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Influence of Sodium and Calcium on Vegetation at Saline Desert (Little Rann of Kutch) of Gujarat State in India

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Abstract: Scrutiny of soil and vegetation with their inter-relationship can effectively assist in recognition of the factors to combat land degradation. Saline desert (Little Rann of Kutch of 8820 ha) was selected, for the study of soil (physical and chemical properties) and vegetation. Species richness for herbs was 12, 46, 9, 13 and 35 at Site 1 to 5. Highest density of herbs (21.967 plants m^{-2}) with high FC, OC, OM, N, P and Ca (31.400, 0.799, 1.377, 0.069%, 63.202 kg ha^{-1} and 194.218 mg kg^{-1}) and low BD, EC, K, Na and Pb at Site 5. Lowest density for herbs (2.208 plants m^{-2}) was found with high values of PD, EC, Na and Pb (2.861 gcc^{-1}, 14.581 dS m^{-1}, 137.310 and 67.309 mg kg^{-1}) and low values of OC, N, Ca and Fe at Site 3. Density of shrubs/trees was highest (8.519 plants 10 m^{-2}) at Site 2 with high values of OC, N, Ca and Mn and low values of EC, Na and Pb. Density has negative correlation with Na, EC and clay while positive with OC and Ca. Low species richness and density is the result of low concentration of OC, OM, N, P, Fe, Ca and high concentration of clay, Na, Pb and EC.

Key words: Calcium, density, desert, herbs, sodium and soil.

Soil (physical and chemical properties) and vegetation study was conducted at Little Rann of Kutch; a saline, brackish desert with soaring salinity (Gupta and Ansari, 2012). It is nominated to be a "biosphere reserve" which is defined by the areas of terrestrial and coastal ecosystems internationally recognized within the framework of UNESCO's Man and Biosphere (MAB) program (Goswami *et al.*, 2014).

Soil salinization directly influences plant growth by increasing osmotic pressure of soil moisture causing physiological drought and deterioration of soil (Abdelfattah, 2009). The main effect of salts on vegetation is that during increased osmotic pressure plants find it gradually more difficult to utilize water from the soil. This is the main cause of less vegetation at saline areas, leading to many of the adverse environmental consequences of salinization of desert. Change in vegetation, either due to dominance of additional salt tolerant species or through reduced growth of existing species, is frequently the first understandable signs of desert salinization trouble. These effects depend, mainly on seasonal conditions, plant growth, root zone and salt levels (Charman and Junor, 1989; Pilania and Panchal, 2014; Vaghasiya *et al.*, 2015).

Great heterogeneity of resources is known to occur in arid and semi-arid ecosystems, mainly due to different plant species and their distribution patterns (Wezel *et al.*, 2000). Spatial heterogeneity of soil resources is recognized as a common feature in natural ecosystems (Palmer, 2003). It has been considered as one of the major drivers of biological processes (Kumar *et al.*, 2006; Zhou *et al.*, 2008) and as a basic element for competitive or facilitative interaction between plants. Consequently, spatial heterogeneity of soil resources may determine landscape patterns, and greatly affect the biogeochemical cycles in many ecosystems (Bekele and Hudnall, 2006; Zuo *et al.*, 2008).

Inter-relation between soil and vegetation have been known since the development of the concept of the factors of soil formation (Jenny, 1941). Vegetation influences soil by recycling different nutrients. Soil and vegetation degradation, is influenced by each other (Langbein and Schumm, 1958). Which suggests that to increase the productivity of the land both soil and vegetation should be studied concurrently. With this alarm the inter-relationship of soil and vegetation was studied at saline desert.

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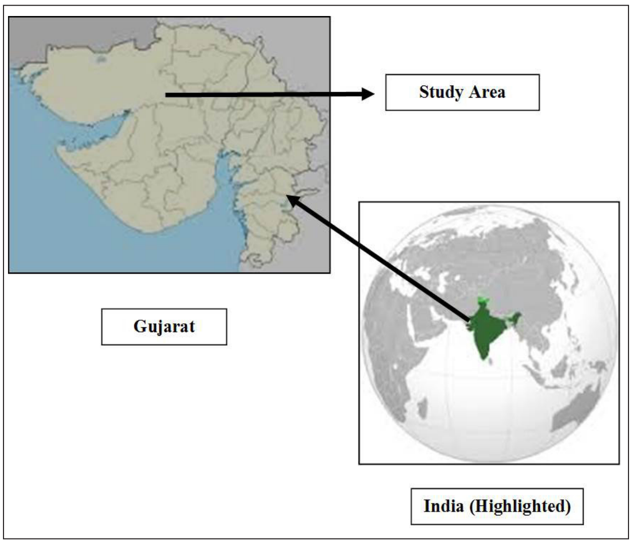

Fig. 1. Little Rann of Kutch - Study area.

Material and Methods

Study area and site selection

The study was conducted in India (Fig. 1) at Little Rann of Kutch (22° 55′′ to 24° 35′′ north latitudes and 70° 30′′ to 71° 45′′ east longitudes) known as "The Wild Ass Sanctuary", named after endangered Ghudkhur (*Equs hemionus khur*).

For the study purpose total five sites were selected at different locations of Little Rann of Kutch. Geographical locations of different sites were 23°45″ to 23°36″ north latitudes and 71°09″ to 71°25″ east longitudes (Site 1), 23°40″ to 23°32″ north latitudes and 71°13″ to 71°32″ east longitudes (Site 2), 23°07″ to 23°18″ north latitudes and 71°19″ to 71°27″ east longitudes (Site 3), 23°31″ to 23°51″ north latitudes and 71°12″ to 70°53″ east longitudes (Site 4), 23°19″ to 23°33″ north latitudes and 71°22″ to 71°39″ east longitudes (Site 5), respectively.

Collection of soil samples

Collection of samples was done in the months of November to February in the year of 2014-2015. Samples were randomly collected from five different sites (32, 48, 16, 40 and 60 samples from Site 1 to 5 respectively), for three depths viz., 0-15, 15-30 and 30-45 cm respectively.

Analysis of physical properties of soil

Soil texture was determined by "Bouyoucos Hydrometer Method" (Bouyoucos, 1951). Soil Aggregates was determined by "wet sieving method" (Yoder, 1936) with the help of a Yoder sieve shaker. Three aggregate fractions were obtained i.e. large macro-aggregates (>2 mm), macro-aggregates (0.125 to 2 mm) and micro-aggregates (<0.125 mm). Soil weight in unit volume was computed to determine bulk density. Particle density was measured following USDA, 1968. Value of bulk density was used to determine porosity of soil (Misra, 1968) and expressed in percentage. Field capacity and water holding capacity was determined following Misra (1968) and the results are expressed in percentage of oven-dry weight (105°C temperature).

Analysis of chemical properties of soil

Soil pH was measured by a pH meter preparing soil paste with distilled water (1:2.5 ratios). Electrical conductivity (EC) was measured by an EC meter (1:25 ratios). organic carbon (OC), organic matter (OM) and total nitrogen (N) were measured following Jackson (1973). Available phosphorus (P) was measured following Olsen *et al.* (1954). Potassium (K), sodium (Na), calcium (Ca), zinc (Zn), copper (Cu), iron (Fe), lead (Pb) and manganese (Mn) were measured following (Lindsay and Norvell, 1978) by atomic absorbance spectrophotometer.

Vegetation analysis

Density for vegetation was analyzed as per Curtis and McIntosh (1950). Species richness (SR) was calculated as per Margalef (1958).

Table 1. Soil texture and aggregate at different study sites and soil depths

Parameters	Soil depth (cm)		Site 1	Site 2	Site 3	Site 4	Site 5
Sand (%)	0-15		25.1 ± 0.53	26.1 ± 0.59	27.6 ± 0.65	38.4 ± 1.90	28.3 ± 0.87
	15-30		26.3 ± 0.47	25.9 ± 0.47	27.1 ± 0.71	40.6 ± 2.28	27.7 ± 0.88
	30-45		25.6 ± 0.62	27.0 ± 1.77	27.1 ± 0.71	38.1 ± 2.07	28.6 ± 1.50
	Combined 0-45	Mean	25.7 ± 0.30	26.4 ± 0.61	27.3 ± 0.34	39.1 ± 1.14	28.2 ± 0.62
		Range	22.1 to 28.3	22.1 to 45.9	25.1 to 29.2	29.9 to 51.9	22.1 to 45.9
Silt (%)	0-15		41.4 ± 1.38	39.9 ± 1.23	28.1 ± 0.63	28.8 ± 1.39	36.3 ± 1.35
	15-30		39.6 ± 1.35	40.6 ± 0.77	28.7 ± 0.86	26.7 ± 2.14	37.2 ± 1.20
	30-45		42.4 ± 1.04	39.8 ± 1.98	28.9 ± 0.71	29.0 ± 1.62	36.3 ± 1.77
	Combined 0-45	Mean	41.1 ± 0.69	40.1 ± 0.77	28.6 ± 0.37	28.1 ± 0.96	36.6 ± 0.81
		Range	33.8 to 46.0	20.0 to 46.0	26.9 to 30.9	14.0 to 36.0	20.0 to 46.8
Clay (%)	0-15		33.4 ± 1.26	33.8 ± 0.84	44.1 ± 0.21	32.6 ± 0.53	35.3 ± 0.60
	15-30		33.9 ± 1.34	33.4 ± 0.79	44.1 ± 0.21	32.5 ± 0.45	35.0 ± 0.62
	30-45		31.9 ± 1.36	33.0 ± 0.98	43.8 ± 0.02	32.7 ± 0.55	34.9 ± 0.84
	Combined 0-45	Mean	33.1 ± 0.70	33.4 ± 0.48	44.0 ± 0.09	32.6 ± 0.27	35.1 ± 0.38
		Range	28.1 to 40.1	29.6 to 39.9	43.8 to 44.8	28.9 to 35.0	29.6 to 39.9
Texture type	0-45 cm		Clay Loam	Clay Loam	Clay	Clay Loam	Clay Loam
Large macro-aggregate (%)	0-15		10.8 ± 1.06	9.3 ± 2.79	13.7 ± 5.40	43.2 ± 7.96	36.1 ± 6.73
	15-30		12.4 ± 5.73	10.2 ± 3.93	20.3 ± 7.06	56.4 ± 5.37	49.0 ± 8.04
	30-45		12.6 ± 5.38	9.8 ± 3.71	21.8 ± 6.44	49.4 ± 8.23	54.4 ± 9.22
	Combined 0-45	Mean	11.9 ± 2.82	9.8 ± 1.97	18.6 ± 3.48	49.7 ± 4.19	46.5 ± 4.69
		Range	1.4 to 50.4	1.1 to 50.4	5.3 to 36.7	6.2 to 78.8	3.0 to 93.7
Macro-aggregate (%)	0-15		26.7 ± 3.26	24.3 ± 2.39	23.6 ± 4.49	14.6 ± 2.35	19.2 ± 2.44
	15-30		25.3 ± 2.86	26.2 ± 2.75	17.8 ± 2.28	11.2 ± 1.79	14.1 ± 2.00
	30-45		26.0 ± 4.29	25.1 ± 3.48	18.6 ± 2.02	13.5 ± 2.69	13.4 ± 2.16
	Combined 0-45	Mean	26.0 ± 2.00	25.2 ± 1.66	20.0 ± 1.81	13.1 ± 1.32	15.5 ± 1.28
		Range	1.7 to 79.7	1.7 to 64.3	4.6 to 56.2	0.6 to 62.6	0.5 to 63.6
Micro-aggregate (%)	0-15		3.0 ± 0.68	3.6 ± 0.73	5.1 ± 1.27	2.9 ± 0.62	2.1 ± 0.26
	15-30		3.7 ± 1.06	3.5 ± 0.72	8.7 ± 2.27	2.6 ± 0.48	2.8 ± 0.47
	30-45		3.1 ± 0.56	2.9 ± 0.42	7.4 ± 1.60	2.6 ± 0.75	1.7 ± 0.34
	Combined 0-45	Mean	3.3 ± 0.45	3.4 ± 0.37	7.0 ± 1.02	2.7 ± 0.36	2.2 ± 0.21
		Range	0.04 to 22.6	0.04 to 22.6	0.4 to 22.8	0.09 to 21.4	0.04 to 12.8

Results

Characterization of soil texture, aggregate and physical properties of soil

Clay loam textured soil were present at four sites (Site 1, 2, 4 and 5) while clay soils were present only at Site 3 (Table 1). Maximum values of sand, clay and silt was found at Site 4, 3 and 1 (39.124, 44.063 and 44.187%) while minimum value for clay and silt at Site 4 (32.697 and 28.179%) and for sand at Site 1 (25.701%). High amount of large macro-aggregate was found at lower depths and macro-aggregates at upper layer of soil. Bulk density (BD) was found maximum (Table 2) at Site 2 (1.988 gcc^{-1}) and minimum at Site 5 (1.334 gcc^{-1}). Particle density (PD) was found highest at Site 3 (2.861 gcc^{-1}) while lowest at Site 4 (1.831gcc^{-1}). Porosity (PO) was found maximum at Site 4 (47.296%) while minimum at Site 3 (19.408%). Field capacity (FC) was found highest at Site 5 (31.400%) and water holding capacity (WHC) at Site 3 (31.560%) while both were minimum at Site 1 (18.134 and 28.119%).

Characterization of chemical properties of soil

pH was maximum (Table 3) at Site 2 (9.293) while minimum at Site 3 (7.711). EC was

Table 2. Physical properties of Soil at different study sites

Parameters	Soil depth (cm)		Site 1	Site 2	Site 3	Site 4	Site 5
BD (gcc^{-1})	0-15		1.5 ± 0.04	1.9 ± 0.02	1.4 ± 0.01	1.4 ± 0.01	1.3 ± 0.01
	15-30		1.4 ± 0.04	2.0 ± 0.02	1.4 ± 0.00	1.5 ± 0.01	1.3 ± 0.02
	30-45		1.5 ± 0.04	1.9 ± 0.02	1.3 ± 0.01	1.4 ± 0.03	1.3 ± 0.02
	Combined 0-45	Mean	1.5 ± 0.02	1.9 ± 0.01	1.4 ± 0.06	1.4 ± 0.06	1.3 ± 0.01
		Range	1.1 to 2.1	1.8 to 2.2	1.3 to 1.4	1.2 to 1.6	1.0 to 1.6
PD (gcc^{-1})	0-15		2.6 ± 0.09	2.5 ± 0.04	3.5 ± 0.28	1.7 ± 0.04	2.0 ± 0.04
	15-30		2.7 ± 0.06	2.6 ± 0.04	2.5 ± 0.14	2.0 ± 0.05	1.9 ± 0.03
	30-45		2.8 ± 0.10	2.4 ± 0.06	2.5 ± 0.05	1.6 ± 0.05	1.9 ± 0.05
	Combined 0-45	Mean	2.7 ± 0.05	2.5 ± 0.03	2.8 ± 0.12	1.8 ± 0.01	1.9 ± 0.02
		Range	1.8 to 3.6	2.1 to 3.6	1.8 to 4.9	1.3 to 2.6	1.4 to 2.7
PO (%)	0-15		39.7 ± 3.21	22.1 ± 0.88	20.1 ± 0.78	54.7 ± 0.94	33.7 ± 1.73
	15-30		45.3 ± 1.95	23.9 ± 1.00	24.8 ± 0.25	41.9 ± 1.51	31.5 ± 1.25
	30-45		44.9 ± 2.02	19.2 ± 1.12	13.2 ± 0.06	45.2 ± 1.04	29.8 ± 1.80
	Combined 0-45	Mean	43.3 ± 1.41	21.7 ± 0.60	19.0 ± 0.65	47.2 ± 0.47	31.6 ± 0.93
		Range	13.0 to 58.3	11.3 to 43.7	9.3 to 41.2	25.3 to 65.8	11.5 to 58.8
FC (%)	0-15		17.5 ± 0.91	18.8 ± 0.88	22.9 ± 1.53	27.8 ± 1.06	29.6 ± 1.14
	15-30		18.3 ± 0.68	18.9 ± 0.69	22.9 ± 1.48	30.7 ± 1.29	33.7 ± 0.82
	30-45		18.5 ± 1.12	19.3 ± 0.91	24.7 ± 1.97	25.8 ± 0.79	30.7 ± 0.98
	Combined 0-45	Mean	18.1 ± 0.52	19.0 ± 0.47	23.5 ± 0.92	28.1 ± 0.36	31.4 ± 0.58
		Range	11.0 to 30.4	11.0 to 30.7	15.4 to 35.2	18.1 to 42.3	16.7 to 45.5
WHC (%)	0-15		26.4 ± 2.32	26.8 ± 1.94	28.2 ± 2.10	30.2 ± 1.30	28.9 ± 0.78
	15-30		28.6 ± 2.79	31.4 ± 2.44	29.1 ± 3.07	31.0 ± 0.70	28.3 ± 0.43
	30-45		29.3 ± 2.00	32.7 ± 2.11	37.2 ± 3.45	27.8 ± 0.95	28.6 ± 1.06
	Combined 0-45	Mean	28.1 ± 1.35	30.3 ± 1.25	31.5 ± 1.73	29.7 ± 0.33	28.6 ± 0.45
		Range	17.5 to 58.6	17.5 to 59.2	13.3 to 54.8	14.0 to 44.1	20.6 to 56.3

maximum at Site 3 (14.581 dS m^{-1}) followed by Site 1 (10.057 dS m^{-1}) while minimum at Site 5 (6.600 dS m^{-1}). OC and N were maximum at Site 5 (0.799% and 0.069%) while minimum at Site 3 (0.654% and 0.056%). OM and P were maximum at Site 5 (1.377% and 63.202 kg ha^{-1}) while minimum at Site 2 (1.128% and 42.860 kg ha^{-1}). K was maximum at Site 4 (934.756 mg kg^{-1}) and minimum at Site 5 (667.746 mg kg^{-1}). Ca was maximum at Site 5 (194.218 mg kg^{-1}) followed by Site 2 (170.607 mg kg^{-1}) while minimum at Site 3 (84.952 mg kg^{-1}). Na was maximum at Site 3 (137.310 mg kg^{-1}) followed by Site 1 (126.338 mg kg^{-1}) while minimum at Site 5 and 2 (60.435 mg kg^{-1} and 77.266 mg kg^{-1}). Fe and Zn were maximum at Site 4 (81.061 mg kg^{-1} and 53.141 mg kg^{-1}) while minimum at Site 1 (27.026 mg kg^{-1} and 9.210 mg kg^{-1}). Pb was maximum at Site 3 (67.309 mg kg^{-1}) and minimum at Site 5 (48.222 mg kg^{-1}). Mn was maximum at Site 5 (40.092 mg kg^{-1}) and minimum at Site 4 (22.205 mg kg^{-1}).

Vegetation analysis at different sites

Species richness of herbs was found maximum at Site 2 (46) followed by Site 5 and 4 (Table 4) while minimum at Site 3 (9). Total density was found to be maximum at Site 5 (21.967 plants m^{-2}) followed by Site 2 (19.277 plants m^{-2}). Minimum density was found at Site 1 and 3 (9.758 and 2.208 plants m^{-2}). Species richness for shrubs/trees was found maximum at Site 2 and 5 (11 and 6 species each) followed by Site 1. Density was found to be maximum at Site 2 and 1 (8.519 and 7.797 plants 10 m^{-2}) while minimum density was found at Site 4 and 3 (3.650 and 1.635 plants 10 m^{-2}).

Effect of soil on vegetation

Species richness for herbs was highest at Site 2 and 5 (46 and 35). Density of herbs was maximum at Site 5, with high concentrations of OC, OM, N, P, Ca and Mn (0.799, 1.377, 0.069%, 63.202 kg ha^{-1}, 194.218 and 40.092 mg

Table 3. Chemical properties of Soil at different sites and soil depths

Parameters	Soil depth (cm)		Site 1	Site 2	Site 3	Site 4	Site 5
pH	0-15		9.0 ± 0.12	9.053 ± 0.15	7.6 ± 0.12	8.0 ± 0.13	7.8 ± 0.15
	15-30		9.2 ± 0.13	9.376 ± 0.18	7.7 ± 0.07	8.1 ± 0.13	7.7 ± 0.18
	30-45		9.1 ± 0.19	9.450 ± 0.18	7.7 ± 0.06	8.1 ± 0.11	7.8 ± 0.18
	0-45	Mean	9.1 ± 0.08	9.293 ± 0.10	7.7 ± 0.04	8.1 ± 0.06	7.8 ± 0.09
		Range	8.5 to 9.9	8.240 to 10.2	7.3 to 7.8	7.3 to 8.7	7.0 to 9.6
EC (dS m^{-1})	0-15		11.6 ± 1.65	8.1 ± 1.07	14.1 ± 4.52	10.7 ± 2.30	8.7 ± 1.15
	15-30		8.5 ± 0.94	5.6 ± 0.86	16.1 ± 2.46	8.0 ± 1.45	5.4 ± 0.96
	30-45		10.0 ± 1.52	6.6 ± 0.92	13.4 ± 4.14	5.6 ± 1.40	5.8 ± 1.12
	0-45	Mean	10.0 ± 0.78	6.8 ± 0.54	14.5 ± 1.75	8.1 ± 1.02	6.6 ± 0.63
		Range	3.0 to 18.5	3.0 to 13.8	2.8 to 22.2	0.3 to 24.0	0.3 to 14.5
OC (%)	0-15		0.70 ± 0.07	0.84 ± 0.06	0.69 ± 0.03	0.70 ± 0.02	0.77 ± 0.03
	15-30		0.69 ± 0.07	0.68 ± 0.02	0.63 ± 0.03	0.75 ± 0.01	0.82 ± 0.02
	30-45		0.67 ± 0.06	0.70 ± 0.01	0.63 ± 0.03	0.77 ± 0.02	0.79 ± 0.02
	0-45	Mean	0.69 ± 0.03	0.74 ± 0.02	0.65 ± 0.02	0.74 ± 0.01	0.79 ± 0.01
		Range	0.22 to 0.96	0.54 to 1.05	0.41 to 0.96	0.53 to 0.98	0.45 to 1.18
OM (%)	0-15		1.20 ± 0.13	1.20 ± 0.06	1.45 ± 0.11	1.20 ± 0.03	1.34 ± 0.05
	15-30		1.19 ± 0.13	1.09 ± 0.05	1.18 ± 0.04	1.30 ± 0.02	1.42 ± 0.05
	30-45		1.17 ± 0.10	1.09 ± 0.06	1.21 ± 0.01	1.32 ± 0.03	1.36 ± 0.03
	0-45	Mean	1.19 ± 0.06	1.12 ± 0.03	1.28 ± 0.04	1.27 ± 0.01	1.37 ± 0.02
		Range	0.39 to 1.66	0.71 to 1.66	0.93 to 1.81	0.92 to 1.69	0.78 to 2.04
N (%)	0-15		0.06 ± 0.01	0.07 ± 0.01	0.06 ± 0.01	0.06 ± 0.01	0.06 ± 0.01
	15-30		0.06 ± 0.01	0.05 ± 0.01	0.05 ± 0.01	0.06 ± 0.01	0.07 ± 0.01
	30-45		0.05 ± 0.01	0.06 ± 0.01	0.05 ± 0.01	0.06 ± 0.01	0.06 ± 0.01
	0-45	Mean	0.06 ± 0.01	0.06 ± 0.01	0.05 ± 0.01	0.06 ± 0.01	0.06 ± 0.01
		Range	0.02 to 0.08	0.04 to 0.09	0.03 to 0.08	0.04 to 0.08	0.03 to 0.10
P (kg ha^{-1})	0-15		45.4 ± 2.35	43.9 ± 1.51	48.9 ± 0.79	52.0 ± 0.535	59.5 ± 0.437
	15-30		44.3 ± 2.32	41.7 ± 1.28	53.4 ± 0.88	56.8 ± 0.589	64.2 ± 0.546
	30-45		44.6 ± 2.47	42.9 ± 1.67	57.6 ± 0.51	57.3 ± 0.964	65.7 ± 0.768
	0-45	Mean	44.8 ± 1.26	42.8 ± 0.83	53.3 ± 0.71	55.4 ± 0.47	63.2 ± 0.41
		Range	35.2 to 57.0	35.2 to 54.7	45.0 to 61.5	46.5 to 65.2	55.5 to 73.5
K (ppm)	0-15		823.2 ± 62.90	809.6 ± 32.53	834.0 ± 18.88	932.5 ± 24.32	676.0 ± 244.11
	15-30		823.8 ± 61.15	822.1 ± 33.65	819.8 ± 13.95	932.5 ± 38.55	667.6 ± 237.09
	30-45		813.0 ± 64.13	800.2 ± 45.77	818.2 ± 15.58	939.1 ± 24.31	659.5 ± 237.65
	0-45	Mean	820.0 ± 33.27	810.6 ± 20.67	824.0 ± 7.58	934.7 ± 16.09	667.7 ± 132.27
		Range	364.6 to 907.2	333.6 to 906.8	790.4 to 875.2	785.1 to 1226.8	60.4 to 1221.0
Ca (ppm)	0-15		83.2 ± 5.02	173.8 ± 3.94	82.2 ± 20.04	158.9 ± 15.00	167.1 ± 5.36
	15-30		100.5 ± 15.94	170.3 ± 5.20	85.5 ± 23.66	134.9 ± 20.27	203.3 ± 10.57
	30-45		106.2 ± 13.04	167.6 ± 6.46	87.0 ± 24.47	109.7 ± 6.94	212.1 ± 5.29
	0-45	Mean	96.6 ± 6.77	170.6 ± 2.92	84.9 ± 10.32	134.5 ± 8.91	194.2 ± 5.03
		Range	57.9 to 182.2	139.2 to 209.1	48.2 to 158.5	54.7 to 191.6	121.4 to 260.4
Na (ppm)	0-15		127.2 ± 11.17	48.6 ± 7.56	139.2 ± 28.80	105.4 ± 10.63	57.9 ± 11.16
	15-30		126.2 ± 11.35	106.7 ± 1.45	137.2 ± 29.50	145.5 ± 2.98	62.1 ± 10.58
	30-45		125.5 ± 11.54	76.3 ± 9.41	135.4 ± 32.43	77.7 ± 11.45	61.2 ± 10.30
	0-45	Mean	126.3 ± 6.02	77.2 ± 5.47	137.3 ± 13.70	109.5 ± 7.04	60.4 ± 5.90
		Range	47.6 to 148.5	20.1 to 124.7	39.0 to 179.9	54.3 to 159.3	10.1 to 157.6

Table 3. Cont...

Parameters	Soil depth (cm)		Site 1	Site 2	Site 3	Site 4	Site 5
Zn (ppm)	0-15		9.1 ± 1.52	13.7 ± 2.09	19.7 ± 2.99	51.3 ± 5.15	52.9 ± 13.79
	15-30		9.0 ± 1.17	13.7 ± 1.85	21.2 ± 1.96	50.7 ± 4.82	52.6 ± 13.83
	30-45		9.4 ± 1.91	14.3 ± 1.58	20.3 ± 3.01	56.6 ± 6.60	52.8 ± 13.76
	0-45	Mean	9.2 ± 0.83	13.9 ± 1.01	20.4 ± 1.23	53.1 ± 3.04	52.8 ± 7.61
		Range	1.4 to 17.1	2.9 to 24.9	11.6 to 28.1	29.1 to 85.0	11.1 to 140.4
Cu (ppm)	0-15		6.3 ± 3.49	9.4 ± 4.01	20.0 ± 6.79	21.6 ± 1.77	21.4 ± 2.09
	15-30		7.4 ± 3.48	8.3 ± 3.45	22.6 ± 2.28	22.2 ± 2.02	21.0 ± 1.72
	30-45		6.7 ± 3.19	7.2 ± 3.19	24.0 ± 2.75	22.8 ± 2.06	22.2 ± 1.9
	0-45	Mean	6.8 ± 1.80	8.3 ± 1.95	22.2 ± 2.05	22.2 ± 1.05	21.6 ± 1.06
		Range	0.2 to 27.3	0.2 to 38.5	4.0 to 36.7	12.7 to 37.5	0.5 to 41.2
Fe (ppm)	0-15		28.5 ± 2.69	37.6 ± 2.31	34.0 ± 6.10	82.8 ± 3.20	67.7 ± 15.79
	15-30		26.4 ± 1.11	37.0 ± 2.00	31.1 ± 4.13	79.9 ± 2.91	67.5 ± 16.24
	30-45		26.0 ± 0.97	37.4 ± 1.89	31.9 ± 4.19	80.3 ± 2.71	68.4 ± 16.62
	0-45	Mean	27.0 ± 0.96	37.4 ± 1.13	32.3 ± 2.23	81.0 ± 1.60	67.9 ± 8.95
		Range	24.5 to 47.3	15.5 to 48.7	22.0 to 46.8	63.8 to 101.6	13.8 to 179.2
Pb (ppm)	0-15		62.9 ± 6.12	65.2 ± 6.56	69.0 ± 10.21	64.7 ± 0.96	48.1 ± 5.27
	15-30		64.1 ± 6.42	59.9 ± 4.53	65.6 ± 9.51	64.3 ± 1.29	48.1 ± 5.54
	30-45		69.2 ± 6.94	62.0 ± 7.54	67.2 ± 10.66	66.2 ± 0.91	48.2 ± 5.01
	0-45	Mean	65.4 ± 3.49	62.3 ± 3.47	67.3 ± 4.60	65.1 ± 0.59	48.2 ± 2.91
		Range	33.1 to 92.3	16.6 to 99.2	48.8 to 93.4	57.5 to 72.6	11.3 to 89.2
Mn (ppm)	0-15		31.6 ± 1.56	38.3 ± 2.46	26.3 ± 5.07	21.9 ± 2.75	40.7 ± 1.33
	15-30		29.9 ± 2.32	34.0 ± 2.10	26.1 ± 5.51	25.1 ± 2.78	39.8 ± 1.31
	30-45		32.8 ± 2.74	30.5 ± 1.47	26.2 ± 5.89	19.5 ± 2.64	39.6 ± 1.38
	0-45	Mean	31.4 ± 1.22	34.3 ± 1.24	26.2 ± 2.48	22.2 ± 1.52	40.0 ± 0.74
		Range	18.9 to 42.6	18.9 to 47.0	12.9 to 39.5	8.8 to 36.7	28.0 to 47.9

kg^{-1}) but low concentrations of EC, K, Na and Pb (6.660 dS m^{-1}, 667.746, 60.435 and 48.222 mg kg^{-1}). Density of herbs and trees was also high at Site 2 with high values of OC, N, Ca and Mn while low values of EC, Na and Pb.

Species richness and density for herbs was found less at Site 3; with high values of EC, Na and Pb (14.581 dS m^{-1}, 137.310 and 67.309 mg kg^{-1}) with clay type of texture but low values of OC, N, Ca and Fe (0.654, 0.056%, 84.952 and 32.383 mg kg^{-1}). Density of herbs with Na, EC and clay (-0.971, -0.948 and -0.658) was found to be negatively correlated (Fig. 2) while shows positive correlation with OC and Ca (0.943 and 0.964).

Discussion

Saline desert of India (Little Rann of Kutch) is highly saline and salinity has negative effects on the vegetation except some salt tolerant species for example *Prosopis juliflora* (Sw.) DC, *Salvadora oleoides* Decne., *Aeluropus lagopoides* (Linn.), *Cressa cretica* Linn. etc. Salt stress is a worldwide problem, and high concentrations of salts have harmful effects on plant growth (Garg and Gupta, 1997; Mer *et al.,* 2000; Vaghasiya *et al.,* 2015) and extreme concentrations kill growing plants (Donahue *et al*., 1983). Bernstein (1962) and Garg and Gupta (1997) reported retardation of germination and growth of seedlings at high salinity. However, plant species differ in their sensitivity or tolerance to salts (Troech and Thompson, 1993; Brady and Weil, 1996).

Mechanism of tolerance involve the capability to decrease the ionic stress on the plant by diminishing the amount of Na^+ that gathered in the cytosol, predominantly those in the transpiring leaves. This process involves up and down regulation of the expression of

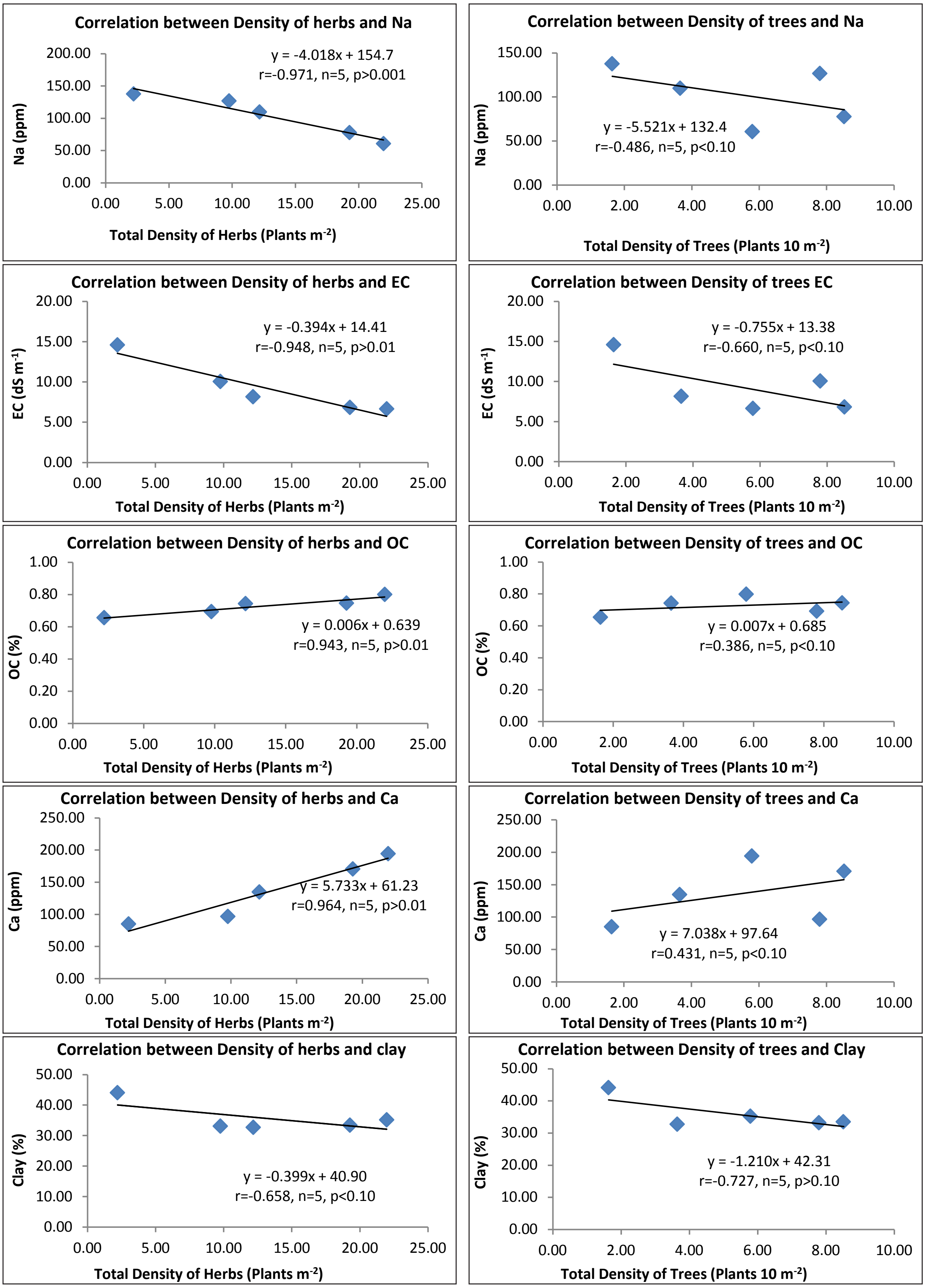

Fig. 2. Correlation between different parameters of soil and vegetation.

specific ion channels and transporters, allowing the control of Na^+ transport (Munns and Tester, 2008; Rajendran *et al.*, 2009). A malfunction in Na^+ exclusion from roots manifests its toxic effect, depending on the species (Munns and Tester, 2008). SOS (Salt Overly Sensitive) proteins are sensor for calcium signal that turn on the machinery for Na^+ export and K^+/Na^+ discrimination (Zhu, 2007). SOS1, encoding a plasma membrane Na^+/H^+ anti-porter, plays a critical role in Na^+ extrusion and controls long-distance Na^+ transport from the root to shoot (Shi *et al.*, 2000; Shi *et al.*, 2002). This anti-porter forms one component in a mechanism based on sensing of the salt stress that involves an increase of cytosolic (Ca^{2+}), protein interactions and reversible phosphorylation with SOS1 acting in concert with other two proteins known as SOS2 and SOS3 (Oh *et al.*, 2010). Increase in cytosolic (Ca^{2+}) is sensed by SOS3 which activates SOS2. The activated SOS3-SOS2 protein complex phosphorylates SOS1, the plasma membrane Na^+/H^+ antiporter, resulting in the efflux of Na^+ ions. Salt stress can also induce the accumulation of ABA, which, by means of ABI1 and ABI2, can negatively regulate SOS2 or SOS1 and NHX1 (Silva and Gerós, 2009; Carillo *et al.,* 2011).

In the present investigation sites zinc, copper and lead were found in the ranges of 9.2 to 53.1, 6.8 to 22.2 and 48.2 to 67.3 mg kg^{-1}. Zinc, copper and lead was found to be 65, 17 and 18 mg kg^{-1} in agriculture soil of Sweden and 89, 48 and 24 mg kg^{-1} in agriculture soil of Japan (Eriksson, 2001; Takeda *et al.*, 2004; Pendias, 2011). World average soil content of zinc, copper and lead were found to be 70, 38.9 and 27 mg kg^{-1} (Pendias and Pendias, 1999; Pendias, 2011), Francek (1992) calculated median soil-lead concentration in roadside soils in a rural community of Mt. Pleasant, of 280 mg kg^{-1} (range: 100 to 840 mg kg^{-1}) and 200 mg kg^{-1} (range: 100 to 220 mg kg^{-1}) in background soils.

Lead (69.039 mg kg^{-1}) and clay (44.172%) both were found to be maximum at upper and middle layer of soil (Site 3), and suggests that clay particles restricts the mobility of the lead. The Pb can vary considerably from one soil type to another. Pb is associated mainly with clay minerals (Riffaldi *et al.*, 1976; Tidball, 1976; Schnitzer and Kerndorff, 1981). At semi desert of Utah, carbon and nitrogen concentration decreases in from surface to subsoil (Charley and West, 2010). High EC and clay affects vegetation negatively and are harmful for the growth of the vegetation (Pilania and Panchal, 2014) and the same type of result was found during this study. EC and Na were found to be as high as 14.581 dS m^{-1} and 137.310 mg kg^{-1}. In addition, high concentrations of Na^+ the availability and uptake of nutrients by plants in saline soils are affected by many factors in the soil-plant environment. The solid phase of the soil and the concentration and composition of solutes in the soil solution control the activity of the nutrient ion. Soil solution pH will influence the speciation and thus availability of certain nutrients (Patel *et al.*, 2011). Parejiya *et al.* (2015) found about 20 species for each studied site at Bandiyabedi forest grassland of Surendranagar district in Gujarat (India); Pilania *et al.* (2014a) documented 65 species of 57 genera belonging to 31 families at Tropical dry deciduous forest of Dahod district of Gujarat and Pilania *et al.* (2014b) documented 80 species belonging to 37 families at home gardens of south Gujarat; which shows that this saline desert have low species richness so major steps are required to increase the vegetation. At Site 3 pH, OC and Ca are low while Na is high with low density and species richness compare to other sites. So it might be possible that pH is affecting the vegetation of this area. Sources of H^+ ions in soil solution consist of carbonic acid produced when carbon dioxide (CO_2) from decomposing organic matter, root respiration, and the soil atmosphere is dissolved in the soil water. Other sources of H^+ ions are root discharge, reaction of aluminum ions (Al^{+3}) with water, nitrification of ammonium from fertilizers and organic matter mineralization. Certain soils are more resistant to a drop or rise in pH. Therefore, the lime requirement, which is the quantity of limestone ($CaCO_3$) required raising the pH (Smith and Doran, 1996). Microaggregates are considered to be the storeroom of the most stable C pool in soils (Edwards and Bremner, 1967; Six *et al.*, 2000; Kong *et al.*, 2005). But during this study the observations were different and it might be due to the high salinity content. Increase in C content from surface to depth due to large macroaggregates (Horn and Smucker, 2005; Park and Smucker, 2005). Same increase of C content from surface to depth was obtained at Sites 1, 2, 3 and 5 except at Site 4; at Site 4 high concentration of Na was obtained which might be affecting this process.

Table 4. Vegetation analysis at different sites of Little Rann of Kutch i.e. Saline Desert

Sites →	Site 1	Site 2	Site 3	Site 4	Site 5
Herbs					
Total density (plants m^{-2})	9.75 ± 0.77	19.27 ± 0.33	2.20 ± 0.19	12.17 ± 1.08	21.96 ± 0.51
Total species	12	46	9	13	35
Dominant species	*Cenchrus ciliaris* Linn. *Aeluropus lagopoides* Linn.	*Aeluropus lagopoides* Linn. *Cressa cretica* Linn.	*Cressa cretica* Linn. *Argemone mexicana* Linn.	*Aristida adscensionis* Linn. *Heteropogon contortus* Linn.	*Cyperus rotundus* Linn. *Aeluropus lagopoides* Linn.
Shrubs and trees					
Total density (plants 10 m^{-2})	7.79 ± 0.77	8.51 ± 0.78	1.63 ± 0.64	3.65 ± 1.29	5.79 ± 0.80
Total species	3	11	2	2	6
Dominant species	*Prosopis juliflora* (Sw.) DC. *Ziziphus nummularia* Burm.	*Prosopis juliflora* (Sw.) DC. *Ziziphus nummularia* Burm.	*Prosopis juliflora* (Sw.) DC. *Salvadora persica* Linn.	*Prosopis juliflora* (Sw.) DC. *Ziziphus nummularia* Burm.	*Prosopis juliflora* (Sw.) DC. Acacia nilotica Linn.

In this study average value for WHC, FC, OC and N were 29.683, 24.065, 0.726 and 0.062% while Panchal and Pandey (2002) found that in Saurashtra Region near Little Rann of Kutch of Gujarat WHC, FC, OC and N were 26.4, 20.2, 0.43 and 0.008%. They mentioned that soil salinity increases with degradation of soil or desertification. Spatial variability of soil physical and chemical properties at a large scale is mainly due to geological, geomorophological and pedological soil forming factors that could be altered and induced by other factors such as land use managements. Therefore, it is essential to study the extent of spatial variability at soil surface (Motaghian *et al.,* 2008). At Site 5, high concentration of Ca (194.218 mg kg^{-1}) with high plant density was found, and this suggests that Ca have negative effects on salinity. The addition of calcium to the soil (as gypsum or lime) displaces Na^+ from clay particles. This prevents the clay from swelling and dispersing (Sumner, 1993) and also makes it possible for Na^+ to be leached deeper into the soil. Thus, exogenously supplied calcium not only improves soil structure, but also alters soil properties in various ways (Shabala *et al.,* 2003) that benefit the plant growth.

Conclusion

Deficiency of essential nutrients and high concentration of salinity and Na in soil is prone to low plant species richness and density; this type of soil can furnish limited number of species and vegetation. Much of growth reduction associated with salinity is due to high Na^+ and low Ca^{2+} levels in this region, thus escalating Ca^{2+} concentration diminish the uptake of Na^+ and amplify Ca^{2+} uptake, consequently decreasing Na^+ toxicity. To combat desertification; require holistic approaches towards sustainable management and plantation of inhabitant, salt tolerent and dominant species like *Cressa cretica* Linn., *Capparis deciduas* (Forsk.), *Acacia nilotica* (Linn.), *etc* with supplying crucial nutrients.

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