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Effect of OC, available N, P_2O_5, K_2O on different fractions of Zn under saline soil of Navsari District

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ABSTRACT

This study examined the correlation between soil organic carbon (OC), available Nitrogen (N), Phosphorus (P_2O_5), Potassium (K_2O) and different Zinc (Zn) fractions in salt-affected soils of Navsari district, covering saline areas during the summer of 2023-24. A total of 60 soil samples were collected from 0-20 cm and 20-40 cm depths across multiple villages in the Jalalpore taluka of Navsari district, representing the coastal saline inland Zone. Soil organic carbon (OC), available N, P_2O_5, K_2O, and different Zinc (Zn) fractions were decreased with an increased in salinity. Correlation analysis revealed a significant relationship between OC, nutrient availability and Zn fractions under varying saline conditions and depths. The Zn fractions followed the order: Org-Zn > Fe-Mn-O-Zn > CO_3-Zn > Exch-Zn >WS-Zn in saline areas. At the 0-20 cm depth, OC showed the strong negative correlations with available P_2O_5 and K_2O, while P_2O_5 was positively related to K_2O but negatively to CO_3-Zn. Available K_2O was negatively associated with CO_3-Zn and WS-Zn inversely correlated with CO_3-Zn. At 20-40 cm depth, OC was negatively correlated with Org-Zn, P_2O_5 remained positively related to K_2O, and available K_2O was negatively associated with both Fe-Mn-O-Zn and CO_3-Zn. Exch-Zn showed negative correlations with CO_3-Zn and Org-Zn. Overall, the findings indicate that higher OC tends to reduce certain nutrient and Zn fractions, while carbonate and mineral-bound Zn forms exhibit interlinked accumulation patterns influenced by nutrient availability and soil depth.

Keywords: *Salt affected soils of Jalalpore Taluka of Navsari district, surface and sub-surface soil, soil chemical properties, soil organic carbon (OC), available Macronutrient N, P_2O_5 and K_2O, Different fractions of Zn., Water soluble (WS), Exchangeable (Exch), Carbonate bound (CO_3), Iron and Manganese oxide bound (Fe-Mn-O) and organic-bound (Org).*

INTRODUCTION

In India, 6.73 Mha of area has been characterized as salt-affected by ICAR-Central Soil Salinity Research Institute (CSSRI), out of which 3.77 Mha is alkali and the remaining 2.96 Mha is saline, threatening the livelihood security of the farming community. Globally salinity impairs the productivity potential of agricultural land. Soil salinity affects plant growth by creating water and ionic imbalance in the plant due to the presence of toxic ions. Salt-affected plants exhibit stunted growth and have darker leaf colour. Nutrient deficiency is another yield-limiting factor and this problem is aggravating gradually due to intensive cultivation, imbalanced and injudicious usage of fertilizers. The widespread deficiency of nitrogen and phosphorus is followed by iron and zinc deficiency. Fe and Zn is an important component of proteins and acts as a structural, functional or regulatory co-factor of a several enzymes. Moreover, it plays a significant role in plant metabolism.

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Generally, the presence of excess salt decreases photosynthesis, total carbohydrate, fatty acid and protein.

The availability of micronutrients greatly depends on the different fractions present in soil. Micronutrient fractions in the soil are affected by the physicochemical properties of the soil and the cropping system. In soil, essential elements such as copper (Cu), zinc (Zn), iron (Fe), and manganese (Mn) are present in different chemical forms. These elements are required for plant growth and act as a cofactor. Plants utilize these micronutrients for the metabolism of lipids, proteins, and carbohydrates. Fluctuation in micronutrients in soils is a global phenomenon and is caused by several governing factors that affect the movement and transformation of these elements in soils such as organic matter content, pH, salinity, and exchangeable capacity. It is essential to determine different fractions of nutrients found in the soil since the transformation and bioavailability of these elements are dependent upon the chemical and physical processes in the soil. Fe and Zn availability to rice is strongly related to different fractions present in the soil. Thus, understanding the distribution of Fe and Zn among various fractions of soils will help to characterize the chemistry of Fe and Zn in soils and possibly their availability for plant uptake. However, the distribution of Fe and Zn among various chemical forms may vary significantly in response to changing soil properties [1].

MATERIAL AND METHODS

A collection of soil samples from saline areas of the Jalalpore taluka of Navsari district was selected for the present study. Navsari district lies between 20.07' North latitude to 21.00' North latitude and 72.43' East longitude to 73.00' East longitude covering a geographical area of 606.06 ha. A total 60 soil samples were collected from the coastal plain (high salt: ECe > 4 dS m^{-1}) of South Gujarat from 0-20 cm and 20-40 cm depths with the help of a screw-auger. The villages were Coastal Soil Salinity Research Station of NAU is located at Danti-Umbhrat of Navsari district and has been doing research on crops and fertilizer, irrigation and reclamation techniques for salt-affected soils since 1966. The location for each sample area is indicated by the map in Fig.1. All the soil sampling areas are under the jurisdiction of Navsari Agricultural University under the South Gujarat Heavy Rainfall Zone, AES-III.

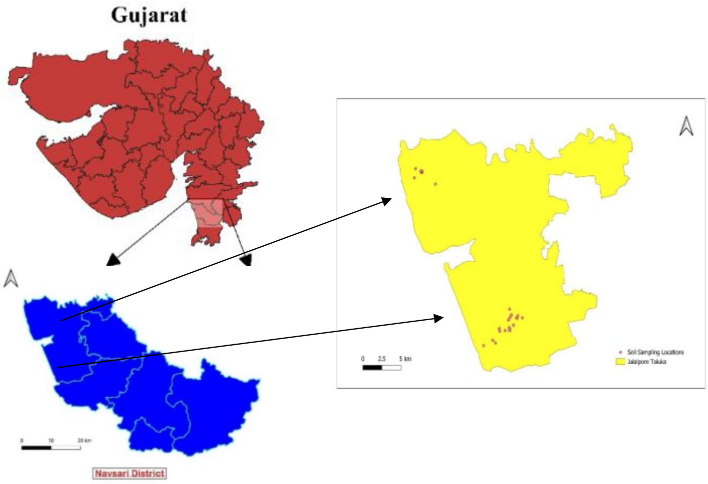


Fig.1 Geographical location of soil samples

The samples were air-dried and ground followed by passing through a 2mm sieve and analysed for different soil physical and chemical properties and fractions of Zn. Soil organic carbon was determined using the Walkley and Black rapid titration method [3]. The available nitrogen in the soil was assessed using the alkaline potassium permanganate method [5]. Phosphorus was determined spectrophotometrically following extraction with 0.5 M $NaHCO_3$ at pH 8.5 [4]. Soil available potassium was measured using the flame photometric method after extraction with 1N NH_4OAc [3]. Analytical procedure of sequential extraction of various Zn fractions [6], Water soluble (F_1): Samples of soil 1 g were extracted at 20°C for 1 hr with 10 ml distilled water. Exchangeable (F_2): The residue of F_1 was extracted at room temperature for 1 hour with 10.0 ml of magnesium chloride solution (1.0 M $MgCl_2$) at pH 7. Carbonate-bound (F_3): The residue of F_2 was extracted with 10.0 ml of 1.0 M sodium acetate/acetic acid buffer at pH 5.0 for 5 hours at room temperature. Fe & Mn oxide bound (F_4): The residue from F_3 was extracted with 10.0 ml of 0.4 M $NH_2OH.HCl$ in 25 % (v/v) acetic acid (pH 2.0) with agitation at 96°C in a water bath for 5 hours. Organic bound (F_5): The residue from F4 was oxidised as follows: 7.5 ml of 30% (v/v) hydrogen peroxide, which had been adjusted to pH 2 with HNO_3, was added to the residue. The mixture was heated to 85°C in a water bath for 5 hours with occasional agitation and allowed to cool down. Then 2.5 ml of 3.2 M ammonium acetate in 20 % (v/v) nitric acid was added, shaken for 0.5 hours, and centrifuged. Simple correlation was made between soil properties & fractions of Zn by using SPSS v.29 software.

Spatial distribution of each soil sample at Jalalpore taluka of Navsari district was mapped by using QGIS v.3.38. Spatial distribution of all soil properties and fraction Zn at 0-20 cm and 20-40 depths under Jalalpore Taluka is shown in Fig. 2.

RESULT AND DISCUSSION

Soil Organic Carbon (%)

Data presented in Table 2 showed that in saline areas, soil organic carbon content in soil was in the ranged from 0.27 to 0.68 per cent and 0.26 to 0.60 per cent at 0-20 cm and 20-40 cm depths, respectively. Results further showed that a higher mean value of organic carbon content was found at 0-20 depth than at 20-40 cm depth with a value of 0.52 per cent in the saline area under study. The results further showed that the decrement in the mean value of organic carbon content at 20-40 cm depth was 19.23 per cent over 0-20 cm depth. High soil salinity leads to flocculation or dispersion of soil's different particles and influences the solubility of soil organic matter (SOM) [7], [8]. Increasing salinity in coastal saline wetlands may result in a lower decomposition rate of organic carbon [2].

Available N, P_2O_5 and K_2O

Considering available N, P_2O_5 and K_2O content in the saline areas at 0-20 cm and 20-40 cm depths (Table N), a higher mean value was found at 0-20 cm depth than 20-40 cm depth for available N, P_2O_5 and K_2O with the respective values of 168.82, 78.40 and 1535.24 kg ha^{-1}, respectively, which was 3.58, 19.04 and 29.86 per cent higher over available N, P_2O_5 and K_2O content at 20-40 cm depth under high saline areas. The findings also indicated that Jogeshwar Faliya had the highest amount of accessible N, but Danti Farm's high saline regions had P_2O_5 and K_2O at a depth of 0-20 cm. Although the Danti farm had the lowest amount of Accessible N, Jogeshwar Faliya had P_2O_5 and K_2O in a salinized area at a depth of 0-20 cm. The data also demonstrated that in saline areas at lower depths (20-40 cm). Danti farm had the highest available N, P_2O_5, and K_2O, with values of 184.40,113.04 and 2664.35 kg ha^{-1}, respectively. In contrast, Danti, Sultanpur, and Jogeshwar Faliya had the lowest amounts of accessible N, P_2O_5 and K_2O, with respective values of 86.05,16.48 and 245.95 kg ha^{-1} at a depth of 20-40 cm. The findings also demonstrated that in high saline areas under investigation, the mean available N, P_2O_5 and K_2O content in soil at 20-40 cm depth was lower than that at 0-20 cm depth, with respective values of 162.98, 65.86, and 1182.18 kg ha^{-1}.

FRACTIONS OF Zn UNDER SALT-AFFECTED SOILS

Different fractions of Zn were estimated from soil samples collected under salt-affected soil of Navsari district saline areas at 0-20 cm and 20-40 cm depths. The results related to different fractions of Zn, *i.e.,* Water Soluble Zn-fraction (WS-Zn), Exchangeable Zn (Exch.-Fe), Carbonate bound Zn (CO_3-Zn), Fe and Mn oxide bound Zn (Fe-Mn-O- Zn), and Organic bound Zn (Org- Zn), are presented in Table 2.

Water Soluble Zn (WS-Zn)

According to the data in Table 2, Danti Farm and Sultanpur had the highest WS-Zn content in saline areas, with respective values of 3.74 and 3.39 mg kg^{-1} at depths of 0-20 cm and 20-40 cm. In Danti Farm and Jogeshwar Faliya, the lowest WS-Zn content was found in depths of 0-20 cm and 20-40 cm., with tune values of 0.09 mg kg^{-1} and 0.04 mg kg^{-1} in high saline regions, respectively.

The findings also indicated that in saline regions, the mean value of 0-20 cm depth is greater than that of 20-40 cm deep, with a WS-Zn concentration of 0.87 mg kg^{-1}. Additionally, the results showed that at depths of 0-20 cm and 20-40 cm,WS-Zn was higher in low-saline areas. In saline regions, the mean value of WS-Zn at lower depths decreases by 19.54 % compared to upper depths.

Exchangeable Zn (Exch-Zn)

The data demonstrated in Table 2 exhibited that in saline areas, the maximum value of Exch-Zn content at 0-20 cm and 20-40 cm depths was found in Danti farm and Jogeshwar faliya with values of 1.94 and 1.54 mg kg^{-1}, respectively. However, the minimum value of Exch-Zn content was found in Danti farm and Jogeshwar faliya with equivalent values of 0.43 and 0.31 mg kg^{-1} at 0-20 cm and 20-40 cm depths, respectively. The result also showed that the magnitude of decrease in the mean value of Exch-Zn content was 27.43 per cent in the lower depth over the upper depth in high saline areas.

Carbonate Bound Zn (CO_3-Zn)

The data displayed in Table 2 showed that in saline areas, maximum CO_3-Zn content at 0-20 cm and 20-40 cm depths was recorded in Mandaliya and Danti farms with respective values of 4.44 and 3.77 mg kg^{-1}. However, minimum CO_3-Zn content was registered in Danti farm with respective values 0.38 mg kg^{-1} and 0.33 mg kg^{-1} at 0-20 cm and 20-40 cm depths, respectively. The results showed that a higher mean value of CO_3-Zn content was obtained at 20-40 cm depth over 0-20 cm depths with a value of 2.08 mg kg^{-1} under a soil sample of a saline area.

Fe and Mn Oxide Bound Zn (Fe-Mn-O-Zn)

The result also showed (Table 2) that in the saline area, the maximum value of Fe-Mn-O-Zn content was found in Jogeshwar faliya and Danti farm with conforming values of 98 and 87.60 mg kg^{-1} at 0-20 cm and 20-40 cm depths. However, the minimum value of Fe-Mn-O-Zn content was noted at 0-20 cm and 20-40 cm depths with tune values of 10 mg kg^{-1} and 7.20 mg kg^{-1} at 0-20 cm and 20-40 cm depths, respectively in saline areas. The result also showed that Fe-Mn-O-Zn content was found to be higher in the upper depth as compared to the lower depth with a mean value of 67.73 mg kg^{-1} under high saline areas.

Organic Bound Zn (Org-Zn)

The Org-Zn content ranged from 16.00 to 108.00 mg kg^{-1} and 13.32 to 97.20 mg kg^{-1} at 0-20 cm and 20-40 cm depths in saline areas (Table 2). The result also showed that the maximum value of Org-Zn content was found in Mandaliya and Jogeshwar faliya with the corresponding value of 108 mg kg^{-1} and 97.20 mg kg^{-1} at 0-20 cm and 20-40 cm depths. However, the minimum value of Org-Zn content was recorded in Danti farm and Jogeshwar faliya at 0-20 cm and 20-40 cm depths with tune values of 16.00 and 13.32 mg kg^{-1} in saline areas, respectively. The result further showed that the upper depth had a higher content of Org-Zn content than the lower depth of the saline areas.

Correlation of Soil Organic Carbon, Available N, P_2O_5, K_2O, and Different Fractions of Zn Under Saline Areas at 0-20 cm and 20-40 cm Depths.

The correlation matrix between soil organic carbon, available N, P_2O_5, K_2O, and Zn was presented in Table 3 for 0-20 cm in saline areas. Soil organic carbon was negatively and significantly correlated with availability P_2O_5 (r = -0.435**), K_2O (r = -0.461**) at 1 per cent level of significance. The data showed that availability P_2O_5 had a positive and significant correlation with avail. K_2O (r = 0.560**) at a 1 per cent level of significance. While, negatively and significantly correlated with CO_3-Zn (r = -0.299*) at the 5 per cent level of significance. The table also revealed that the availability K_2O negatively and significantly correlated with CO_3-Zn (r = -0.597**) at a 1 per cent level of significance. While, negative and significant correlation was found between WS-Zn and CO_3-Zn (r = -0.312*) at 5 per cent level of significance. The result revealed that CO_3-Zn positively and significantly correlated with Fe-Mn-O-Zn (r = 0.354**) at 1 per cent level of significance. The Table 4 showed the correlation matrix between soil organic carbon, available N, P_2O_5, K_2O, and fractions of Zn under saline areas at 20-40 cm depths. The soil organic carbon negatively and significantly correlated with Org-Zn (r = -0.282*) at a 5 per cent level of significance. In case of avail. P_2O_5 positively and significantly correlated with availability. K_2O (r = 0.423**) at a 1 per cent level of significance. However, available K_2O negative and significantly correlated with Fe-Mn-O-Zn (r = -0.331**) and CO_3-Zn (r = -0.263*) at 1 per cent and 5 per cent level of significance. Negative and significant correlation was found between Exch-Zn and CO_3-Zn (r = -0.283*) and Org-Zn (r = -0.321*) at a 5 per cent level of significance. CO_3-Zn positively and significantly correlated with Fe-Mn-O-Zn (r = 0.347**) and Org-Zn (r = 0.420**) at a 1 per cent level of significance.

Table 1: Organic carbon, available N, P_2O_5 and K_2O content in soils of saline areas at 0-20 and 20-40 cm depths

Sr.no.	Name of Village	Depth: 0-20 cm				Depth: 20-40cm			
		OC (%)	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	OC (%)	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
1	ONJAL	0.57	196.69	90.30	1705.00	0.48	184.40	68.46	1684.84
2		0.60	122.93	84.04	1237.02	0.50	159.81	107.93	1334.32
3		0.62	184.40	88.77	1347.76	0.47	147.52	77.40	1495.60
4		0.68	208.98	98.86	1011.76	0.48	172.10	36.53	1147.24
5	JOGESHWAR FALIYA	0.63	159.81	27.21	640.28	0.50	184.40	54.41	583.03
6		0.62	184.40	68.21	807.74	0.47	178.25	32.44	615.01
7		0.57	208.98	34.23	675.76	0.29	172.10	65.40	615.28
8		0.63	184.40	31.42	453.20	0.48	172.10	65.40	459.11
9		0.62	147.52	81.36	379.01	0.42	184.40	33.98	274.44
10		0.66	98.34	30.91	547.55	0.29	184.40	48.15	788.66
11		0.65	159.81	17.24	312.88	0.47	172.10	34.36	379.81
12		0.62	196.69	34.36	333.85	0.45	184.40	27.46	245.95
13		0.50	184.40	66.80	1365.50	0.38	159.81	54.79	1836.98
14		0.54	159.81	78.42	965.53	0.42	172.10	37.68	899.14
15		0.56	147.52	70.38	697.54	0.44	147.52	53.90	591.63
16		0.41	184.40	48.79	1850.69	0.36	178.25	71.78	1775.96

17		0.54	172.10	36.27	514.21	0.45	159.81	53.77	435.19
18		0.48	135.22	83.53	764.20	0.41	184.40	60.67	670.12
19		0.53	159.81	95.16	737.32	0.51	172.10	26.95	454.81
20	MANDALIYA	0.54	196.69	52.62	850.21	0.44	184.40	69.48	723.88
21		0.51	184.40	87.49	863.65	0.47	122.93	77.66	706.94
22		0.50	110.64	49.30	599.69	0.36	178.25	83.66	526.31
23		0.54	196.69	72.55	573.89	0.47	184.40	33.21	430.62
24		0.57	184.40	83.92	636.52	0.50	147.52	42.79	507.23
25		0.48	122.93	92.47	734.09	0.41	178.25	99.88	572.81
26	MANDALIYA	0.45	159.81	86.98	542.44	0.35	159.81	65.27	552.65
27		0.44	184.40	61.95	925.21	0.45	184.40	37.04	938.65
28		0.60	196.69	84.04	1470.07	0.48	159.81	72.55	1427.87
29		0.51	184.40	95.92	802.10	0.44	184.40	72.55	808.82
30	SULTANPUR	0.54	159.81	69.87	887.58	0.50	135.22	29.38	586.52
31		0.56	184.40	48.79	723.88	0.41	147.52	16.48	531.69
32		0.56	159.81	31.04	725.22	0.36	172.10	53.77	655.87
33		0.30	184.40	105.89	680.06	0.26	184.40	92.73	864.73
34		0.42	98.34	95.16	2634.78	0.41	147.52	83.79	814.46
35		0.48	184.40	110.61	2189.64	0.39	159.81	77.79	2664.35
36		0.53	196.69	108.70	2101.75	0.44	178.25	70.63	2289.37
37		0.41	184.40	95.67	2131.58	0.30	172.10	74.59	2458.18
38		0.36	196.69	116.36	2318.94	0.33	159.81	83.28	2531.83
39		0.53	147.52	79.32	2234.53	0.41	147.52	59.27	662.59
40		0.48	159.81	121.60	1971.92	0.42	172.10	66.29	2104.97
41		0.38	184.40	112.53	2514.89	0.30	159.81	72.55	742.43
42		0.42	159.81	87.49	2654.94	0.33	135.22	94.65	661.25
43		0.53	184.40	75.23	2150.67	0.60	159.81	93.50	2414.36
44	DANTI	0.47	196.69	82.38	3093.89	0.39	147.52	113.04	777.64
45		0.42	159.81	97.46	2538.28	0.36	172.10	80.21	753.18
46		0.50	196.69	106.91	2171.64	0.45	159.81	87.49	2356.57
47		0.53	184.40	67.95	2130.24	0.42	184.40	106.27	2544.46
48		0.54	122.93	44.58	2049.87	0.51	172.10	74.34	747.00
49		0.48	110.64	103.46	2536.67	0.42	135.22	83.92	696.46
50		0.57	159.81	87.49	2132.93	0.45	122.93	81.87	2415.17
51		0.47	184.40	94.77	2461.13	0.36	110.64	67.82	705.06
52		0.56	196.69	59.78	2197.98	0.42	86.05	95.28	2364.90
53		0.48	159.81	78.81	2526.18	0.35	110.64	65.27	747.00
54		0.57	159.81	108.06	2232.65	0.48	184.40	59.39	2410.60
55		0.62	122.93	88.26	2464.36	0.45	147.52	70.89	2274.59
56		0.57	184.40	110.36	3155.71	0.39	159.81	71.14	794.30
57		0.47	159.81	108.70	2233.73	0.44	184.40	75.23	2271.36
58	DANTI	0.57	208.98	95.16	2011.43	0.56	172.10	52.62	2330.23
59		0.30	122.93	95.03	3768.58	0.30	184.40	51.35	873.87
60		0.27	196.69	83.28	2144.22	0.30	159.81	81.11	2403.07
Max.		**0.68**	**208.98**	**121.60**	**3768.58**	**0.60**	**184.40**	**113.04**	**2664.35**
Min.		**0.27**	**98.34**	**17.24**	**312.88**	**0.26**	**86.05**	**16.48**	**245.95**
Mean		**0.52**	**168.82**	**78.40**	**1535.24**	**0.42**	**162.98**	**65.86**	**1182.18**

Table 2: Different fractions of Zn (mg kg^{-1}) in soils of saline area at 0-20 and 20-40 cm depth

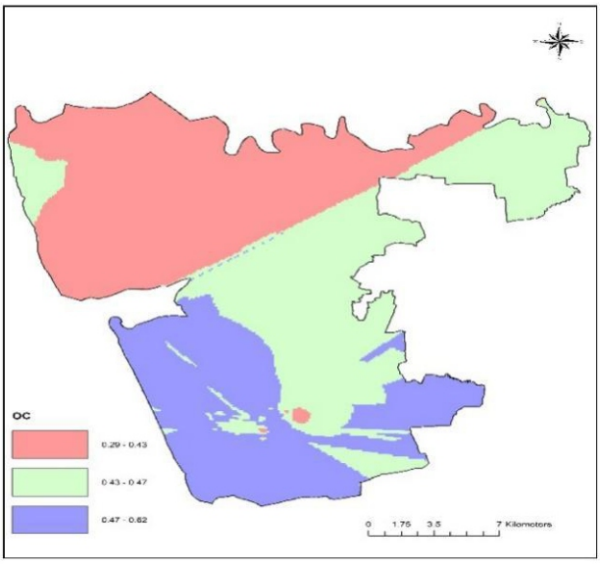
Sr. No.	Name of village	0-20 cm					20-40 cm				
		WS-Zn	Exch-Zn	CO_3-Zn	Fe-Mn-O-Zn	Org-Zn	WS-Zn	Exch-Zn	CO_3-Zn	Fe-Mn-O-Zn	Org-Zn
1		0.74	1.33	2.34	56.00	91.00	0.64	0.44	1.02	52.80	49.20
2		0.36	1.22	2.37	97.00	83.00	0.26	0.51	1.90	85.20	42.00
3		0.58	1.67	2.76	85.00	87.00	0.48	1.54	2.54	87.60	44.40
4		0.34	1.41	1.95	68.00	75.00	0.54	1.45	1.53	67.20	37.20
5	**MATWAD**	0.32	1.52	2.10	74.00	91.00	0.35	1.54	2.17	74.40	46.80
6		0.41	1.71	2.66	76.00	86.00	0.37	1.40	2.71	76.80	33.60
7		0.25	1.30	1.56	69.00	69.00	0.41	0.73	1.67	68.40	37.20
8		0.35	1.56	2.18	96.00	55.00	0.43	0.88	1.79	82.80	78.00
9		0.41	1.33	2.53	68.00	46.00	0.35	0.31	2.08	67.20	64.80
10		0.24	1.60	2.15	74.00	89.00	0.30	0.78	3.75	74.40	81.60
11		0.40	1.03	2.03	85.00	96.00	0.04	0.66	1.72	87.60	88.80
12		0.46	0.89	2.92	88.00	84.00	0.36	0.74	1.76	85.20	90.00
13		0.36	0.75	3.44	98.00	80.00	0.39	0.41	2.33	86.40	97.20
14		0.47	0.66	2.10	87.00	91.00	0.41	0.50	2.51	78.00	85.20
15	**NANI PETHAN**	0.35	0.66	1.87	56.00	97.00	0.26	0.62	2.15	52.80	13.32
16		0.51	0.97	3.86	68.00	83.00	0.35	0.55	1.88	67.20	45.60
17		0.39	0.86	2.45	74.00	108.00	0.26	0.65	1.92	74.40	40.80
18		0.38	0.78	3.51	84.00	90.00	0.38	0.71	2.82	86.40	93.60
19		0.38	0.66	2.55	35.00	80.00	0.42	0.62	2.53	27.60	84.00
20		0.74	0.62	4.44	68.00	74.00	0.26	0.80	2.21	67.20	72.00

21		0.36	0.98	3.41	84.00	71.00	0.27	0.86	1.33	86.40	88.80
22		0.47	1.22	2.42	74.00	79.00	0.31	0.88	1.91	74.40	81.60
23	**MOTI PETHAN**	0.42	1.05	1.77	65.00	83.00	0.25	0.91	2.50	63.60	81.60
24		0.38	1.03	2.32	64.00	87.00	0.47	0.77	2.74	62.40	54.00
25		1.11	1.56	1.53	56.00	82.00	1.01	0.70	3.68	52.80	81.60
26		1.18	1.47	1.52	47.00	90.00	1.08	0.68	3.73	42.00	91.20
27		1.63	0.89	2.11	61.00	82.00	1.53	0.61	2.95	58.80	80.40
28	**MOTI PETHAN**	1.89	1.14	2.69	82.00	83.00	1.79	0.54	3.16	84.00	94.80
29		2.99	1.19	1.21	95.00	86.00	0.19	0.62	3.74	82.80	92.40
30		2.08	1.38	1.65	67.00	75.00	1.98	0.62	1.65	66.00	82.80
31		2.44	1.15	1.56	70.00	98.00	3.39	0.67	3.67	69.60	93.60
32		1.92	0.83	1.51	84.00	79.00	1.82	0.68	3.77	86.40	82.80
33		0.79	1.79	2.53	87.00	87.00	0.69	0.73	3.61	76.80	94.80
34		0.66	1.33	1.99	94.00	16.00	0.56	0.71	3.77	73.20	86.40
35	**MACHAD**	1.28	1.00	1.81	11.00	96.00	0.41	0.79	2.93	76.80	80.40
36		1.50	1.67	1.93	91.00	87.00	0.35	0.83	3.25	70.80	81.12
37		0.27	1.56	2.36	84.00	101.00	0.17	0.83	3.26	86.40	70.80
38		1.60	1.40	1.43	43.00	89.00	1.50	0.76	2.23	37.20	76.80
39		1.02	0.43	1.47	34.00	98.00	0.85	0.74	1.54	26.40	80.40
40		0.90	1.94	1.88	65.00	18.90	0.69	0.80	3.14	63.60	87.60
41		0.76	1.34	1.70	95.00	101.00	0.66	0.74	3.49	85.20	87.60
42		0.35	0.59	1.80	84.00	80.00	0.35	0.67	3.55	86.40	78.00
43	**KHAKHWADA**	0.43	0.77	2.07	48.00	76.00	0.62	0.94	2.12	43.20	85.20
44		0.09	0.83	0.68	68.00	90.00	0.71	0.86	1.39	67.20	81.60
45		1.24	1.73	0.46	41.00	85.00	1.14	0.88	0.33	34.80	54.00
46		1.40	1.47	0.42	45.00	90.00	1.30	0.80	0.41	39.60	42.00
47		1.44	0.48	0.38	10.00	85.00	1.34	0.73	0.51	67.20	44.40
48	**ANCHELI**	1.15	1.26	0.41	65.00	96.00	1.05	0.79	0.83	63.60	18.00
49		1.18	1.23	0.43	68.00	106.00	1.08	0.91	1.37	67.20	88.80
50		1.21	1.47	0.45	74.00	85.00	0.95	0.95	1.30	7.20	42.72
51		1.31	1.17	0.41	65.00	103.00	0.35	1.08	1.41	63.60	63.60
52		1.05	0.83	0.46	95.00	82.00	0.95	1.06	1.21	82.80	64.80
53	**KHARSAD**	0.85	0.79	0.43	84.00	100.00	0.75	1.04	0.90	86.40	70.80
54		3.74	0.55	0.43	74.00	98.00	0.76	1.16	0.95	74.40	56.40
55		0.31	1.44	0.44	47.00	93.00	0.74	1.16	0.76	42.00	78.00
56		0.34	1.48	0.45	68.00	90.00	0.65	1.15	0.56	67.20	88.80
57		0.39	0.69	0.42	39.00	93.00	0.61	1.40	0.51	32.40	49.20
58	**CHIZGAM**	0.56	0.48	0.43	35.00	90.00	0.46	1.09	0.74	27.60	42.00
59		0.50	0.96	0.42	85.00	69.00	0.40	0.76	0.39	87.60	78.00
60		0.69	0.74	0.45	10.00	100.00	0.59	0.62	0.65	9.60	88.80
	Max.	**3.74**	**1.94**	**4.44**	**98.00**	**108.00**	**3.39**	**1.54**	**3.77**	**87.60**	**97.20**
	Min.	**0.09**	**0.43**	**0.38**	**10.00**	**16.00**	**0.04**	**0.31**	**0.33**	**7.20**	**13.32**
	Mean	**0.87**	**1.13**	**1.73**	**67.73**	**84.25**	**0.70**	**0.82**	**2.08**	**65.42**	**69.87**

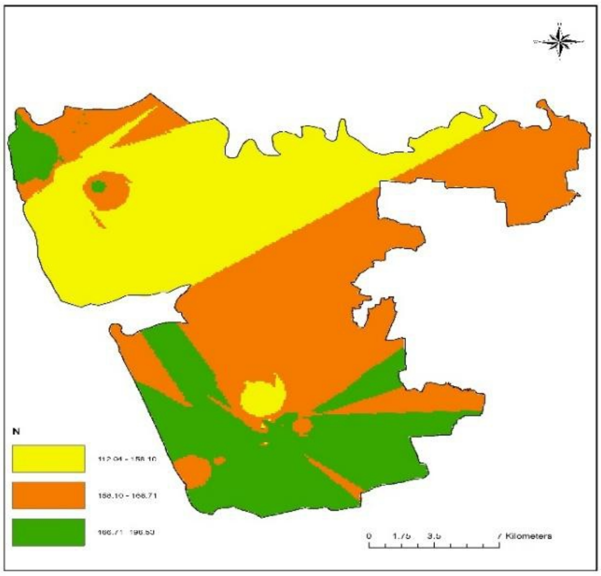
Table 3: Correlation between soil organic carbon, available N, P_2O_5, K_2O and fractions of Zn

0-20 cm depth									
	OC	**N**	**P_2O_5**	**K_2O**	**WS-Zn**	**Exch-Zn**	**CO_3-Zn**	**Fe-Mn-O-Zn**	**Org-Zn**
OC	1								
N	0.016	1							
P_2O_5	-0.435**	0.065	1						
K_2O	-0.461**	-0.042	0.560**	1					
WS-Zn	-0.070	0.079	0.189	0.074	1				
Exch-Zn	0.057	-0.095	0.164	-0.084	-0.027	1			
CO_3-Zn	0.159	0.105	-0.299*	-0.597**	-0.312*	0.021	1		
Fe-Mn-O-Zn	0.170	-0.114	-0.228	-0.198	-0.053	0.229	0.354**	1	
Org-Zn	-0.026	0.151	-0.040	0.072	0.134	-0.252	-0.248	-0.208	1
20-40 cm depth									
	OC	**N**	**P_2O_5**	**K_2O**	**WS-Zn**	**Exch-Zn**	**CO_3-Zn**	**Fe-Mn-O-Zn**	**Org-Zn**
OC	1								
N	0.017	1							
P_2O_5	-0.207	-0.238	1						
K_2O	0.061	-0.066	0.423**	1					
WS-Zn	0.005	-0.186	-0.074	0.062	1				
Exch-Zn	0.214	-0.128	0.048	0.170	-0.119	1			
CO_3-Zn	-0.200	0.159	-0.141	-0.263*	0.068	-0.283*	1		
Fe-Mn-O-Zn	-0.145	0.036	-0.075	-0.331**	-0.173	-0.054	0.347**	1	
Org-Zn	-0.282*	-0.015	-0.051	-0.147	0.148	-0.321*	0.420**	0.201	1

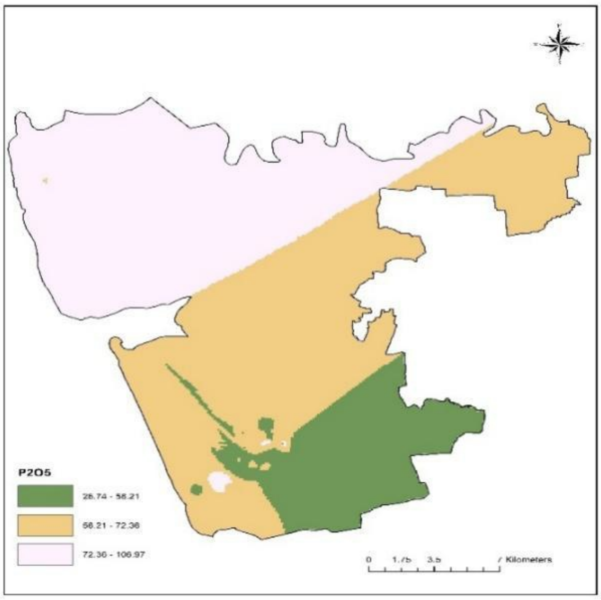
***. Correlation is significant at the 0.01 level (2-tailed).*
**. Correlation is significant at the 0.05 level (2-tailed).*



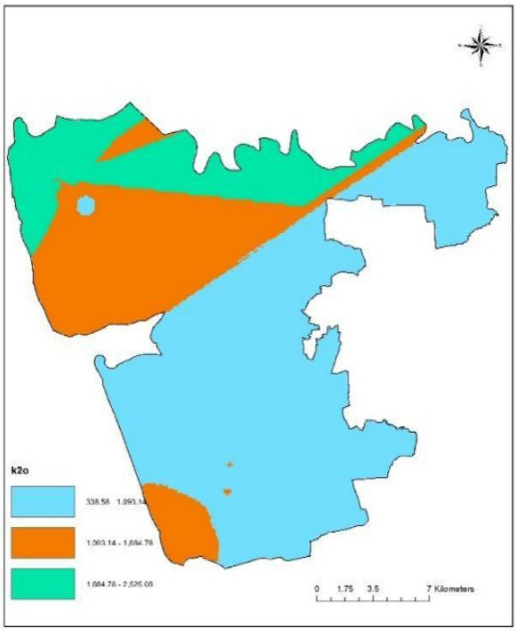
Spatial distribution of OC (%)



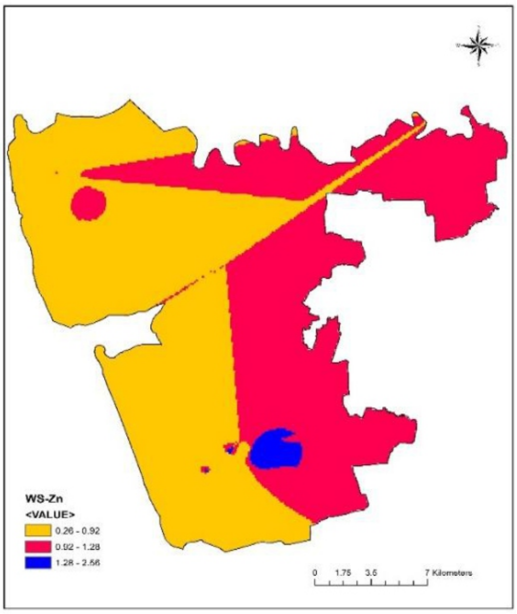
Spatial distribution of Nitrogen (%)



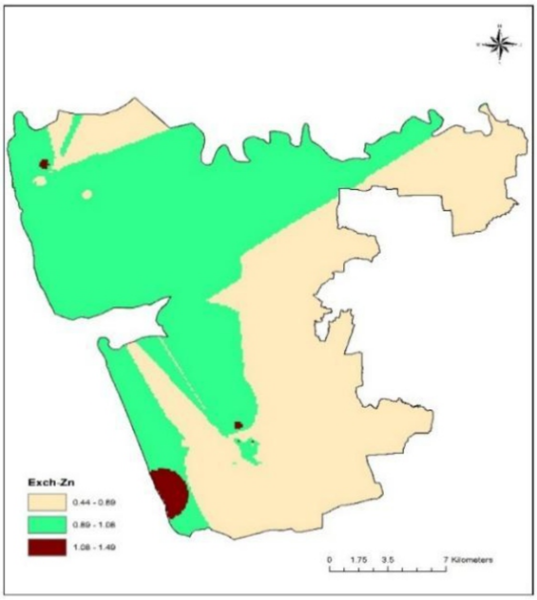
Spatial distribution of P_2O_5 (kg ha^{-1})



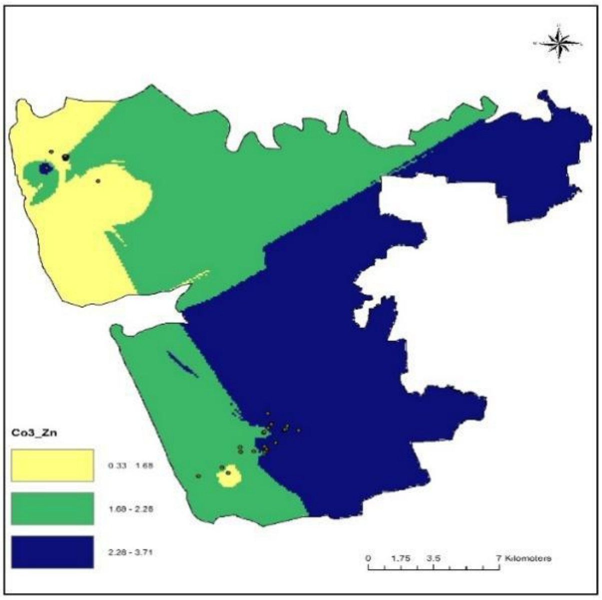
Spatial distribution of K_2O (kg ha^{-1})



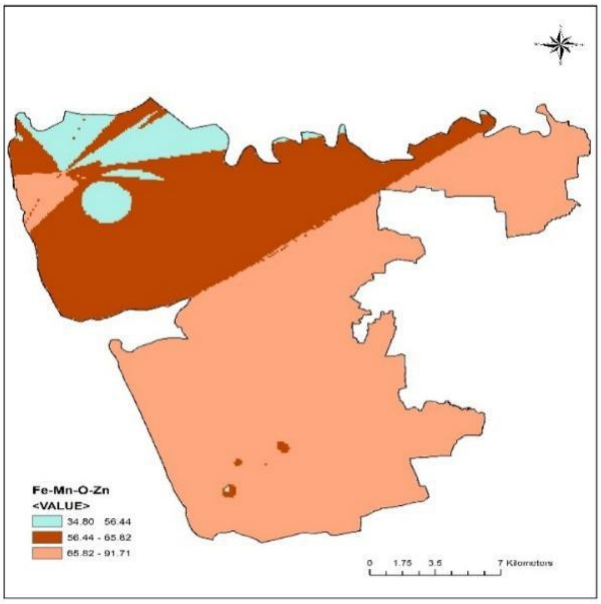
Spatial distribution of WS-Zn (mg kg^{-1})



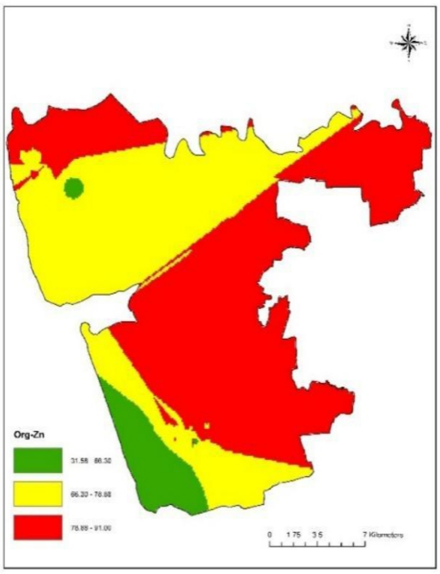
Spatial distribution of Exch-Zn (mg kg^{-1})



Spatial distribution of CO_3-Zn (mg kg^{-1})



Spatial distribution of Fe-Mn-O-Zn (mg kg^{-1})



Spatial distribution of Org-Zn (mg kg^{-1})

Fig. 2. Spatial distribution of soil properties and fractions of Zn

Conclusion

The correlation analysis revealed significant relationships between soil organic carbon, nutrient availability and various fractions of Zn under different saline conditions and soil depths. Zn fractions followed the order: Org-Zn > Fe-Mn-O-Zn > CO_3-Zn > Exch-Zn > WS-Zn, with higher concentrations of all Zn fractions in saline areas. At the surface layer (0-20 cm), soil organic carbon showed strong negative correlations with available P_2O_5 and K_2O, while P_2O_5 was positively correlated to K_2O but negatively to CO_3-Zn. Available K_2O also had a strong negative association with CO_3-Zn, and WS-Zn was inversely related to CO_3-Zn. At the sub-surface layer (20-40 cm), soil organic carbon negatively correlated with Org-Zn, while P_2O_5 maintained a positive relationship with K_2O. Available K_2O was negatively associated with both Fe-Mn-O-Zn and CO_3-Zn. Exch-Zn showed negative correlations with CO_3-Zn and Org-Zn, whereas CO_3-Zn was positively related to both Fe-Mn-O-Zn and Org-Zn. Overall, these results highlight complex interactions where higher organic carbon tends to reduce certain nutrient and Zn fractions. While Carbonate and mineral-bound Zn forms often show interlinked accumulation patterns, influenced by nutrient availability and soil depth.

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