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Comparison of Irrigation Water Quality Between Inland and Coastland Areas for Rice Cultivation

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The main objectives of this study are first to determine and to compare quality of irrigation water sources in between inland and coastland rice fields, second to give some suggestions in order to reduce adversely effect of poor irrigation water quality on the environment and on rice yield. This study was carried out in Cankiri-Kizilirmak district (inland) and Samsun-Bafra delta plain (coastland). Both of them are located on Kizilirmak Basin. For this purpose, total of 19 water samples including 8 surfaces and 11 ground waters were collected from the study areas. Global positioning system (GPS) was used to determine to coordinates of sampling points. To evaluate irrigation water quality, EC, pH, cations (Na^+, K^+, Ca^{2+}, Mg^{2+}), boron, anions ($Cl^–$, $HCO_3^–$, CO_3^{2-}, SO_4^{2-}), TDS and SAR were determined by spectrometric, colorimetric and volumetric methods. According to laboratory analysis results, all of the water samples had moderate alkaline reaction, class IV salinity except for SB-1, SB-2 and GB-5 (C_3S_1) in Bafra region and class II alkalinity (C_4S_2) except for GB-6, SK-1, GK-4. On the other hand, TDS, boron, total anions or cations concentration were found significantly different each other. These results show that the water in both of the areas is probably going to be affected by local conditions. Due to poor irrigation water quality, irrigation efficiency of the research areas should be increased, improve drainage system and use better genotypes/varieties with tolerance to salinity to reduce high salinity problems and increase further rice productivity.

Key Words: Water quality, Kizilirmak Basin, Rice irrigation.

INTRODUCTION

Agricultural water use plays the most critical role in water resources management all around the world. Currently, 17 % of the total agricultural land is irrigated and 40 % of food and fiber demand are supplied from this irrigated land with the use of 70 % of available water resources[1]. In addition, irrigated agriculture is dependent on an adequate water supply of usable quality. Water quality concerns have often been neglected because of good quality water supplies have been plentiful and readily available. This situation is now changing in many areas. Intensive use of nearly all good quality supplies means that new irrigation projects and old projects seeking new or supplemental supplies must rely on lower quality and less desirable sources. To avoid problems when using these poor quality water supplies, there must be sound planning to ensure that the quality of water available is put to the best use[2]. On the other hand, some scientists[3] reported that irrigation induced salinity was reckoned as a pervasive threat to agricultural production and to the environment due to its adverse effects on the sustainable use of land and water resources. It is reported that the cleaning of native vegetation for agriculture and over-irrigation raised ground water levels and mobilized salts, which is finding its way into streams and causing increased salinity[4].

In the near eastern region extending from the Atlantic Ocean (Mauritania and Morocco) in the west to Pakistan and Kyrgyzstan in the East and from Turkey and Kyrgyzstan in the North to Somalia in the South, 91 % of the total water use is directed towards agriculture[5]. In Turkey, 36 % of available water resources are under control and nearly 74 % of this water is used by 25 % of irrigable agriculture land[6]. Within agriculture, rice is the dominant irrigated crop. At the same time, it is also among the largest water consuming crops. The irrigation of rice is still traditional and results in the loss of large amounts of water, with all the consequences and negative impacts on the environment and production potential. With water becoming increasingly scarce, the future of rice production will therefore depend heavily on developing and adopting strategies and practices that will use water efficiency in irrigation schemes[5]. In Turkey, irrigation water for rice is from rivers, groundwater and dams, but pumping is only for 5 % of the total. Most of the soils in the major rice production areas are clay and sandy-clay. During the rice growing season, flooding on a rotational basis is the main watering method. Part of the water that enters the paddy fields is lost to drainage canals from paddy fields, which explains high values of water use by rice. In the Black sea region, rice growers use the Kizilirmak river water for irrigating rice, by pumping water directly into their fields. There are also small dams and rivers and underground water sources used for irrigation[7].

This study was carried out in two different areas of Turkey. Due to the fact that supplementary irrigation plays an important role at times of agricultural activities, the main objectives of this study were first to determine and to compare quality of irrigation water sources in between inland and coastland rice fields, second to give some suggestion in order to reduce adversely effect of poor irrigation water quality on the environment and on rice yield.

EXPERIMENTAL

Description of the study areas: This study was carried out in Cankiri-Kizilirmak district (inland) and Samsun-Bafra delta plain (coastland). Both of them are located on Kizilirmak Basin. The Kizilirmak river is the longest river of Turkey. Kizilirmak river rises to the east of Kocaviran district center and has a length of 1355 km. The mean discharge of the Kizilirmak river was 40.0 $m^3 s^{-1}$ and minimum and maximum monthly discharges were 6.0 and 149.0 $m^3 s^{-1}$, respectively. Kizilirmak river falls into the Black sea. Water quality class of Kizilirmak river[8,9] is C_3S_1.

Cankiri-Kizilirmak district rice field area is located in Central Anatolia of Turkey (4473000-4468000 m N- 585000-587000 m E UTM) and covers an area of 1065.3 ha. Its lies at an elevation from sea level 730 m. The terrestrial climate prevails in the study area. According to meteorological data, the mean annual temperature, rainfall and evaporation are 11.8 ºC, 349.7 and 693.5 mm, respectively. In addition, the study site has mesic soil temperature regime and aridic moisture regime[10]. Inland rice field area is formed on quaternary alluvial deposits carried by Kizilirmak river. This area consists of two different physiographical units. These are flood plain soils and yang-old river terrace soils. These areas are mainly flat and slightly sloped. The majority of soils were Aridisol and Entisol[10]. While top soil texture is commonly clay, subsoil texture varies from silty clay loam, loam and silty loam to sandy loam. Soil organic matter content ranges from 0.91 to 1.99 %. EC and pH values of soils are changing 7.41-9.30 and 4.83-79.46 dS m^{-1}. While the main crop is rice, melon-watermelon, sugar beet and wheat, barley and forages have been also grown.

The second study area is The Bafra Plain found in the Kizilirmak Delta and located in the central Black Sea region of Turkey. The study area (around the Doganca Village) is far 10 km from north of the Samsun-Bafra district (4615-4615 km N- 243-250 km UTM), It covers 4823.7 ha and its lies at an elevation from sea level 1-3 m. The current climate in the region is semi-humid. The summers are warmer than winters (the average temperature in July is 22.2 ºC and in January is 6.9 ºC). The mean annual temperature, rainfall and evaporation are 13.6 ºC, 764.3 and 726.7 mm, respectively. According to soil taxonomy[10], the study site has mesic soil temperature regime and ustic moisture regime. These areas are mainly flat and slightly sloped (0.0-2.0 %). The majority of soils were Vertisol, Inceptisol and Entisol[10]. Top soil texture is heavy (31-60 % clay), while sub soil texture is different due to alluvial deposit in the study area. Soil organic matter content ranges from 1.70 % to 5.92. EC and pH values of soils are changing 7.28-8.01 and 0.61-2.79 dS m^{-1}. The study area has been under intensive agricultural activities. Rice, maize, pepper, water-melon, cucumber and tomato with sprinkler and furrow irrigations in the summer and cabbage and leek in the winter have been produced in the study area.

Water sampling: This paper presents the results from surface and ground water quality survey performed in 2007 within the irrigated agricultural in inland and coastland rice field areas. Total (survey and ground water) 19 water samples were collected using global positioning system (GPS) to coordinate points of sampling. Water samples were taken from drainage canal, wells and irrigation system. Water quality parameters include EC (electrical conductivity), pH, cations (Na^+, K^+, Ca^{2+}, Mg^{2+}), boron, anions (Cl^-, HCO_3^-, CO_3^{2-}, SO_4^{2-}). Measurements of the chemical parameters were performed in the laboratory Electrical conductivity and pH values were measured with WTW-LBR40 EC meter and HANNA pH microprocessor pH meter. Boron, anions, cations, sodium absorption rate (SAR), pH and EC were analyzed by taking into consideration of associated literature[11]. The quality classes (C_xS_x) were determined according to the diagram of salinity laboratory of USA. All water quality parameters were evaluated considering the irrigation water quality criteria[12-14].

RESULTS AND DISCUSSION

Samsun Bafra Plain Delta and Cankiri-Kizilirmak district are located on Kizilirmak Basin. These areas are rice producing zones which are mostly irrigated from Kizilirmak river water and ground water. The results of surface and groundwater quality parameters were given in Tables 1 and 2. The electrical conductivity is a valuable indicator of the amount of material dissolved in water[15]. In addition, soil salinity (indirectly measured through EC) exerts osmotic effects on plants[16,17] and often causes physiological drought if the salinity levels are greater than the critical limits of the crop[18]. Many researchers[19,20] indicated that EC values increase 4.0, 5.0 and 7.2 dS m^{-1} whereas the rice production decreases 25, 50 and 75 %, respectively. In another study[21], similar result was also determined in the west side of the Sacramento Valley to assess salinity problems on rice.

In Bafra region, EC values ranged from 1.741 to 2.865 dS m^{-1} in surface water while, they changed from 2.094 to 4.684 dS m^{-1} in ground water (Table-1). EC value of GB-6 well water used for irrigation area about 5.0 dS m^{-1} because of seawater intrusion to groundwater. The recommended value[12,14,22] of EC for irrigation water is 2.5-3.0 dS m^{-1}. In this case, surface water sources are suitable and doubtful suitable for irrigation in the study area. This situation used Wilcox diagram was also shown in Fig. 1.

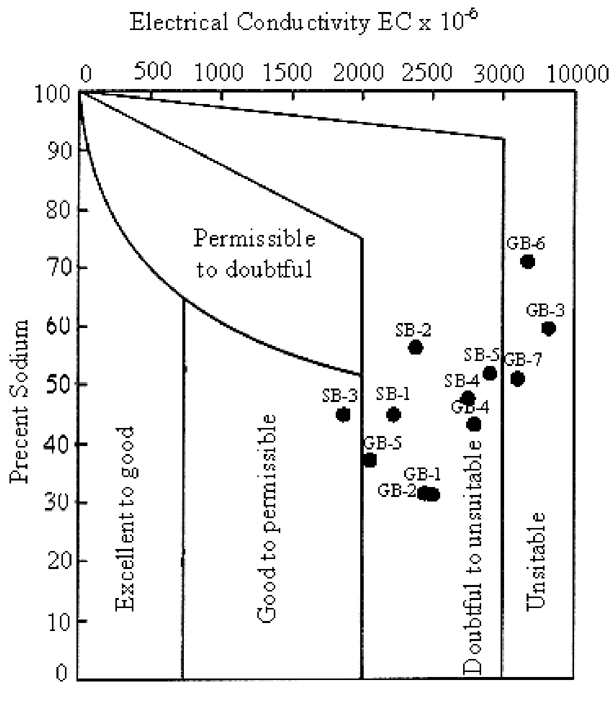

Fig. 1. Wilcox diagram for surface and ground water classification of the Samsun-Bafra Doganca district

TABLE-1

WATER QUALITY PROPERTIES OF SURFACE AND GROUND WATER SAMPLES IN SAMSUN-BAFRA DOGANCA DISTRICT

Sample No.	Coordinate (North-East, UTM)	Cations (me L^{-1})				Anions (me L^{-1})				Total anions or cations (me L^{-1})	pH	EC (dS m^{-1})	B (mg L^{-1})	TDS (mg L^{-1})	SAR	Class
		Na^+	K^+	Ca^{2+}	Mg^{2+}	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}							
Surface water samples																
SB-1	4617228, 743771	9.81	0.21	4.53	6.05	-	2.95	9.33	8.32	20.6	7.74	2.094	0.77	1340	4.27	C_3S_1
SB-2	4617334, 748924	17.28	0.28	1.90	10.48	0.60	5.68	13.91	9.75	29.94	8.72	2.590	1.54	1658	6.95	C_4S_1
SB-3	4617911, 744591	9.81	0.14	4.53	6.05	-	2.95	9.33	8.25	20.53	8.01	1.741	0.93	1114	4.27	C_3S_1
SB-4	4618841, 745875	14.68	0.40	6.31	14.55	1.66	9.08	13.58	11.62	35.94	7.94	2.755	1.37	1763	4.55	C_4S_1
SB-5	4618406, 750835	16.89	0.13	4.76	10.23	-	2.61	18.50	10.90	32.01	8.45	2.865	1.44	1834	6.17	C_4S_1
Ground water samples																
GB-1	4615703, 747513	11.33	0.05	3.81	18.53	0.80	6.60	13.00	13.32	33.72	8.03	2.590	0.95	1658	3.39	C_4S_1
GB-2	4617775, 747403	11.97	0.14	1.08	19.86	0.93	5.76	12.00	14.36	33.05	7.94	2.755	1.08	1763	3.70	C_4S_1
GB-3	4614214, 750730	20.50	0.09	0.73	15.06	2.10	9.86	14.58	9.84	36.38	7.95	3.251	1.74	2081	7.30	C_4S_1
GB-4	4620152, 748069	13.29	0.54	1.26	13.33	1.50	7.98	12.08	6.86	28.42	8.60	2.480	1.54	1587	4.92	C_4S_1
GB-5	4620684, 746191	9.81	0.24	3.20	10.18	0.36	4.71	9.16	9.20	23.43	7.63	2.094	0.92	1340	3.79	C_3S_1
GB-6	4622124, 748479	28.91	0.40	2.68	9.63	0.86	6.83	32.33	1.60	41.62	7.83	4.684	1.94	2998	11.65	C_4S_2
GB-7	4623521, 746704	16.51	0.16	5.00	12.10	0.05	3.73	17.25	12.74	33.77	7.66	3.196	1.54	2045	5.65	C_4S_1

TABLE-2

WATER QUALITY PROPERTIES OF SURFACE AND GROUND WATER SAMPLES IN CANKIRI-KIZILIRMAK DISTRICT

Sample No.	Coordinate (North-East, UTM)	Cations (me L^{-1})				Anions (me L^{-1})				Total anions or cations (me L^{-1})	pH	EC (dS m^{-1})	B (mg L^{-1})	TDS (mg L^{-1})	SAR	Class
		Na^+	K^+	Ca^{2+}	Mg^{2+}	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}							
Surface water samples																
SK-1	4467477, 584198	13.98	0.29	8.30	9.90	-	3.36	13.66	15.45	32.47	7.98	2.580	1.85	1651	4.63	C_4S_1
SK-2	4468580, 585580	67.65	0.45	12.95	55.25	-	6.05	69.58	60.67	136.30	8.11	12.603	6.48	10082	11.58	C_4S_2
SK-3	4470056, 586308	13.29	0.18	8.35	9.35	-	3.38	12.91	14.88	31.17	7.92	2.544	1.80	2035	4.47	C_4S_1
Ground water samples																
GK-1	4468935, 585856	73.22	0.31	24.15	16.80	-	11.05	64.25	39.18	114.48	8.65	14.863	10.03	11890	16.18	C_4S_2
GK-2	4469751, 585931	80.82	0.26	29.75	52.20	-	7.61	123.66	31.76	163.03	7.95	17.835	6.01	14268	12.63	C_4S_2
GK-3	4470532, 585593	56.92	0.33	22.70	27.00	-	4.93	64.41	37.61	106.95	8.04	10.701	3.31	8561	11.42	C_4S_2
GK-4	4472747, 587185	18.45	0.18	36.75	22.75	-	5.23	18.50	54.40	78.13	7.85	4.994	2.85	3196	3.38	C_4S_1

In Cankiri-Kizilirmak rice region, all of the EC values were higher than 3.0 dS m^{-1} except for SK-1 and SK-3 which are low suitable or doubtful to unsuitable for irrigation water quality according to Ayers and Westcot[12] and Wilcox diagram (Fig. 1). Due to the high water evaporation in this area, the water table is mobilized and rised up along with salt in soil to the root zone of rice crop and causing salt accumulation on surface soil. This build-up of salt makes it increasingly difficult for rice and most plants to extract water for their growth, as the accumulation of Na^+ and Cl^- at extreme levels is also toxic for the plants[23]. This case was also determined in this study. Na^+ and Cl^- ions were accumulated in plant root zone and surface (Table-2). This is the reason that the high electrical conductivity values in some water samples showed that they were unsuitable for irrigation and contribute to salinity problems on rice productivity.

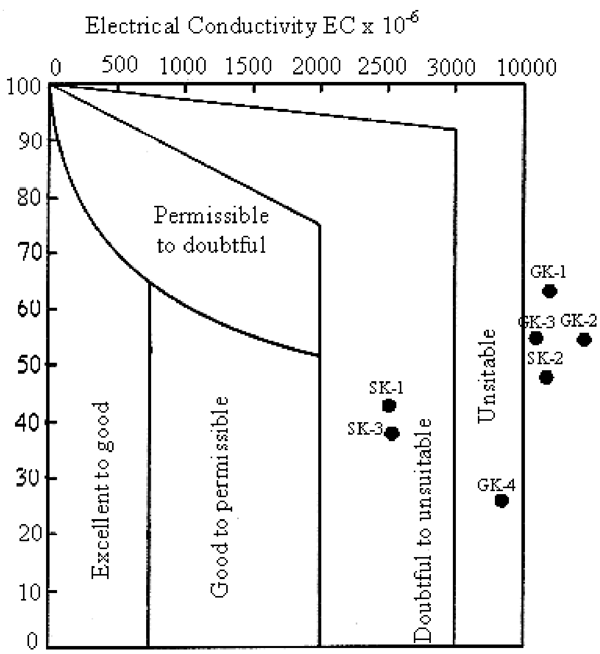

Fig. 2. Wilcox diagram for surface and ground water classification of the Cankiri-Kizilirmak

The pH values of surface and ground water were found between 7.74-8.72 and 7.63-8.60 in Bafra region, while surface and ground water had 7.92-8.11 and 7.85-8.65 pH values. This high pH values result from geological formation (generally calcareous and oligomiocene gypsum formation in Cankiri) and seawater intrusion (in Bafra region). In terms of pH values for rice cultivation, water quality of both study areas doubtful or low suitable for irrigation applications.

Anions (Cl^-, HCO^-, CO^{2-}, SO_4^{2-}), cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) and boron of the water samples taken from surface and ground water were determined. Total anion or cation and boron were particularly increased in ground water samples in both study areas. On the other hand, total anions or cations and boron was found quite higher value in Cankiri region than that of Bafra region. This can be stem from chemical composition of the parent material. In addition, boron values are high from threshold level for ground water samples in Cankiri region so, they are not suitable quality for irrigation. This case is also valid for surface water sample coded SK-2, whereas boron levels were lower than 2.0 mg L^{-1} in Bafra region.

Total dissolved solids (TDS) indicate the general nature of water quality or salinity. Water samples containing less than 2000 mg L^{-1} of TDS is consider the permission class according to irrigation water resource quality criteria[12]. TDS values were between 1114-1834 mg L^{-1} in surface water samples in Bafra region therefore can be us for irrigation activities. On the other hand, TDS values were found significantly high both surface and ground water except for SK-1 in Cankiri-Kizilirmak region.

It is desired that Ca^{2+} and Mg^{2+} concentration are higher Na^+. The SAR (sodium adsorption ratio) is the best important indicator of the relation in between these cations[24]. In addition, the SAR is used to predict the danger of sodium accumulation in the soil. An excess Na present in natural soils is the danger of loss of soil structure with the resulting reduction in soil permeability and aeration. In the research waters, SAR values ranged between 3.38-12.63 except for GK-1 (16.18) which is higher than threshold level of irrigation water quality criteria[12]. However, moderate suitable class in reference 14 and 22. Most of the water samples were classified as C_3S_1 quality.

Conclusion

Rice producer use the Kizilirmak river water for irrigating rice by directly from field channel or pumping into their fields in both inland and coastland. It was determined that all of the water samples had moderate alkaline reaction, class IV salinity except for SB-1, SB-2 and GB-5 (C_3S_1) in Bafra region and class II alkalinity (C_4S_2) except for GB-6, SK-1, GK-4. On the other hand, TDS, boron, total anions or cations concentration were found significantly different each other. These results show that the water in the both areas is probably going to be affected by sea water impact, climatic condition and geological formation in the study areas. Due to poor irrigation water quality, irrigation efficiency of the research areas should be increased, improve drainage system and use better genotypes/varieties with tolerance to salinity to reduce high salinity problems and increase further rice productivity. In addition, reference 18 reported that soil/water system- applied gypsum, to counter sodic hazards of irrigation water, is suitable and economical to sustain irrigated rice in their study. As a conclusion, in this studies, in order to maintain a sustainable rice cultivation of the both regions, some alternative applications were suggested for the use of limited water resources and improvement of the agriculture by taking into account the important natural values.

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