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Impact of Different Periods of Irrigation on Soil Properties and Crop Yield in Vertisols of Ghataprabha Command Area

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A study was undertaken to assess the effect of different periods of irrigation(10-15, 15-20, 20-30 and >30 years) on soil properties and yield of sugarcane and maize under Vertisols of Ghataprabha command area. In each irrigated years, five soil profile and adjacent one unirrigated soil sample was collected from parts of Belagavi and Bagalkot districts. The results of the study revealed that pH and electrical conductivity increased in profile samples from 7.79- 8.62 and 0.3-1.11, respectively in long-term irrigated field and higher values were recorded in soils irrigated for more than 30 years as compared to unirrigated soils. The contents of exchangeable cations were increased with soil depth in irrigated fields. The exchangeable sodium percentage values increased from 8.74-14.2 in different periods of irrigation and with depth in profile samples. The sodium adsorption ratio was increased from 2.24-5.05 in irrigated profile soils as compared to unirrigated soil sample. Bulk density values increased whereas hydraulic conductivity, maximum water holding capacity and per cent water stable aggregate values decreased in irrigated soils as compared to unirrigated soils. The maize and sugarcane yield was decreased in long-term irrigated soils.

(Key words: *Irrigation, Salinity and Soil properties)*

Total salt affected area in India is 6.9 mha (Anon., 2012). The objective of irrigation is to supply plants with water, as needed, to increase yields. An irrigation project should take water use efficiency into account as well as the economy involved for irrigation. The history of irrigated agriculture has shown that irrigation can cause severe deterioration of soil productivity. About one-third of the world's irrigated lands have reduced their productivity levels as a consequence of poorly managed irrigation that has caused water logging and salinization. Therefore, actual productivity of irrigated area is far below its potential (Kadrekar, 1993). In Karnataka, Ghatprabha reservoir has a capacity of 49 TMC of water with an ultimate irrigation potential of about 7.84 lakh ha in Belagavi and Bijapur district of North Karnataka. In irrigated Ghataprabha command area, there is a need to study the effect of irrigation on soil physico-chemical properties because of decline in crop productivity.

MATERIAL AND METHODS

A field survey work was conducted in the Ghataprabha command area of Belagavi and Bagalkot districts from which representative five profile soil samples were collected from 10-15, 15-20, 20-30 and >30 years of irrigated and adjacent non-irrigated areas from parts of Gokak, Raibag, Mudhol and Athanitalukas of Belagavi and Bagalkot districts. The soil was alkaline in nature and analysed for physico-chemical properties of soil. Soil samples were first air dried in shade then powdered gently with a wooden pestle and mortar and sieved through 2 mm sieve then stored in clean polyethylene bags for analysis. The Ghataprabha river water pH is 7.70 and electrical conductivity (EC) is 0.25 dS m^{-1}. The sugarcane and maize yield data were collected from farmers from different period of irrigated area and statistically analysed.

The soil pH was measured in 1:2.5 soil water suspension using pH meter and EC (dSm^{-1}) was measured in the supernatant solution of 1:2.5 soil water suspension using conductivity bridge (Sparks,1996). Cation exchange capacity (CEC) of the soil sample was determined by sodium saturation method (Black,1965b). Bulk density of soil was determined by clod method as described by Black (1965a), percent aggregate stability (PAS) was determined by wet sieving method as described by Yoder (1936). The maximum water holding capacity (MWHC) was determined by using Keen's cup as described by Piper (2002). Hydraulic conductivity (HC) was measured by using plexi glass permeameter as described by Black (1965a).

RESULTS AND DISCUSSION

Soil Chemical Properties

The land irrigated for more than 30 years of irrigation, registered highest pH of (8.62) and it remained on par with 20 - 30 years of irrigation (8.57). The lowest

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pH (7.89) was recorded in unirrigated field. The interaction effect of different period of irrigation and soil depths was found to be significant with respect to soil pH. The highest pH (8.72) was observed in 60-80 cm soil depth in land irrigated for more than 30 years of irrigation. The lowest soil pH (7.79) was observed in unirrigated land at 0-20 cm depth as indicated in Table 1. This is attributed to the movement of calcium to lower horizons and precipitated as calcium carbonate which increased the pH of the soil. The mean electrical conductivity was found higher (1.11 dS m^{-1}) in the land irrigated for more than 30 years (Table 1). The lowest soil electrical conductivity (0.30 dS m^{-1}) was registered in unirrigated land. Among the different depths, the 0-20 cm soil depth recorded the highest EC (1.14 dSm^{-1}) and lowest EC (0.38 dSm^{-1}) was recorded in more than 80 cm soil depth. The interaction effect of long-term irrigation and soil depths was found to be significant with respect to EC. The EC was highest (1.80 dS m^{-1}) in the land that received irrigation for more than 30 years at 0-20 cm depth the lowest EC (0.22 dSm^{-1}) registered in unirrigated field at more than 80 cm depth. This might be due to irrigation water gradually adds some electrolytes to the soil. EC decreased with the depth due to high ground water table and aridity. Similar observations were reported by Jacob *et al.* (1995) that EC of saturated soil extract (ECe) was found to be significantly higher in irrigated areas.

The highest CEC [58.25 cmol (p+) kg^{-1}g] was recorded in the land irrigated for more than 30 years. The lowest CEC [52.30 cmol (p+) kg^{-1}] was noticed in unirrigated land. In general, as the soil depth increased the CEC also increased in all the irrigated lands. The interaction effect was significant between periods of irrigation and soil depths with respect to CEC. The highest CEC [62.53 cmol (p+) kg^{-1}] was recorded in more than 30 years of irrigation at more than 80 cm soil depth. The lowest CEC [49.54 cmol (p+) kg^{-1}] was observed in unirrigated land at 20-40 cm depth (Table 2). Adejumobi *et al.* (2014) revealed that irrigation practices on the soils of Omi irrigation scheme Kogi state Nigeria after 13 years of operation, the soil CEC levels have also increased from 10 cmol (p+) kg^{-1} to 35 cmol (p+) kg^{-1} after irrigation.

Long-term irrigation favoured build-up of ESP in soil. The land that was irrigated for more than 30 years recorded significantly higher ESP (14.24%) as compared to other lands. This was on par with the 20-30 years of irrigation (13.27%). The ESP was significantly higher than the unirrigated land. The lowest ESP (8.74%) was noticed in unirrigated land. The ESP increased with depth in all the lands. Among the depths, >80 cm depth was recorded highest ESP (15.10%) and lowest ESP (10.13%) was observed in 0-20 cm depth. The interaction effect of long-term irrigation and soil depths was found to be significant with respect to ESP. The highest ESP (17.28%) was recorded in land that was irrigated with 30 years at >80 cm depth and lowest ESP (6.74%) was noticed in non-irrigated land at 20-40 cm depth. The increased ESP in irrigated fields was attributed to accumulation of sodium in soils due to irrigation. (add references)

The land irrigated for more than 30 years recorded higher SAR (5.05). The lowest SAR (2.24) was noticed in unirrigated land (Table 2). The SAR increased with depth in all the lands. Among the soil depths, > 80 cm soil depth recorded highest SAR (4.80) and significantly lower SAR (2.26) was observed in 0-20 cm soil depth. Similarly, Vaidya *et al.* (2007) revealed that five year continuous irrigation has increased SAR 4-5 fold and it increased with depth but it was opposite in un-irrigated field.

Soil Physical Properties

The highest bulk density (1.29 Mg m^{-3}) was recorded in the land irrigated for more than 30 years. In general, the bulk density was increased with depth in all lands. The lowest bulk density (1.22 Mg m^{-3}) was observed in unirrigated land. The highest bulk density (1.35 Mg m^{-3}) was recorded in the soil with > 80 cm soil depth with > 30 years of irrigation (Table 3). The highest bulk density was recorded due to the mechanized cultivation and continuous irrigation but decreased total non-capillary porosity. Singh *et al.* (2013) reported that the irrigation increased bulk density in soils of Rajasthan.

MWHC in soil was significantly influenced by different period irrigation. Highest content of MWHC (67.27%) was recorded in the unirrigated land as compared to all the irrigated land. The lowest content of MWHC (61.48%) was noticed in land with irrigation of > 30 years. Similar observations were recorded by Kadu and Kanaskar (2009) and reported that the irrigation decreased water holding capacity and moisture content at field capacity.

Long-term irrigation has significantly influenced hydraulic conductivity in the soil. The lowest hydraulic conductivity (0.36 cm hr^{-1}) was recorded in > 30 years

Table 1. *The influence of different periods of irrigation on pH and EC (dS m^{-1}) of profile soil samples*

Soil depth (cm)	$pH_{(1:2.5)}$						$EC_{1:2.5}$ (dS m^{-1})					
	Unirrigated	Periods of irrigation (years)				Mean	Unirrigated	Periods of irrigation (years)				Mean
		10-15	15-20	20-30	>30			10-15	15-20	20-30	>30	
0-20	7.79	8.06	7.96	8.54	8.49	8.17	0.44	0.57	0.81	1.43	1.80	1.14
20-40	7.93	8.12	8.08	8.46	8.56	8.23	0.27	0.50	0.65	0.68	1.56	0.86
40-60	7.80	8.20	8.45	8.60	8.69	8.35	0.30	0.37	0.48	0.87	1.14	0.76
60-80	7.86	8.23	8.60	8.58	8.72	8.40	0.28	0.31	0.40	0.59	0.88	0.62
>80	8.07	8.51	8.67	8.66	8.63	8.51	0.22	0.27	0.26	0.36	0.16	0.38
Mean	7.89	8.22	8.35	8.57	8.62		0.30	0.41	0.52	0.79	1.11	

	pH SEm±	pH CD (P=0.05)	EC SEm±	EC CD (P=0.05)
P	0.08	0.22	0.10	0.29
D	0.08	0.22	0.10	0.29
P x D	0.17	0.49	0.23	0.66

P = Periods of irrigation (years) D = Depth (cm)

Table 2. *Effect of different periods of irrigation on cation exchange capacity, exchangeable sodium percentage and sodium adsorption ratio of profile soil samples*

Soil depth (cm)	CEC [cmol(p+) kg^{-1}]						ESP (%)						SAR					
	Unirrigated	Periods of irrigation (years)				Mean	Unirrigated	Periods of irrigation (years)				Mean	Unirrigated	Periods of irrigation (years)				Mean
		10-15	15-20	20-30	>30			10-15	15-20	20-30	>30			10-15	15-20	20-30	>30	
0-20	51.73	52.53	54.52	55.54	57.66	54.77	8.15	9.75	8.69	12.38	11.69	10.13	1.64	1.55	2.86	2.18	3.04	2.26
20-40	49.54	55.27	55.17	56.38	55.71	53.88	6.74	11.65	10.64	13.06	12.37	10.89	1.99	1.64	2.33	2.61	3.71	2.46
40-60	50.54	55.38	56.12	56.94	56.76	54.96	8.87	9.37	12.94	10.08	13.94	11.04	2.91	2.08	2.99	3.29	4.42	3.14
60-80	53.96	54.76	56.38	58.39	58.61	56.37	9.80	12.18	13.35	14.05	15.95	13.07	2.02	3.33	2.74	4.43	5.58	3.62
>80	55.72	55.92	54.47	60.57	62.53	58.04	10.12	14.36	16.97	16.78	17.28	15.10	2.63	3.83	3.52	5.54	8.50	4.80
Mean	52.30	54.77	55.33	57.56	58.25		8.74	11.46	12.52	13.27	14.24		2.24	2.48	2.89	3.61	5.05	
	SEm±		CD (P=0.05)				SEm±		CD (P=0.05)				SEm±		CD (P=0.05)			
P	0.82		2.30				0.75		2.09				0.37		1.03			
D	0.82		2.30				0.75		2.09				0.37		1.03			
P x D	1.83		5.14				1.67		4.68				0.83		2.31			

P = Periods of irrigation (years) D = Depth (cm) CEC= Cation exchange capacity
ESP= Exchangeable sodium percentage SAR = Sodium adsorption ratio

Table 3. *Effect of different periods of irrigation on soil physical properties of profile soil samples*

Soil depth (cm)	Bulk density (Mg m^{-3})						MWHC (%)						HC (Cm hr^{-1})						PAS (> 0.25 mm)					
	Unirri gated	Periods of irrigation (years)				Mean	Unirri gated	Periods of irrigation (years)				Mean	Unirri gated	Periods of irrigation (years)				Mean	Unirri gated	Periods of irrigation (years)				Mean
		10-15	15-20	20-30	>30			10-15	15-20	20-30	>30			10-15	15-20	20-30	>30			10-15	15-20	20-30	>30	
0-20	1.20	1.19	1.22	1.23	1.24	1.21	69.15	66.98	66.98	63.68	65.76	66.98	0.96	0.81	0.65	0.78	0.51	0.74	51.30	50.21	48.31	47.45	45.60	48.57
20-40	1.22	1.20	1.24	1.21	1.25	1.22	68.39	65.59	65.59	64.56	64.28	66.02	0.87	0.68	0.71	0.64	0.42	0.66	50.20	49.50	47.91	46.78	44.10	47.70
40-60	1.23	1.23	1.25	1.27	1.28	1.25	67.25	64.17	64.17	63.78	61.87	64.63	0.76	0.61	0.63	0.48	0.35	0.57	48.78	48.75	47.15	46.14	43.74	46.91
60-80	1.20	1.26	1.29	1.30	1.32	1.27	66.36	65.28	65.28	63.00	59.23	63.80	0.70	0.72	0.45	0.36	0.28	0.50	47.80	47.21	45.60	45.12	44.68	46.08
>80	1.25	1.27	1.31	1.33	1.35	1.30	65.21	62.18	62.18	60.20	56.24	61.91	0.59	0.52	0.39	0.45	0.24	0.44	47.33	46.12	45.68	44.50	42.59	45.24
Mean	1.22	1.23	1.23	1.27	1.29		67.27	64.84	64.84	63.04	61.48		0.77	0.66	0.57	0.54	0.36		49.08	48.64	46.93	46.00	44.14	
	SEm±		CD (P=0.05)				SEm±		CD (P=0.05)				SEm±		CD (P=0.05)				SEm±		CD (P=0.05)			
P	0.02		0.05				0.57		1.59				0.04		0.10				0.64		1.78			
D	0.02		0.05				0.57		1.59				0.04		0.10				0.64		1.78			
P x D	0.04		0.12				1.27		3.56				0.08		0.23				1.43		3.99			

P = Periods of irrigation (years) D = Depth (cm)BD = Bulk density MWHC= Maximum water holding capacity
HC = Hydraulic conductivity PAS= Percent stable aggregates

of irrigation. The highest hydraulic conductivity (0.77 cm hr^{-1}) was noticed in unirrigated lands. In general, hydraulic conductivity was decreased with increasing soil depth. The > 80 cm soil depth recorded lowest hydraulic conductivity (0.44 cm hr^{-1}). The highest hydraulic conductivity was observed(0.74 cm hr^{-1}) at soil depth of 0-20 cm. Vaidya *et al.* (2007) reported that five year of continuous irrigation had decreased the hydraulic conductivity two fold and it increased with depth under irrigated field.

The lowest percentage aggregate stability (PAS) (44.14%) was recorded in > 30 years of irrigation. The highest content of PAS (49.08%) was noticed in unirrigated land. In general, PAS were decreased with increasing soil depth. Soils at> 80 cm depth recorded lowest PAS (45.24%).

Maize and Sugarcane yield

Maize yield has influenced by long-term irrigation showed differences among the lands. Maize yield was increased in irrigated land as compared to unirrigated land. The lowest maize yield was recorded in unirrigated land which ranged from 38.29 to 52.30 q ha^{-1} with an average value of 43.63 q ha^{-1}. Among the irrigated lands highest maize yield was recorded in the 10-15 years of irrigated land which is ranged between 64.90 to 76.50q ha^{-1} with a mean value of 70.48q ha^{-1} and standard deviation was 4.09. The coefficient of variation was 5.80% (Table 4).

Sugarcane yield as influenced by long-term irrigation showed differences among the lands. The lowest sugarcane yield was recorded in > 30 years of irrigated field and which ranged from 92.50 to 149.70 t

Table 4. *Influence of different periods of irrigation on maize and sugarcane yield*

Sample No.		Maize (qha^{-1})				Sugarcane (tha^{-1})			
		Periods of irrigation (years)				Periods of irrigation (years)			
	Unirrigated	10-15	15-20	20-30	>30	10-15	15-20	20-30	>30
1	41.10	76.40	72.80	61.70	44.50	145.00	137.50	127.50	147.80
2	41.80	68.50	68.50	55.00	50.80	167.50	125.00	145.00	115.00
3	52.30	70.20	71.60	64.30	42.30	159.60	167.50	105.40	105.00
4	41.10	71.40	61.80	65.00	48.90	174.30	148.30	137.50	92.80
5	44.20	69.70	69.70	57.50	52.00	162.50	125.00	157.90	137.50
6	40.50	74.30	72.10	54.90	47.50	127.50	162.30	147.50	136.80
7	45.20	76.20	62.40	57.90	43.90	170.00	122.50	144.80	148.30
8	41.00	70.50	70.50	56.90	42.00	166.30	141.70	122.30	120.00
9	40.20	74.90	64.20	65.20	52.10	150.00	111.80	142.50	92.50
10	46.30	69.30	69.30	58.60	53.70	167.10	130.80	112.90	122.50
11	41.00	65.20	65.20	57.70	49.80	159.80	127.50	157.90	102.40
12	46.10	64.90	64.90	56.10	37.00	147.50	155.00	108.75	107.50
13	43.60	76.48	72.10	55.00	38.60	147.50	149.80	102.50	98.50
14	41.70	65.10	63.90	56.30	42.00	157.50	165.00	105.00	127.50
15	44.60	73.50	72.90	56.20	48.80	145.00	115.00	108.60	119.60
16	43.55	76.10	62.70	55.20	47.10	176.50	125.00	118.13	112.50
17	39.80	69.90	69.90	54.90	38.90	162.50	135.00	118.60	148.90
18	51.40	64.90	64.90	55.70	37.00	160.00	162.50	102.50	137.50
19	49.80	67.40	62.50	54.90	51.60	167.20	144.80	126.25	127.30
20	40.90	72.80	61.80	57.50	42.00	175.00	165.00	142.60	149.70
21	50.20	65.80	66.30	65.80	49.50	168.20	158.60	132.80	110.00
22	38.29	66.90	66.90	54.80	44.50	135.00	141.90	158.60	122.50
23	42.50	75.20	60.10	56.40	47.10	117.50	165.00	135.00	105.00
24	44.20	67.50	67.50	55.20	52.20	160.00	142.50	124.20	107.50
25	39.30	70.50	62.70	57.40	48.80	170.00	150.00	133.90	96.80
Range	38.29-52.30	64.90- 76.50	60.10-72.90	54.80-65.80	37.00-53.70	117.50-176.50	111.80-167.50	102.50-158.60	92.50-149.70
Mean	43.63	70.48	66.69	57.84	46.10	157.56	143.00	128.75	119.66
SD	4.14	4.09	4.16	3.75	5.30	16.48	17.77	18.67	18.95
CV	9.50	5.80	6.24	6.48	11.50	10.46	12.43	14.50	15.84

ha^{-1}. The highest sugarcane yield was registered in the 10-15 years of irrigated land, which ranged from 117.50-176.50 t ha^{-1} with a mean value of 157.56 t ha^{-1}. The long-term irrigation resulted in decrease in sugarcane and maizeyields. This is due to salinity hazard reduced the plant growth and yield through its osmotic effect (causing water deficit), toxic effect of ions and imbalance of uptake of essential nutrients.

CONCLUSIONS

In Ghataprabha command area, long-term irrigation ledto increase in soil pH, EC, CEC, ESP, SAR and increase in bulk density values. However, soil physical parameters likehydraulic conductivity, maximum water holding capacity and per cent water stable aggregate values decreased in irrigated soils as compared to unirrigated soils. Sugarcane and maize yield decreased in long term irrigated soils. Judicious use of irrigation water at farm level must be made to improve the water use efficiency. Reclamation of land using drainage systems to removal of salts in a holistic approach. Effort must be made to encourage microirrigation for high water demanding crops like sugarcane. Sugarcane cultivation should be restricted through pressurised irrigation system only.

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