8: Maximum groundwater salinities before and after turnover (July)

Groundwater	1994–1996		1998–2000	
salinity (dS/m)	Area (ha)	%	Area (ha)	%
0–0.5	–	–	–	–
0.5–1.0	294.75	1.52	–	–
1.0–1.5	751.50	3.88	–	–
1.5–2.0	688.50	3.55	19,008.50	98.13
2.0–2.5	13,419.00	69.28	360.75	1.87
2.5–3.0	3,449.50	17.81	–	–
3.0–3.5	508.75	2.63	–	–
3.5–4.0	165.75	0.86	–	–
4.0–5.0	91.50	0.47	–	–

Table - 10: Groundwater salinity standard deviations before and after turnover (July)

Standard	1994–1996		1998–2000	
deviation(dS/m)	Area (ha)	%	Area (ha)	%
0–0.25	5,552.00	28.66	19,303.75	99.66
0.25–0.50	12,026.00	62.08	65.50	0.34
0.50–0.75	1,161.75	6.00	–	–
0.75–1.00	354.50	1.83	–	–
1.00–1.25	85.00	0.44	–	–
1.25–1.50	67.00	0.35	–	–
1.50–1.75	52.50	0.27	–	–
1.75–2.00	70.50	0.37	–	–

Table - 7: Water table depth standard deviations before and after turnover (July)

Standard	1994–1996		1998–2000	
deviation(cm)	Area(ha)	%	Area(ha)	%
0–25	13,222.75	68.26	17,192.50	88.63
25–50	5,669.75	29.27	2,143.25	11.06
50–75	364.50	1.88	33.50	0.31
75–100	95.50	0.49	–	–
100–125	16.75	0.10	–	–

Table - 9: Average groundwater salinities before and after turnover (July)

Groundwater	1994–1996		1998–2000	
salinity (dS/m)	Area (ha)	%	Area (ha)	%
0–0.5	145.25	0.75	–	–
0.5–1.0	823.25	4.25	–	–
1.0–1.5	771.00	3.98	–	–
1.5–2.0	5,066.25	26.16	19,369.25	100
2.0–2.5	11,957.75	61.73	–	–
2.5–3.0	483.25	2.49	–	–
3.0–3.5	122.50	0.64	–	–
3.5–4.0	–	–	–	–
4.0–5.0	–	–	–	–

Table - 11: Results of variance analyses for turnover of irrigation management

Source	Total irrigation water	Total drainage	Ground water salinity	Depth to water table
Turnover	6392.3**	402.51**	191.72**	207,149**
Error	13.8	1.94	1.53	1030

** difference with turnover is significant ($p < 0.01$)

Results and Discussion

Some climate data for July in the MKP irrigation area are given in Table 1. According to Table 1, maximum rainfall for July before (1996) and after (1998) turnover of irrigation management were measured as 20.2 mm and 21.9 mm respectively. Average temperature values ranged from 23.6°C to 24.7°C and average relative humidity ranged from 55.3% to 64.9% between 1994-1996 and 1998-2000. Amounts of irrigation water delivered to the network and discharged as drainage water are given in Table 2. Amounts of delivered irrigation water to the network and discharged water are more stable in period of after irrigation management turnover than before. The variations of cropping pattern that occurred over the investigated period (1994-1996 and 1998-2000) in the MKP irrigation system is given in Table 3. As can be seen in Table 3, after turnover of irrigation management corn and several vegetables production were increased while clover and sugar beet production were decreased in MKP irrigation area. Monthly plant water consumption for July was calculated from climate data using the Blaney Criddle method (Table 4) (Anonymous, 1986; Ozgenc and Erdogan, 1988) and no measured data on pan evaporation was available for use with other plant water consumption calculation methods.

The area with minimum DWT between 0 and 100 cm covered 0.04% of the total area before turnover of irrigation management and none after turnover of irrigation management. The area with minimum DWT between 100 and 200 cm increased from 56.21% of the total area before turnover of irrigation management to 97.07% after. The area with minimum DWT between 200 and 300 cm decreased from 43.75% of the total area before turnover of irrigation management to 2.93% after (Table 5, Fig. 1). Similar results were observed when we compared maps of average DWT before and after turnover of irrigation management (Table 6). As can be seen in Table 2, after turnover, average annual amount of water delivered to irrigation network was 4699 hm^3 higher than the amount before turnover,

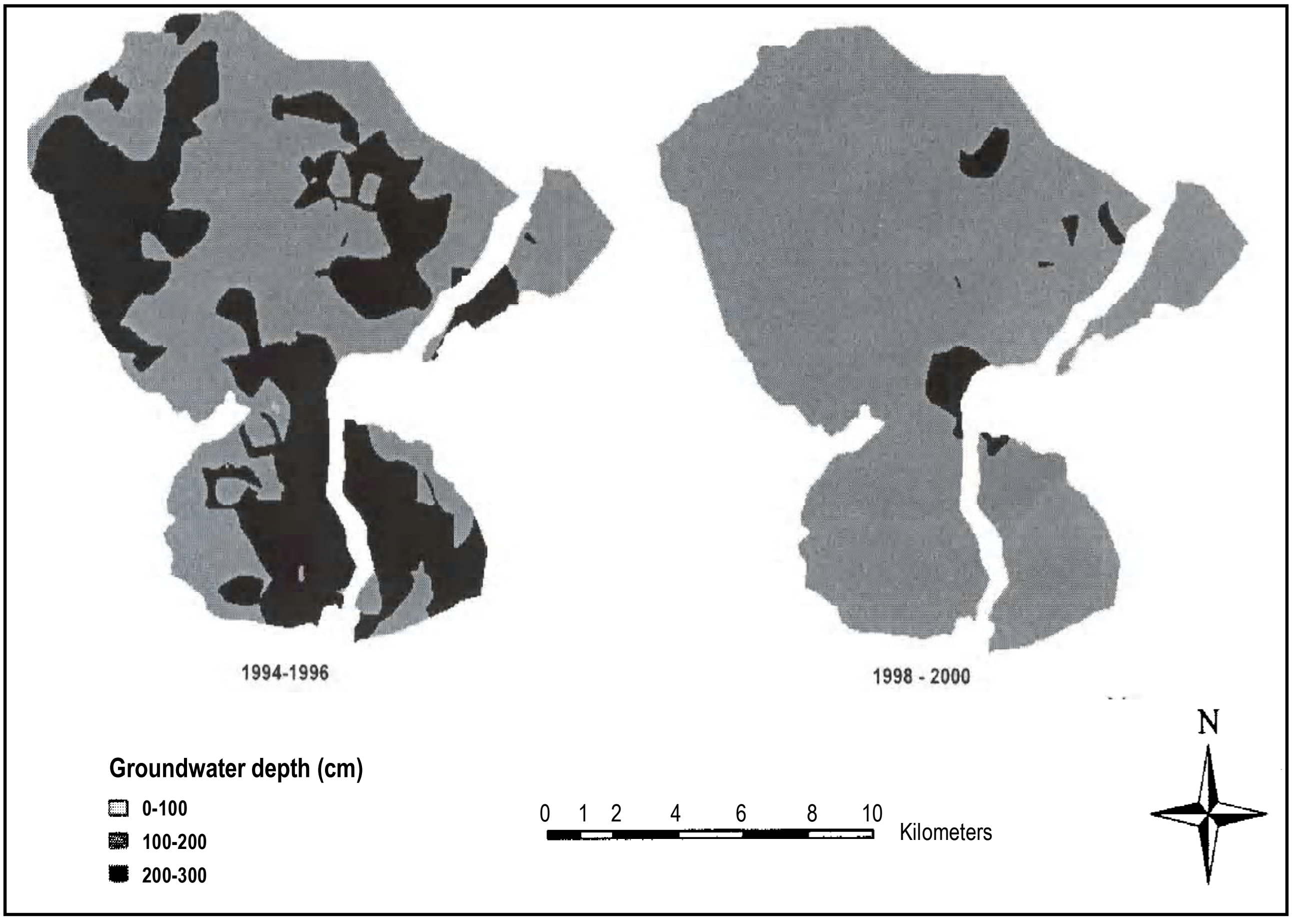

Fig. 1: Spatial distribution of the values of minimum depth of the water table in July, before and after turnover of irrigation management

consequently, after turnover, depth to groundwater decreased, thus the area with a groundwater depth of 100-200 cm was increased (Table 5 and 6).

The percentage of the area with 0-25 cm DWT standard deviation increased from 68.26% of the total area before turnover of irrigation management to 88.63% after (Table 7). This shows that DWT variations (in the investigated period) decreased after turnover of irrigation management. Annual amount of water delivered to irrigation network is less changeable compared to the period before turnover (Table 2). This contributed to a less annual change in the groundwater depth.

The area with maximum GWS between 1.5 and 2.0 dS/m increased from 3.55% of the total area before turnover of irrigation management to 98.13% after (Table 8). On the other hand, the area with maximum GWS between 2.0 and 2.5 dS/m decreased from 69.28% of the total area before turnover of irrigation management to 1.87% after. Similar results were observed when we compared the average GWS maps before and after turnover of irrigation management (Table 9), showing that average GWS level decreased after turnover of irrigation management. The fact that the annual water discharged from irrigation network increased compared to the period before turnover alongwith the rise in the amount of annual water delivered to irrigation network compared to the period before turnover (Table 2) was effective on the decrease in groundwater salinity.

When we compared the GWS standard deviation maps for before and after turnover of irrigation management, we found GWS values to range between 0-0.5 dS/m after turnover of irrigation management, whereas they had ranged between 0-2.0 dS/m before (Table 10). These results showed that annual deviation of GWS values decreased after turnover of irrigation management. After turnover, because of water delivered to irrigation network and water discharged from irrigation network showed less variability, the annual variation in GWS values was decreased.

ANOVA showed that the difference between before and after turnover of irrigation management for GWS, DWT, total irrigation water, and total drainage water was significant ($p < 0.01$), as shown in Table 11.

We concluded, that DWT and GWS decreased considerably after turnover of irrigation management. However, the amounts of water delivered to the irrigation network and discharged from it significantly increased after turnover of irrigation management. Although the observed decrease in DWT is apparently unproblematic, if it were sustained then secondary salinization could become a major hindrance to irrigation sustainability. Decreased GWS might be the result of salt leaching owing to more water being delivered to and discharged from the system.

Diker *et al.* (1999) reported that the fraction of land area with DWT between 0 and 100 cm decreased from 3.83% to 2.7% after WUA were given managerial control. Their studies were carried out on the lower seyhan plain (Adana, Turkey). They also found that the area with GWS of 7.35 dS/m decreased from 0.4% to 0%, while the area with GWS between 0 and 0.75 dS/m increased from 22.2% to 32.7%.

Turnover of irrigation management in the MKP project area had significant effects on DWT and GWS. Decreased DWT should be prevented, not only to provide a suitable environment for plant growth but also for human health and environmental sustainability; therefore, monitoring and evaluation of groundwater should be continued. Units dedicated to the performance of such monitoring and evaluation should be established in WUA.

References

Anonymous: Mustafakemalpasa sulama projesi tesis tanitim foyu, DSI karacabey sube mudurlugu, Bursa. Turkish (1967).

Anonymous: Mustafakemalpasa sulama projesi ve tarimsal yonu, DSI genel mudurlugu, I. Bolge Mudurlugu, 11. Teknik sube mudurlugu, Karacabey isletme bakim basmuhendisligi, Bursa. Turkish. p. 22 (1981).

Anonymous: Irrigation water management: Crop water needs, training manual no: 3, Food and agriculture organization of the United Nations, Rome, Italy (1986).

Anonymous: Grid commands, environmental systems research institute, Inc., Redlands, California, USA (1994).

Anonymous: Genel nufus tespiti, Idari bolunus, DIE, ISBN : 975-19-2290-9, Yayin No: 2281, Ankara. Turkish (1997).

Anonymous: Mustafakemalpasa sulamasi tabansuyu raporu (Ekim 1999 - Eylul 2000). Devlet su isleri genel mudurlugu 1. Bolge mudurlugu, Bursa. Turkish (2000).

Anonymous: Turkiye'de katilimci sulama yonetimi calismalari. DSI genel mudurlugu isletme ve bakim dairesi baskanligi, APK sube mudurlugu, Ankara. Turkish (2002).

Diker, K., M. Cetin and H. Ozcan: Sulama tesislerinin sulama birliklerine devir isleminin taban suyu duzeyi ve kalitesi uzerine etkilerinin cografik bilgi sisteminden yararlanilarak arastirilmasi, VII. Kulturteknik kongresi, Kapadokya. Turkish. pp. 206-214 (1999).

Gundogmus, E., B. Cakmak, H. Tanrivermis and M. Turker: Turkiye'de sulama tesislerinin birlik ve kooperatiflere devri ve devir sonrasi tesislerin isletmeciliginde yasanan sorunlar. 1. Ulusal sulama kongresi, Kulturteknik Dernegi, Antalya. Turkish. pp. 82-91 (2001).

Hutchinson, M.F.: Development of a continent wide DEM with applications to terrain and climate analysis. *In*: Environ. model with GIS, (*Eds*: M.F. Goodchild *et al.),* Oxford university press, New York, pp. 392-399 (1993).

Kiymaz, S., A. Yazar and A. Hamdy: Asagi seyhan ovasi sulama alaninda kurulan sulama birliklerinin sistem performansinin degerlendirilmesi. 2. Ulusal sulama kongresi, Kulturteknik dernegi, Aydin. Turkish. pp. 56-65 (2003).

Lin, Z.C.: Participatory irrigation management by farmers: Local incentives for self financing irrigation and drainage district in China. The environment and social development unit, WBOB. p. 27 (2002).

Maritz, P.J.: Irrigation management transfer, sharing lessons from global experience: Comments on overview paper, department of agriculture, Republic of South-Africa. p. 18 (2001).

Meinzen Dick, R. and M. Zwarteveen: Gendered participation in water management: Issues and illustrations from water users' association in South Asia. Women and water workshop international irrigation management institute, 15-19 September 1997, Sri Lanka. p. 18 (1997).

Ozgenc, N. and F.C. Erdogan: DSI sulamalarinda bitki su tüketimleri ve sulama suyu thtiyaclari, devlet su isleri genel mudurlugu, isletme ve bakim dairesi baskanligi, Ankara, Turkish (1988).

Quintero-Pinto, L.E.: Benefits and second generation problems of irrigation management transfer in columbia. EDI participatory irrigation management case study series. International network on participatory irrigation management, Washington. p. 27 (1999).

Samad, M. and D. Vermillion: Assessment of participatory management of irrigation schemes in Sri Lanka: Partial reforms, partial benefits. International water management institute, research report 34, Colombo, Sri Lanka (1998).

Svendsen, M. and D. Vermillion: Irrigation management transfer in the colombia basin: Lessons and international implications. Research paper-No: 12, IIMI, Colombia, Sri Lanka. p. 94 (1994).

Svendsen, M., J. Trava and S.H. Johnson: Participatory irrigation management: Benefits and second generation problems. Lessons from an international workshop help at cento international de agricultural tropical (CIAT), Cali. p. 13 (1997).

Topak, R., B. Acar, M. Kara, N. Ciftci and M. Sahin: Cumra ve cumra ova sulama birlikleri sulama sebekelerinde yeni isletme seklinin performans gostergelerine etkileri. 2. Ulusal sulama kongresi, kulturteknik dernegi, Aydin. Turkish (2003).

Vermillion, D.L.: Irrigation management transfer in the columbia basin, USA: A review of context, process and results. IMT case study, INPIM, International e-mail conference on irrigation management transfer. p. 17 (2001).

Vermillion, D.L. and C. Garces-Restrepo: Results of management turn over in two irrigation districts in columbia. International water management institute, research report 4, Sri Lanka. p. 38 (1996).

Wahba, G.: Spline Models for observational data. CBMS-NSF regional conference series in applied mathematics, Philadelphia: Soc. Ind. Appl. Maths (1998).

Wijayaratna, C.M. and D.L. Vermillion: Irrigation management turnover in the philippines: Strategy of the national irrigation administration. Short report series on locally managed irrigation, report No: 4, Local management program, international irrigation management institute, Sri Lanka. p. 23 (1994).

Yercan, M.: Management turning over and participatory management of irrigation schemes: A case study of the gediz river basin in Turkey. *Agric. Wat. Manage.,* **62**, 205-214 (2003).