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FULL-LENGTH RESEARCH ARTICLE

Comparison of Drainage Water Quality and Soil Salinity in Irrigated Areas with Surface and Subsurface Drainage Systems

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Abstract Drainage should be practiced in conjunction with irrigation to ensure maximum production and for environmental protection in all irrigation projects. An efficient drainage system removes salts added to the soil brought in by irrigation water. Various problems such as the increase in soil salinity, waterlogging, and water table rise into the crop root zone may be encountered when an efficient drainage system has not been provided in an irrigated area. Surface drainage removes excess water accumulated in the cropped area, and excess water and harmful salt solutions in the soil profile are removed by subsurface drainage. In this study, an area of 6,120 ha in the Erzincan irrigation area and where drainage waters are used for irrigation, was chosen for the study. Monthly water samples were taken from two points on surface drainage canals and again two points on drainage outlet of subsurface drainage system during irrigation season. In order to determine the rate of salt removed from soil by surface and subsurface drainage canals, salinity values of drainage waters were determined. In addition, in order to determine the effect of irrigation water on drainage water, water samples were taken from the same points on irrigation canals bringing water to the mentioned areas each month. Although water samples from surface and subsurface canals had high salinity, no water sample from irrigation canals with high salinity was encountered. Two pilot areas of 10 ha under the influence of surface and subsurface drainages were selected and soil samples were taken to determine soil salinity at the end of the irrigation season. In order to compare data taken from two pilot areas, *t* test was performed using SPSSWIN program. High salinity levels were found in the areas where subsurface drains do not exist, compared to the deeper parts of the same soil profile. Lack of proper drainage system leads to salinity and sodicity in soil. Therefore, to avoid environmental problems, it is very important to ensure proper drainage conditions.

Keywords Drainage · Salinity · Water table · Erzincan · Turkey

Introduction

In surface water-irrigated areas, waters from drainage canals are used for irrigation, even if they are low quality, when adequate quantity of good quality water from the surface sources are not available. In such cases, salt is added to soil and thus, environmental problems emerge. Studies have revealed that salinity problems occur in one-third of the irrigated crop lands all over the world and it is believed that this situation may not change for better in the near future [8]. According to Rhoades [13], as long as drainage water is of permissible quality to be used by plants, it can be reused for irrigation. If water gained from irrigation return flow from upper area could be captured and used for irrigating lower areas, the general water use efficiency of the basin can be increased [4]. However, this water source is of lower quality compared to springs and

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therefore, if they are used, they can have possible negative effects on soil and the qualities of shallow groundwater. Various systems have been used to drain the excess water both on the surface and between the soil horizons in order to keep the water table below a certain level comprising surface and subsurface drainage infrastructures [10]. Drainage of stationary water on soil surface which can increase water table in the soil profile and harm plant root zone is accomplished by providing surface drainage system, while the excess water present in the soil profile can be removed using subsurface drainage system. A number of reports have been recently published related to drainage system solutions and designs [2, 5, 6, 15]. Bahçeci and Nacar [3] stated that subsurface drainage is more effective in salt cleaning in soil profile and salt cleaning process can begin immediately after providing suitable drainage.

Materials and Methods

Materials

In this study, an area of 6,120 ha, which has been operated by Turkish State General Directorate of State Hydraulic Works since 1964 on the left side of Euphrates in Erzincan irrigation facility and where surface and subsurface drainage facilities are in use, was selected.

Wheat, bean, and sugar beet are the major crops grown in the study area, besides vegetables, fruits, and poplar trees. Kom Creek is one of the water sources of the area and the other is the left coast main canal whose water comes from Euphrates River. In the study area which was gradually opened to the irrigation, surface drainage network was constructed together with irrigation facilities. Subsurface drainage network has not yet been completed although it was started 15 years after the partial subsurface drainage system started to be used in 1980. Traditional open drainage canals are also present in the area. Drainage coefficient which indicated maximum capacity of the drainage system for subsurface drainage was found to be 0.0017 m/day in the irrigation area. [1]. The study area experiences Continental climate type. Surface drainage network consists of discharge and collector canals linked with secondary drainage canals. Secondary creeks flow into main discharge canal. The depth of the main discharge canal is between 2.50 and 3.00 m in the lower parts, while the depth of the collector and secondary discharge canals are between 1.20 to 1.50 m. In addition to secondary canals needed after the opening of the irrigation facility, there are also surface drainage canals. Drains consisting of subsurface drainage network are concrete pipes laid below the surface at depths ranging from 1.5 to 2.0 m. Inner radius of the drains ranges from 16 to 20 cm as one moves toward downstream of the network. Drainage coefficient for the study area is 0.0017 m/day and the distance between subsurface drains in the fields is between 100 and 120 m.

Methods

Sampling and Analysis of Water

Sampling was done at measurement wells, irrigation, and drainage (discharge) canals in order to monitor the variations in the levels of water table and water quality parameters and their changes with respect to time. When taking water samples principles in Demirtaş [7] were considered. When taking water samples from water table observation wells, August was chosen to be suitable considering the statement by Özgenç and Erdoğan [12], where this month was found to be the time when plant water consumption is the highest. Water samples from irrigation and surface drainage canals were taken in order to determine the effects of irrigation on local groundwater salinity and the amount of salt removed from soil. Monthly water samples were taken from irrigation and surface drainage canals and subsurface drains beginning from May to October which are the beginning and end points of irrigation season. Samples of irrigation water were taken from two points at the beginning and on the lower parts of the canals. Water samples taken from irrigation canals were named Irrigation 1 and 2. Samples taken from main drainage canal were named Surface Drainage 1 and 2. In addition, two drain water samples were taken from two drains one of which is in the area where soil sample was taken. Water samples from drainage canals were taken from source and lower parts of main discharge canals and subsurface drain outlets. Samples taken from drains were called Subsurface Drainage 1 and 2. Water samples were taken monthly during irrigation period. Water samples taken from water table observation wells, irrigation, surface and subsurface drainage canals were immediately sent to the laboratory in order to analyze their conductivity. Analysis of electrical conductivity (EC) was performed according to Greeberg et al. [11].

Soil Sampling and Analysis

Soil samples were taken from two pilot areas where surface and subsurface drainage systems were constructed in order to compare the functionality of drainage networks. While selecting this area, the areas, which have been in constant use since the construction of the system, were considered to be suitable. Each of the pilot areas is 10 ha. In order to avoid the adverse effects of the features of irrigation water on soil quality, soil sampling was started from the end of irrigation period. When determining the points where soil samples were taken, decision sampling method determined in the study of Şimşek [14] was adopted. In this method, representative sampling units were selected and sampled by considering the known features of population in the decision sampling. Decision sampling method is recommended in the studies carried out to determine some physical and chemical characteristics of prevalent soil types. The distance between each sampling point is between 75 and 100 m. The sampling points in the subsurface drained area were larger in number to smoothen out the possible large point-to-point variation in the measured parameters due to inherent heterogeneity of the field. In the pilot area, where surface and subsurface drainage networks were constructed, soil samples were taken from 10 and 16 points, respectively, at the depths of 0–30, 30–60, and 60–90 cm. EC value of soil was measured according to the method of Rhoades [13]. After the transfer of the EC results of 78 soil samples obtained from three different depths and different points to digital data form, *t* test was performed to compare data from two pilot areas by using SPSSWIN program.

Results and Discussion

Evaluation of Water Samples Taken from Irrigation and Drainage Networks

EC values were measured as a measure for the amount of water-solved salt in order to determine the effects of irrigation water quality on soil and plants. Analysis of EC was performed according to Greeberg et al. [11]. Results of the conductivity analysis of water from irrigation, surface and subsurface drainage canals are presented in Table 1. According to the classification of US Salinity Laboratory, if the EC is lower than 250 µS cm^{-1}, between 250 and 750, 750 and 2250, and higher than 2250 µS cm^{-1}, salinity is little, moderate, high, and very high, respectively. As can be seen from Table 1, water samples from irrigation canals, surface and subsurface drainage canals are mainly moderately saline. However, two of the samples from surface drainage canals and one of those from subsurface drains were found to be highly saline. Even though there are water samples from surface and subsurface canals with high salinity rates, no water samples from irrigation canals were found to be highly saline. Water samples from irrigation canals were found to be moderately saline. Moderately saline water with electrical conductivity between 250 and 750 µS cm^{-1} can safely be used for the plants out of those very susceptible to salinity in soil with good salt permeability. It is suitable for the plants resistant to salinity to control salinity rate. Among the field crops grown in study area, barley and sugar beet are resistant to salinity, wheat is moderately resistant, bean is very sensitive. Tomato is the most resistant while onion is the least. Among the fruits in the area, apple and apricot are the least resistant plants to salinity.

Evaluation of Soil Samples

Soil samples taken from pilot areas (10 from surface and 16 from subsurface) are shown as A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, K1, K2, K3, K4, K5, K6, 1 K7, K8, K9, K10, K11, K12, K13, K14, K15, and K16. In order to compare the soil samples from the areas for salinity, *t* test was used and results are given in Table 2. Statistical parameters for EC and depths and groups are given in Tables 3 and 4. According to the results obtained from soil samples, seasonal salinity problems in water table may cause from soil. According to the results of *t* test, in which EC values of the soil samples taken from the areas where surface and subsurface drainage systems were constructed

Table 1 Salinity content of water samples from irrigation drainage canals (µS cm^{-1})

Sample name	Sample date					
	May 15	June 15	July 15	August 15	September 15	October 15
Irrigation I	380	495	500	500	510	450
Irrigation II	410	500	526	540	510	394
Surface drainage I	480	755	575	585	905	507
Surface drainage II	550	650	650	690	690	505
Subsurface drainage I	550	600	650	684	680	500
Subsurface drainage II	540	700	700	785	700	480

Table 2 *t* test results of soil salinity values

	EC (µS cm^{-1})	
	T	*P*
A(0–30)–A(30–60)	1.499	0.168
A(0–30)–A(60–90)	2.581	0.030
A(30–60)–A(60–90)	3.656	0.005
K(0–30)–K(30–60)	4.011	0.001
K(0–30)–K(60–90)	7.320	0.000
K(30–60)–K(60–90)	2.170	0.046
A(0–30)–K(0–30)	0.976	0.339
A(30–60)–K(30–60)	0.481	0.634
A(60–90)–K(60–90)	−1.257	0.221
A–K	0.594	0.554

Table 3 Statistical parameters soil samples related to EC values (μS cm^{-1}) (between depths)

	A			K		
Depth (cm)	0–30	30–60	60–90	0–30	30–60	60–90
Minimum	182	168	154	224	175	71
Maximum	924	448	210	462	448	364
Mean	410	270	180	339	256	209
Standard deviation	279	75	16	73	68	71
Variation coefficient	68,048	27,777	8,889	21,534	26,563	33,971

Table 4 Statistical parameters soil samples related to EC (μS cm^{-1}) (between groups)

	A	K
Minimum	154	71
Maximum	924	462
Mean	287	268
Standard deviation	188	88
Variation coefficient	65,505	32,836

and compared, differences between two groups were found to be insignificant. However, when EC values were compared in each group considering the sampling depths, differences were found to be significant between 0–30 and 60–90 cm at 0.05 significance level and 0.01 between 30–60 and 60–90 cm. In the subsurface drainage system, differences between soil samples taken from the depths between 0–30 and 30–60 cm and 0–30 and 60–90 cm were found to be significant at 0.01 significance level; and at 0.05 between 30–60 and 60–90 cm. EC values decreased in the soil profile from top to down. In some areas where subsurface drains are not present, higher salinity rates were determined in the lower profile. In the areas where fertilization was performed, salinity values were again higher.

Conclusions

The most important of the environmental impact of irrigation is the effect of waste-water drainage in the receiving environment. The failure of proper drainage conditions, leads to salinity and sodicity in soil and therefore create environmental problems. Therefore, it is very important to ensure proper drainage conditions. To ensure proper drainage conditions, an effective drainage system should be constructed.

In the research area, a deficient drainage system was constructed gradually after the constitution of irrigation network. When constructing irrigation networks, drainage networks should also be constructed.

In the areas where subsurface drainage system is not constructed, no efficient surface drainage system can be obtained in the soil profile even if surface drainage system is constructed. With the opening of holes deeper than water table level in the surface drainage canal network, water table level can be reduced since subsurface water flow turns into surface runoff [9]. In the area where subsurface drainage network was constructed, it was seen that salt was removed from soil along the profile due to the presence of high salinity values among the water samples from drains.

Surface and subsurface drainage systems, which are constructed by different establishments and are complementary to each other should be constructed in close collaboration of related institutions. Problem solving capacity of present drainage systems should be determined and if the systems are not so efficient, causes should be sought and systems should be improved.

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