Impacts of Different Drainage Managements on Water Saving, Salt Balance and Nutrients Losses in the Harran Plain, South East Turkey

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Abstract

The impacts of varying drainage managements on salinization, nutrients leached and water savings in the Harran plain were determined. Controlled (CD) and free flow drainage (FD) systems were compared in terms of drainage water quality, the number and amounts of irrigation, degree of soil salinity. In CD area , total of 517 mm of water were applied, and drain flow was a total of 42 mm and drainage ratio was 8 %. In FD area, total of 490 mm of water were applied and total drainage water amounts reached to 61 mm and the drainage ratio was 12.5%, this was a value higher than that of attained from the other controlled drainage area. Varying drainage conditions do not have any significant effect on the plant nutrient element losses. However, the lessening in the amount of the drainage water, due to controlled drainage, will cause lessening also in the plant nutrient element losses. Both in draining conditions showed no significant variability in soil salinity.

Key Words Controlled drainage, Harran Plain, nutrients losses, salt balance

Güneydoğu Anadolu Bölgesi, Harran Ovasında Farklı Drenaj Yönetimlerinin Su Kazanımı, Tuz Dengesi ve Bitki Besin Element Kayıplarına Etkisi

Öz

Bu çalışmada Harran Ovasında farklı drenaj yönetimlerinin toprak tuzluluğu, bitki besin elementlerinin yıkanması ve su kazanımı üzerine etkileri belirlenmiştir. Toprak tuzluluk düzeyi, drenaj suyu kalitesi ve sulama sayı ve sulama suyu miktarları kontrollü (KD) ve serbest (SD) drenaj alanlarında karşılaştırılmıştır. KD alanında toplam 517 mm sulama suyu uygulanmasına karşılık 42 mm drenaj suyu oluşmuş ve drenaj oranı % 8 olmuştur. SD alanında ise 490 mm sulama suyu uygulanmış, drenj suyu ise 61 mm olarak meydana gelmiş, drenaj oranı kontrollü drenaj alanındakinden daha yüksek olarak gerçekleşmiş ve yaklaşık % 12,5 olmuştur. Farklı drenj yönetimleri drenaj suları ile kaybolan bitki besin element kayıp oranlarını önemli düzeyde etkilememiştir. Ancak, kontrollü drenj alanından daha az su drene olması nedeniyle bitki besin element kaybı da az olmuştur. Her iki drenaj yönetimi de toprak tuzluluğunda önemli bir değişmeye neden olmamıştır.

Anahtar Kelimeler: Kontrollü drenaj, Harran Ovası, bitki besin element kayıpları, tuz dengesi

INTRODUCTION

About 250-300 million m^3 of water is discharged through drainage from the Harran Plains annually. Both storing and discharging such a large volume of water presents a seriuos challange. Diverting drainage waters into river systems is a common practice world wide. This may not cause a problem if the salinity and contamination levels of the water are within the acceptable range. However, it is still necessary to reduce the level of drainage water and its salt content in order to minimize the impact of drainage waste-water when used for irrigation.

While approximately 150000 hectares have been opened to irrigation, there is further construction of sub-surface pipe drainage systems currently under construction in 50000 ha in the southern parts of the Harran Plain. However, there is no structure controlling the drain flows within the drainage systems. That is why the overflow-drainage (surface) which happens occasionally during the irrigation seasons, increases the amount of drainage water discharge, loss of plant nutrients and water inadequacy.

Irrigation system is managed by way of a rotational operation method in which the irrigation intervals are fixed. While there are 2 rotations, however tertiaries are irrigated every 15 days. In the plain soils with high hydraulic conductivity, the water table is dropped down to the drain level soon after the irrigation. Since the subsequent irrigation takes place every two weeks, plants may suffer from water stress. Farmers try to overcome the stress by way of draining surplus water following irrigation. The water inside the drainage channels is discharged via the return pumps either back into the irrigation system, or to the main discharge channel at the Syrian border, where outlet inadequacy also causes problems. Since pumping leads to excess enegry, production costs are therefore increased.

That is why on-site controlled drainage trials have been deemed necessary for the development of the criteria, which will contribute to maintaining sustainable agriculture with minimum environmental damage. The benefits being expected from controlled drainage include water recovery, irrigation time and labour savings, increase in the efficiency of the water utilization in the basin. Continuation of agricultural production even at times of water shortage, increase in productivity, lowering of the drainage water volume, and savings in the utilization of agricultural fertilizer. Controlled drainage is an issue which has hardly been dealt with in Turkey. Yet, extensive studies have been conducted on controlled drainage in irrigation areas worldwide. While the problems associated with global warming are mounting, studies aiming water recovery, collecting data on this issue and utilizing such datain the management of drainage systems have become an issue of increasing importance.

Many studies have been conducted on the utilization of underground water plant in the world. While Kruse et al., (1985) highlight that corn derives approximately 55 % of its water from the groundwater at 0.6 m of depth with 6.0 dS m^{-1} and Meyer et al., (1996) 13-55 % of the water need is derived from the groundwater reserved at 0.6 m depth, indicating that as salinity increases, utilization of water in fine-textured soils, and salty groundwater decreases.In other words the increase of salinity in the groundwater affect the rate of water intake by plants, however, they still significantly benefits from the groundwater. On the other hand, Dugaset et al., (1990) water utilization of the soybean in the clay and compressed-layered soil from the underground water at 1 m of depth is less than that in the uncompressed soil. The moisture content of the topsoil diminish, the hydraulic gradient and potential water flow towards the root part increases the amount of the water intake from the underground water.

The nitrogen being washed from the fields, due to over-fertilization of corn, causes environmental problems. Evans et al., (1999) pointed out that one way to solve this problem is to change the strategies of water table management. According to Soppeet al., (2002), the higher the feasible humidity in the root section is, the lower the groundwater utilization and the wider the irrigation intervals become. The lower amounts of irrigation water stir up utilization from groundwater. Careful planning and management of water table systems may improve the water quality (Evans et al., 1987). Madramoto et al., (1992) as long as the water table is kept in between 60 and 80 cm, higher efficiency is obtained from the soybean in comparison to that being obtained via traditional drainage systems, and that the nitrate losses are thereby reduced by 52 %.

Fouss et al., (2002) point to the facts that, by means of the control structures to be built up at the drain outlets, nitrate-N losses from the arable lands may be reduced down to 35 %, and the water table should not be dropped deeper than 0.60-0.75 m for most of the soils during the growing period. While nitrate losses occur in proportion to the ratio of the drainage water losses, shallow water table further creates a larger zone, which stirs up denitrification in the soil profile, and this causes the reduction of nitrate-N concentration, which also means lesser washing of nitrate.

Ayars et al., (2006) reported that, the water table may be effectively monitored at the irrigation sites via various types of control structures, and that such monitoring will reduce the total salt load as well as drainage water. However, they also pointed out that it is critical under controlled drainage to take the salt accumulation at the root section into consideration. According to Tan et al., (1999), the controlled drainage system reduces nitrogen loss from the sandy loamy soils. Bahçeci et et al., (2008), in a model study of the effects of controlled drainage on the water and salt balance at Harran Plains, found that the control of drain outlets by 75 % throughout the growing period may not cause any critical salt accumulation in the soil.

In a system under controlled drainage, which allows the water table to rise no higher than 69 cm above the drains, drainage flow duration is annually reduced from 40 to 62 % (Ramoska et al., 2009). As you can see, depending on the weather conditions, controlled drainage application throughout the growing period reduces drainage water amount by 25 %, and nitrate washing by 20-28 %, and increases the output by 5.6-10 %. Control of the water table serves as a beneficial application with positive effects on the environment, reduce drainage water, nutrient losses and water stress.

MATERIALS AND METHODS

Material

Harran Plain is surrounded by Şanlıurfa and the Germüş Mountains from its north, Turkish-Syrian border, the Tektek Mountains from its east, and the Fatik Mountains from the west (Figure 1). With 65 km of length in the north-south direction, the plain displays varying width from 60 km at its widest point in the south to 30 km at its narrowest point which stretches across the middle of the plain. In terms of topographical structures, it is composed of nearly flat lands in general. The overall slope varies between 0-2 %, its elevation at the higest point is 480 m and 335 m at its lowest (overall slope is by 0-2 %, its elevation varies from 480 m at the highest to 335 m at the lowest). While the overall surface area of the Plain is 225.109 hectares, the surface area of the irrigation area designated for the project is about 151000 hectares (Anonim, 2003).

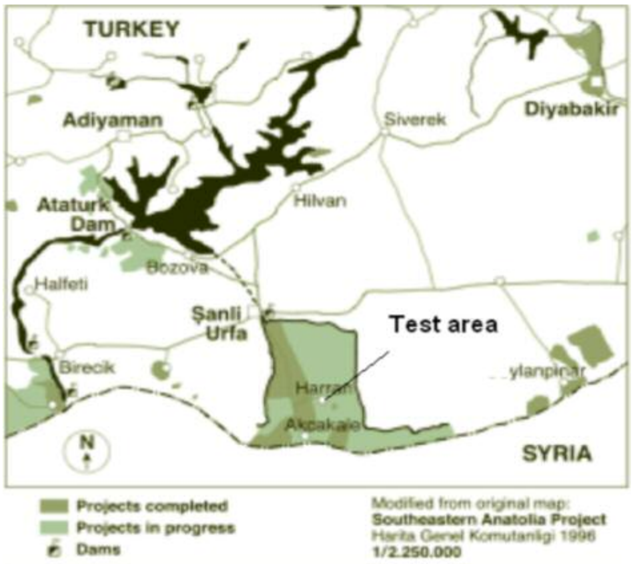

Figure 1. The site of test area
Şekil 1. *Deneme yeri*

Harran Plain is under the continental climatic conditions of the Southeastern Turkey and those of the Mediterranean. It is hot and arid in the summer, and cold and wet in the winter with high differences between day and night temperatures. While the annual average precipitation in Harran Plain is 365 mm, its annual average temperature is 17.2^{O}C, and the annual evaporation is about 1848 mm (DMİ, 2012).

Method

Two subjects are dealt with in the study. These are namely comprised of Free Drainage (FD) and Controlled Drainage (CD). The changing of the effective drain depth depends on controlling the water table depth during the irrigation season. Drain outlet was raised 1 m above the drain levels.

Having been constructed nearly 2 years ago, the drainage system, on which the trial has been built drain depths varying in between 1.70 and 1.80 m. In designing subsurface drainage systems, drainage coefficient of 2.58 mm d^{-1} was considered. There are slight differences between the drain depths, depending on the topographical structure of the land. Corrugated pipes are installed with 0.1 % gradiant as lateral drains.

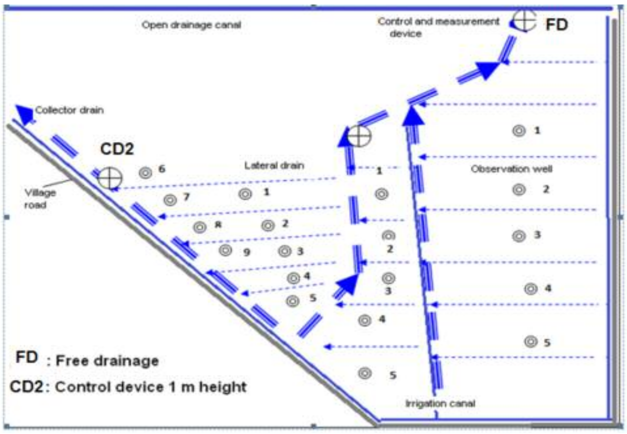

Figure 2. Experimental plan

Şekil 2. *Deneme planı*

Lateral drains with diameters of 100 mm are connected at 100 m and 60 m intervals (Figure 2). Sand-gravel is applied as envelope material. Depending to the shapes of the parcels, the lengths of the lateral drains vary in between the average of 264-305 m at FD area, while the same measurements vary in between 150-320 m at CD area.

Soil samples were taken from 20 cm to 180 cm depth, taking the drain depth into consideration, at the beginning and the end of irrigation period. The samples were dried in the shade, filtered portions thereof are removed, and pH, electrical conductivity, and solubility Na analyses are measured.

Measurement of the Irrigation Waters

Irrigation water being collected from canalettes via siphons and are discharged into the furrows. Amounts of irrigation water, number, features, flow rates, and running hours of siphons were determined by way of recording. Flow rates of the siphons, were determined by both calculation and on-site measurment methods.

Measurement of the Drainage Waters

Amount of drainage water was measured via cut-throat spillways mounted at manhole outlets, while EC_{dw} was measured Ec metre and the nitrate concentrations in the drainage water is made with Lovibond MaxiDirect nitrate measurement kit.

RESULTS AND DISCUSSION

Nitrate Load in Drainage Waters

In 2011, significant amounts of phosphate were not observed in drainage waters (FD and CD area less than 1 ppm). Nitrate content of drainage water was between 35-40 ppm at the beginning of the season and verage nitrate concentrations values varied between 32 and 11 ppm (Table 1). Nitrate levels tended to decrease towards the end of the season. In July and August, the average nitrate content was found between 32.28 and 29.11 ppm in the CD and between 28.11 and 22.34 ppm in FD areas. In September, it was 15.50 and 11.03 ppm respectively. Nitrate levels in 2012 and 2013 remained at lower levels (19-22 ppm, usually). Either increasing or decreasing trends were observed throughout the season.

The trial subjects, FD and CD, did not significantly affect the nitrate concentrations of drainage water. The highest change in nitrate content was between 45-55 ppm and the lowest value for change was determined as 5-10 ppm. Nitrate contents in all drainage water increased following fertilization reduction due to soils.

While the drainage water was found to be free of sand and silt, EC values were slightly higher at controlled drainage areas, and similarly as displaying increase towards the end of the season. Salinity of drainage water, particularly in the CD area, reaches its highest levels in September. The highest EC_{dw} values were measured at CD area, values from FD areas were found to be the lowest. Monthly average values were 2.274, 2.571, and 3.337 dS m^{-1} at CD area, and, 1.895, 1.790, and 1.983 dS m^{-1} at FD area in July, August, and September respectively.

Table 1. Average nitrate content of drainage water in test areas (ppm)

Cizelge 1. *Test alanlarında drenaj suyunun nitrat içerikleri (ppm)*

Years	July		August		September	
	CD	FD	CD	FD	CD	FD
2011	32.28	28.11	29.11	22.34	15.50	11.93
2012	19.82	21.84	21.2	18.73	19.75	22.3
2013	22.30	20.58	21.51	18.81	26.18	20.5

Results of the Term-End Soil Analysis

While soil salt values varied between the average of 0.899 and 1.023 dS m^{-1} at CD area, no significant variation occurs within the period of three years (Table 2). While the average salt value at the free drainage area is 0.899 dS m^{-1} at the beginning, it first displays a decrease, however, at the end of the irrigation season to 0.679 and it increases up to 1.313 dS m^{-1} at November 2012 and decrease the third season to 1.022 dS m^{-1} (Figure 3). While the cause of such an insignificant increase at the free drainage area in view of soil saltiness cannot be discovered, however, it is also not attributed to have stemmed from different drainage conditions.

In FD area, at the beginning of the trial, while the average soil salinity was 1.527 dS m^{-1}, the end of the trial has been decreased by 1.340 dS m^{-1}. Only at the end of the irrigation season, in 2012, the soil salinity has been increased to 2.131 dS m^{-1}. In the last year of the experiment, salt value of the soil was 1.136 dS m^{-1} at the beginning of the irrigation season and it was 1.25 dS m^{-1} at the end of the irrigation season at 100 cm depth (Figure. 3).

Soil depths obtained from the assessment results of the analysis are shown in Table 2. According to T-test results, the Free and Controlled Drainage at different soil depths in the area where there is insignificant variability in soil salinity was observed. In CD area, for 0.60, 1.0 and 1.60 m depth, while the initial average salinity values were 0.785, 0.899 and 0.954 dS m^{-1} at the end of trial, these values

Table 2. The change of soil salinity at different soil depths and under various drainage conditions

Cizelge 2. *Değişik drenaj koşullarında farklı derinliklerde toprak tuzluluğunun değişimi*

Soil depth	CD		FD	
cm	ECe-2011	ECe-2013	ECe-2011	ECe-2013
60	0.785	0.890	1.263	0.925
Ttest	0.223^{ns}		0.106^{ns}	
100	0.899	1.023	1.527	1.340
Ttest	0.219^{ns}		0.475^{ns}	
160	0.954	1.115	1.523	1.655
T test	0.078^{ns}		0.555^{ns}	

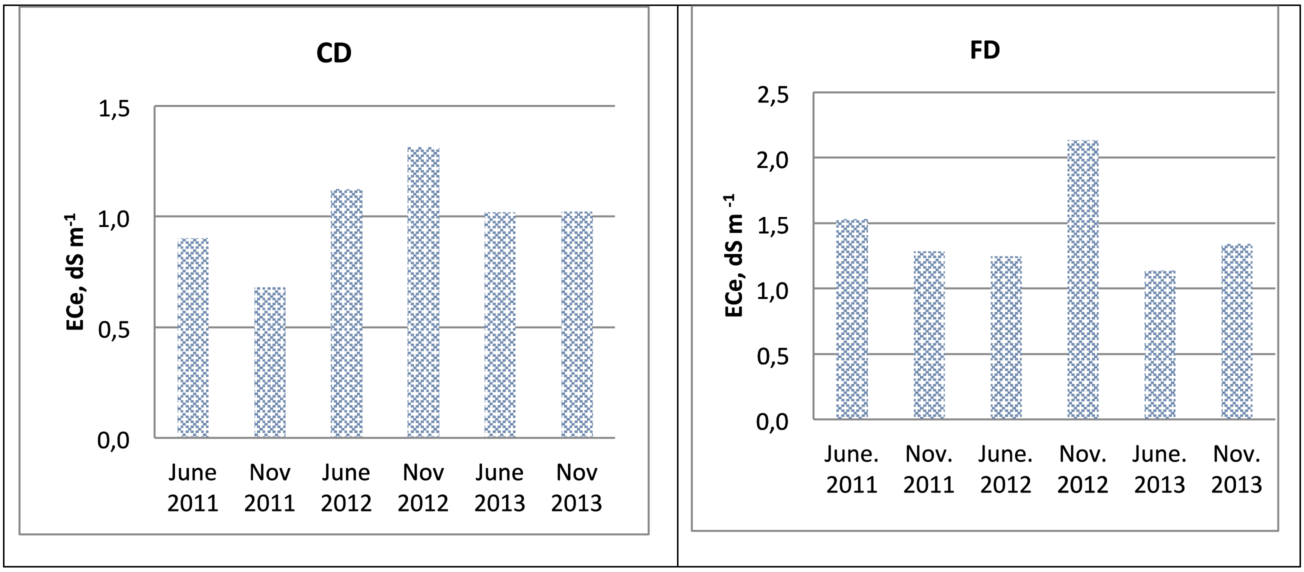

Figure 3. Average soil salinity (ECe) in FD and CD test areas at 100 cm soil depth

Şekil 3. *SD ve KD test alanlarında, 100 cm toprak derinliğinde ortalama toprak tuzluluğu (ECe)* were 0.890, 1.023 and 1.115, respectively. In the same way, in FD area, for 0.60, 1.0 and 1.60 m depth, while the initial average salinity values were 1.263, 1.527 and 1.523, dS m^{-1}, at the end of trial, these values were 0.925, 1.340 and 1.655 respectively. T-test results, both in draining conditions showed no significant variability in soil salinity (Table. 2).

Irrigation and Drainage

The amounts of irrigation and drainage waters in test areas were depicted in Table 3. The local farmers' irrigation practices, there has been no response to the applications. During the irrigation season, five times in the CD field, and six time FD field was irrigated. CDs field received 517 mm and 490 mm of water was applied to the FD field. This field is made up of drainage water quantities, 42 mm in the CD area and 56 mm in the FD area.

In CD parcel, there is flow for a total 22 days throughout the season and the water flow to CD area is more than the other trial areas, both in the number of times and amount. That is why the amount of drained water therein is also high. As a result of the respective measurements, total of 517 mm of water is applied, and there is also a total of 42 mm of drain flow there to. While the drainage ratio is 8 %, this is lower than the same attained from the free drainage area.

While irrigation water is flown in FD area for 5 times, the amount of the applied irrigation water is 490 mm, due to water shortage and at the end of the drainage flow for 80 days, total drainage water amounts reached to 61 mm. While drainage ratio is 12.5 %, this was a value higher than that of attained from the other controlled drainage area. The effect of controlled drainage on water-saving was not significant. The reason for this was the high natural drainage of soils.

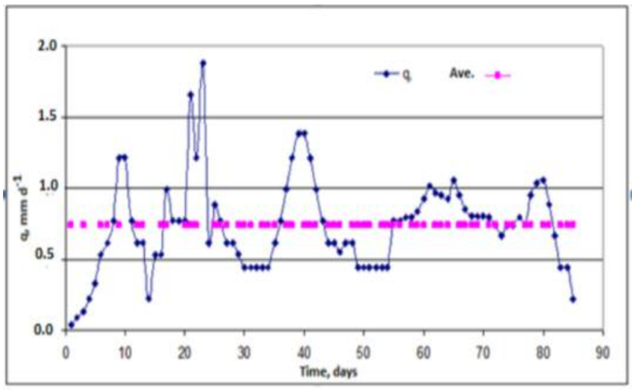

Figure 4. Change of drain flows in free drainage area

Şekil 4. *Serbest drenaj alanında dren akışlarının zamansal değişimi*

While the drain flows were quite low throughout the irrigation season, the maximum average flow attained was 1.8 mm d^{-1} per day. The average drainage flow was q=52/80 =0.65 mm d^{-1} from the free drainage area according to the available data (Figure. 4).

As shown, in the experiment obtained seasonal drain flow is very low, compared the drainage coefficients used in subsurface drainage system designed in the Harran Plain.

Table 3. Irrigation water applied to the fields and the amount of water drained

Cizelge 3. *Uygulanan sulama suyu ve drene olan su miktarları*

Date	Irrigation interval, day	Irrigation water, mm	Date	Irrigation interval, day	Irrigation water, mm
	CD			FD	
11-3/06		100	24-27/06		129
25-8/06	12	87	10-17/07	15	55
11-3/07	14	61	25-30/07	15	56
26-8/07	13	84	10-16/08	17	118
11-13/08	13	100	03-06/09	14	46
03-5/09	20	85			
Total irrigation water, mm		517			490
Drainage water, mm		42	Drainage water, mm		61
Drainage ratio, %		8	Drainage ratio, %		12.5

Water Ponding at the Land Surface

Water ponding was not occured during the summer. Pondings occur at quite a low amount, due to water accumulation at the parcel ends in connection with the open drainage channel. No rise occurred at the controlled drainage areas as well and thereby contribution of the water table to ponding.

Cultivation Time, Fertilization and Crop Yields

While CD area is cultivated on April 20th, 2012, and FD areas on May 5th, 2012, and 300 kg 20:20 bottom fertilizer, and 400 kg ammonium nitrate is applied per hectare.

According to the measurements dated to the harvest time, among the controlled drainage areas, 4300 kg ha^{-1} unginned cotton is harvested from CD, and 4000 kg ha^{-1} unginned cotton is harvested from FD areas. No significant difference was found in view of the cotton output between the controlled and free drainage areas.

CONCLUSIONS

No significant physical and chemical change is found at the plain soils caused by the varying drainage conditions out of the monitoring and evaluation processes lasted for three years. Two years of monitoring is not, for sure, a sufficient period to create any significant variance. Varying drainage conditions do not have any significant effect on the plant nutrient element losses. However, the lessening in the amount of the drainage water, due to controlled drainage, will cause lessening also in the plant nutrient element losses.

Used in designing the drainage coefficient is much higher than the values measured in the experiment. This new subsurface drainage system in the area where it will be built, it should be taken into account.

It would not be wrong to say that, in view of the attained results, controlled drainage does not have any adverse effect on the plain soils, and instead that, it is an application helpful in view of the lessening of the drainage water.

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