Anales de Biología 38: 81-90, 2016
DOI: http://dx.doi.org/10.6018/analesbio.38.08

ARTICLE

Influence of soil properties on plant density and species richness of saline desert

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Received: 8 January 2016
Accepted: 29 April 2016
Published on-line: 7 June 2016

Resumen

Influencia de las propiedades del suelo en la densidad de plantas y la riqueza de especies de desierto salino

El ambiente edáfico tiene una significativa influencia en la productividad. La salinidad es uno de los principales factores que afectan negativamente a la vegetación. Se estudió un ecosistema desértico de la India (Pequeño Rann de Kutch; 7020 ha) para medir la influencia de las propiedades del suelo en la vegetación. Tanto la riqueza de especies (SR) como la densidad de hierbas y arbustos/árboles (17.018 plantas m^{-2} y 8.617 plantas 10 m^{-2}) fueron mayores en el punto 4, con valores altos de OC, OM, N, P, Ca y Fe (0.684, 1.179, 0.059 %, 42.338 kg ha^{-1}, 170.732, 32.016 mg kg^{-1}) y bajos niveles de arcilla, EC y Na (33.654%, 9.441dSm^{-1} y 68.699 mg kg^{-1}). Valores altos de arcilla, Na y EC con bajo Ca y Fe resultaron en bajas densidades de SR (lugares 2 y 5). Las bajas SR y densidad se deben a bajas concentraciones de OC, OM, N, P, Fe, Ca y alta concentración de arcilla, Na y EC.

Palabras clave: Calcio, Desierto, Salinidad, Suelo, Sodio, Vegetación.

Abstract

Soil environment have significant influence on the productivity of land. Salinity is one of the major factors which negatively affect the vegetation. To measure the influence of soil properties on vegetation, desert ecosystem in India (Little Rann of Kutch of 7020 ha) was studied. Species richness (SR) as well as density for herbs and shrubs/tree (17.018 plants m^{-2} and 8.617 plants 10m^{-2}) was highest in the site 4, with high OC, OM, N, P, Ca and Fe (0.684, 1.179, 0.059 %, 42.338 kg ha^{-1}, 170.732 and 32.016 mg kg^{-1}) and low clay, EC and Na (33.654%, 9.441dSm^{-1} and 68.699 mg kg^{-1}). High amount of clay, Na and EC with low Ca and Fe results into low density with low SR (site 2 and 5). Low SR and density are due to low concentration of OC, OM, N, P, Fe, Ca and high concentration of clay, Na and EC.

Key words: Calcium, Desert, Salinity, Soil, Sodium, Vegetation.

Introduction

Soil salinization and sodification had been identified as a major cause of land degradation. Salt-affected areas increase at a high rate, by about two million hectares per year (Postel 1996). Soil and vegetation together are vital factors of any ecosystem. The risk of soil degradation depends on the total salt content and on the salt composition; especially in relation to sodium concentration.

Salinization is the augment of the soluble salt in the root zone of the soil while sodification is the increase of exchangeable sodium in the root zone of the soil. The two processes may operate concurrently and form saline-sodic soils. The distribution is relatively more extensive in the arid and semi-arid regions. Soil is a natural resource that is not renewable within a point of petite time scale. Responsiveness of erosion extent and intensity for determining principal strategies and most encouraging soil conservation, as well as control of erosion and sediment yield are matters of concern for researchers, so that they can envisage the spatial pattern and erosion hazards rates (Morgan 1996). The division of plant species in saline soil is closely related with soil water potentials and factors controlling the level of salinity stress, including precipitation, depth of the water table (Ungar *et al.* 1979). Soils on landscape surfaces and good plant cover conditions may recover with time by accruing organic material, increasing floral and faunal activity, enhancing soil aggregate stability, increasing infiltration capacity, and decreasing erosion potential (Trimble 1990).

Vegetation cover is the chief factor to control soil degradation by water and wind erosion, the efficiency varies greatly with vegetation type and land cover. Soil erosion is expected to be more affected by changes vegetation cover than by runoff (Nearing *et al.* 2005).

The effect of vegetation on soil parameters have been known since the development of the concept of the factors of soil formation (Jenny 1941). Vegetation influences the soil by recycling different nutrients, which suggests that to increase the productivity of the land both soil and vegetation should be studied simultaneously.

The major goal of this study was to understand the inter-relation of soil (physical and chemical properties) and vegetation of the saline desert. 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., *Acacia nilotica* (Linn.), *Salvadora oleoides* Decne., *Aeluropus lagopoides* (Linn.), *Cressa cretica* Linn. etc. Salt stress is a worldwide problem, but is of special concern in arid and semi-arid regions. High concentrations of salts have harmful effects on plant growth (Mer *et al.* 2000; Vaghasiya *et al.* 2015) and excessive concentrations kill growing plants (Donahue *et al.* 1983). Many investigators have reported retardation of germination and growth of seedlings at high salinity (Garg and Gupta 1997).

Soil and vegetation degradation both are influenced by each other reduction in the perennial cover or vegetation cover is regarded as an indicator of the onset of desertification (Thornes 1996). All kinds of cover that secure against the erosive elements such as runoff, raindrop impacts and wind referred to as land cover. Type of land cover includes vegetation, stone, litter and gravel covers. Generally unnatural land use that diminishes the amount of land cover on an incline may cause severe erosion and sediment construction (Refahi 2006). With this alarm our aim was to study inter-relation of soil and vegetation and to identify the effect of different soil properties on plant density and species richness at the saline desert of western India soil.

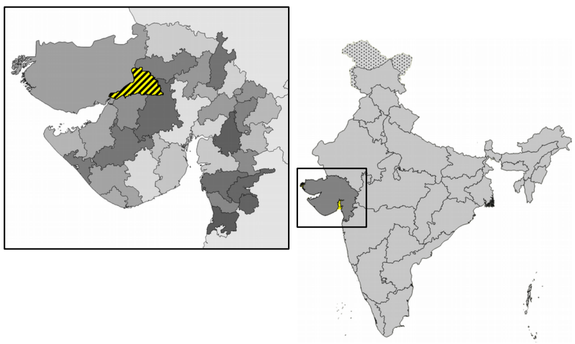

Figura 1. Zona de estudio en el Pequeño Rann de Kutch.
Figure 1. Study Area in Little Rann of Kutch.

Material and methods

Study Area

The study was conducted in India at Little Rann of Kutch (22º 55" to 24º 35" North latitudes and

70º 30" to 71º 45" East longitudes) known as "The Wild Ass Sanctuary", named after endangered ghudkhur (*Equs hemionus khur* Lesson, 1827). The Little Rann of Kutch (Fig. 1) occupies an area of 6979 sq km of which the Wild Ass Sanctuary encompassing 4953 sq km.

Soil Analysis

Collection of soil samples

Collections of samples were done in the months of mid June to October (2014). To represent the harsh condition of this area the ombro-thermic diagram is given (Fig. 2). Samples were randomly collected from five different sites (20, 16, 20, 64 and 36 samples from site one to five respectively), for three depths i.e., 0-15, 15-30 and 30-45 cm respectively. Soil samples were thoroughly mixed depth wise, and from the composite soil, one sample was drawn for each depth and brought to the laboratory. All these soil samples were air dried and stored in polyethylene bags to determine their physical and chemical properties. For soil aggregate analysis, soil samples were collected separately from each site. Due care was taken, specially, in sampling and in transportation to the laboratory, so that the soil aggregate should not be disturbed.

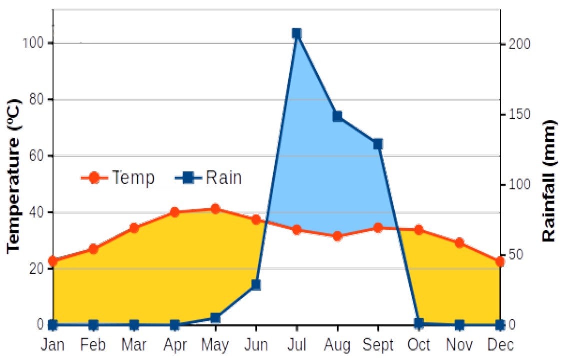

Figura 2. Diagrama ombrotémico del área de estudio, basado en los datos de temperatura y precipitaciones de diez años (2004-2014).

Figure 2. Ombro-thermic diagrams for study area based on temperature and rainfall data for ten years (2004 to 2014).

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. Soil weight in unit volume was computed to determine bulk density (BD). Particle density (PD) was measured by method given by USDA (Richards 1968). Value of bulk density was used to determine porosity (PO) of soil (Misra 1968) and expressed in percentage.

Soil Moisture Constants

Field Capacity (FC) and water holding capacity (WHC) was determined following Misra (1968) and the results are expressed in percentage of oven-dry weight (Oven-drying was done at 105 ºC temperature).

Analysis of Chemical Properties of Soil

Soil pH was measured by pH meter preparing soil paste with distilled water (1:5 ratio). Electrical Conductivity (EC) was measured by an EC meter (1:2 ratio). As per Jackson (1973), Organic carbon (OC), Organic matter (OM) and Nitrogen (N) were measured by using UV Visible spectrophotometer. Available Phosphorus (P) was measured by the method of Olsen *et al.* (1954). As per Lindsay and Norvell 1978, Potassium (K), Sodium (Na), Calcium (Ca), Zinc (Zn), Copper (Cu), Iron (Fe), Lead (Pb) and Manganese (Mn) were measured by Atomic Absorbance Spectrophotometer.

Vegetation analysis

Vegetation was quantitatively analyzed for density following Curtis and McIntosh (1950). Species richness (SR) was calculated as per Margalef 1958.

Results

Characterization of physical properties of soil

BD was maximum (Table 1) at site one (2.080 gcc^{-1}) while minimum at site four (1.765 gcc^{-1}). PD was highest at site two (3.313gcc^{-1}) while lowest at site five (2.612gcc^{-1}). At each site BD and PD was maximum at lower depths except at site two. PO maximum values obtained at upper layer of soil at sites one, three and four. FC and WHC were determined to know the soil moisture content of the soil and expressed in percentage of oven-dry weight. FC was highest at site four (22.935 %) while minimum at site one (20.114 %) and WHC was highest (37.152 %) at site one and lowest (24.254 %) at site four.

	Soil Depth		Site 1	Site 2	Site 3	Site 4	Site 5
BD (gcc^{-1})	0-15		2.065 ± 0.075	2.146 ± 0.075	1.853 ± 0.049	1.721 ± 0.052	1.756 ± 0.074
	15-30		2.047 ± 0.085	2.011 ± 0.043	1.961 ± 0.036	1.769 ± 0.045	1.845 ± 0.068
	30-45		2.127 ± 0.058	1.929 ± 0.049	1.931 ± 0.029	1.804 ± 0.047	1.855 ± 0.068
	Combined 0-45	Mean	2.080 ± 0.041	2.029 ± 0.034	1.915 ± 0.022	1.765 ± 0.028	1.818 ± 0.040
		Range	1.380 to 2.843	1.700 to 2.409	1.522 to 2.088	1.128 to 2.303	1.280 to 2.294
PD (gcc^{-1})	0-15		3.008 ± 0.188	3.695 ± 0.415	3.091 ± 0.240	2.681 ± 0.106	2.484 ± 0.106
	15-30		2.734 ± 0.223	2.940 ± 0.081	3.199 ± 0.213	2.740 ± 0.106	2.712 ± 0.051
	30-45		3.081 ± 0.204	3.305 ± 0.201	2.978 ± 0.253	2.618 ± 0.120	2.639 ± 0.119
	Combined 0-45	Mean	2.941 ± 0.116	3.313 ± 0.156	3.089 ± 0.131	2.679 ± 0.063	2.612 ± 0.055
		Range	1.642 to 4.926	2.008 to 5.814	1.799 to 4.329	1.597 to 4.762	1.783 to 4.831
PO (%)	0-15		31.568 ± 3.478	35.864 ± 5.265	35.974 ± 3.965	33.936 ± 2.213	29.689 ± 2.083
	15-30		24.453 ± 2.790	31.328 ± 1.337	35.230 ± 3.895	32.888 ± 2.007	32.083 ± 2.011
	30-45		28.139 ± 2.927	41.090 ± 4.290	30.870 ± 4.340	28.628 ± 2.138	28.613 ± 1.791
	Combined 0-45	Mean	28.053 ± 1.753	36.094 ± 2.277	34.024 ± 2.271	31.817 ± 1.223	30.128 ± 1.119
		Range	10.190 to 58.625	17.846 to 66.364	13.012 to 55.194	10.005 to 62.460	15.435 to 67.369
FC (%)	0-15		18.644 ± 1.033	26.459 ± 1.861	22.115 ± 0.481	22.491 ± 0.450	20.259 ± 1.095
	15-30		18.852 ± 0.828	22.862 ± 1.548	20.903 ± 0.231	21.692 ± 0.575	19.050 ± 1.023
	30-45		22.846 ± 1.561	17.927 ± 1.379	20.797 ± 1.405	24.621 ± 1.131	21.595 ± 1.241
	Combined 0-45	Mean	20.114 ± 0.712	22.416 ± 1.049	21.272 ± 0.487	22.935 ± 0.438	20.301 ± 0.643
		Range	10.968 to 34.016	13.434 to 38.686	16.031 to 30.788	11.847 to 38.267	12.399 to 37.806
WHC (%)	0-15		33.089 ± 2.365	26.467 ± 0.464	28.187 ± 0.726	24.622 ± 0.549	27.261 ± 0.881
	15-30		40.578 ± 2.552	24.780 ± 1.239	28.125 ± 0.553	23.957 ± 0.512	27.443 ± 1.521
	30-45		37.790 ± 3.098	25.103 ± 0.844	27.596 ± 0.241	24.183 ± 0.463	27.858 ± 1.236
	Combined 0-45	Mean	37.152 ± 1.553	25.450 ± 0.509	27.969 ± 0.303	24.254 ± 0.281	27.520 ± 0.699
		Range	19.662 to 52.502	19.214 to 31.140	24.721 to 33.562	16.986 to 33.567	19.214 to 49.069

Tabla 1. Descripción de propiedades físicas del suelo en diferentes lugares y profundidades. BD=Densidad aparente, PD=Densidad de partículas, PO=Porosidad, FC=Capacidad de campo, WHC=Capacidad de carga hídrica; se proporcionan la media y rango, por separado, para profundidades de 0-45 cm.

Table 1. Descriptive of physical properties of soil at different sites and soil depths. BD=Bulk density, PD= Particle density, PO= Porosity, FC= Field capacity, WHC= Water holding capacity; separate mean and range is given for 0-45 cm depth.

Characterization of soil texture and soil aggregate

Site one, three and four contain clay loam type while site two and five contain clay type texture. Maximum values of sand (35.238 %), clay (44.160 %) and silt (40.335 %) was found at site four, two and one while minimum value for sand (26.067 %) and clay (33.589 %) at site one and for silt (27.569 %) at site two (Table 2). High amount of large macro-aggregate was at lower depths except at site three.

Characterization of chemical properties of soil

Correlation of Na and Ca was negative (-0.696) and positive correlation of K and Zn (0.737) (Fig. 3). pH (Table 3) was maximum at site one (9.036) while minimum at site five (7.796). EC was maximum at site two (14.031 dSm^{-1}) followed by site three (13.171 dSm_{-1}) while minimum at site four (9.441 dSm^{-1}). OC (0.684 %), OM (1.179 %), N (0.059 %) and P (42.338 kg ha^{-1}) were maximum at site four, while OC (0.605 %), OM (1.042 %) and N (0.052 %) were minimum at site two and P (36.031 kg ha^{-1}) at site five. K was maximum at site one (873.672 mg kg^{-1}) and minimum at site four (53.118 mg kg^{-1}). Ca was maximum at site one and four (170.923 and 170.732 mg kg^{-1}) while minimum at site two and five (51.989 and 91.120 mg kg^{-1}). Na was maximum at site two and five (166.149 and 141.128 mg kg^{-1}) while minimum at site four and one (68.699 and 72.380 mg kg^{-1}). Zn was maximum at site two and minimum at site one. Cu (22.460 mg kg^{-1}), Fe (48.053 mg kg^{-1}) and Mn (38.565 mg kg^{-1}) were maximum at site three while Cu and Fe (18.061 and 19.577 mg kg^{-1}) were minimum at site two and Mn (24.799 mg kg^{-1}) at site four. Pb was maximum at site five (48.843 mg kg^{-1}) and minimum at site three (42.932 mg kg^{-1}).

	Soil Depth		Site 1	Site 2	Site 3	Site 4	Site 5
Sand (%)	0-15		25.732 ± 0.723	28.836 ± 0.502	33.405 ± 1.884	35.049 ± 1.684	28.406 ± 0.266
	15-30		26.439 ± 0.767	28.279 ± 0.762	33.991 ± 2.076	35.311 ± 1.733	28.048 ± 0.344
	30-45		26.056 ± 0.067	27.457 ± 0.751	34.223 ± 2.152	35.354 ± 1.776	27.657 ± 0.293
	Combined 0-45	Mean	26.076 ± 0.315	28.191 ± 0.366	33.873 ± 1.028	35.238 ± 0.959	28.037 ± 0.172
		Range	23.974 to 28.227	26.202 to 30.332	28.007 to 38.040	22.980 to 42.127	25.202 to 29.332
Silt (%)	0-15		39.900 ± 2.939	27.378 ± 0.498	29.998 ± 1.302	31.359 ± 1.705	27.671 ± 0.280
	15-30		38.356 ± 2.557	26.900 ± 1.268	28.412 ± 1.209	31.102 ± 1.643	27.569 ± 0.593
	30-45		42.748 ± 1.177	28.430 ± 0.641	29.799 ± 1.854	30.864 ± 1.719	28.258 ± 0.332
	Combined 0-45	Mean	40.335 ± 1.265	27.569 ± 0.457	29.403 ± 0.765	31.108 ± 0.936	27.833 ± 0.234
		Range	32.018 to 46.024	23.947 to 29.908	25.994 to 36.008	24.026 to 49.018	22.947 to 28.908
Clay (%)	0-15		34.368 ± 2.753	43.786 ± 0.034	35.778 ± 0.587	33.591 ± 1.295	43.923 ± 0.107
	15-30		35.204 ± 2.524	44.821 ± 0.595	36.196 ± 0.493	33.587 ± 1.287	44.383 ± 0.297
	30-45		31.196 ± 1.189	43.874 ± 0.818	35.979 ± 0.543	33.782 ± 1.347	44.086 ± 0.364
	Combined 0-45	Mean	33.589 ± 1.216	44.160 ± 0.311	35.984 ± 0.276	33.654 ± 0.725	44.131 ± 0.153
		Range	28.130 to 42.006	41.860 to 45.878	33.988 to 38.002	28.002 to 46.955	40.860 to 44.878
Large Macroaggregate (%)	0-15		7.209 ± 1.157	34.363 ± 3.056	58.646 ± 10.485	16.018 ± 4.512	21.256 ± 4.896
	15-30		17.584 ± 7.184	42.381 ± 8.588	43.003 ± 13.454	31.780 ± 7.736	26.911 ± 6.345
	30-45		11.757 ± 4.364	38.712 ± 9.521	54.002 ± 18.433	61.267 ± 8.789	25.857 ± 6.492
	Combined 0-45	Mean	12.183 ± 2.854	38.486 ± 4.095	51.884 ± 7.946	36.355 ± 4.923	24.675 ± 3.338
		Range	2.678 to 41.156	16.636 to 63.158	10.658 to97.285	0.926 to 95.223	2.582 to 63.158
Macroaggregate (%)	0-15		32.841 ± 5.076	25.075 ± 3.019	12.228 ± 3.091	31.338 ± 2.306	28.325 ± 3.519
	15-30		18.779 ± 2.784	23.320 ± 4.197	20.204 ± 5.178	26.167 ± 3.344	25.048 ± 3.011
	30-45		25.174 ± 5.475	22.428 ± 4.802	18.569 ± 5.674	13.487 ± 3.035	25.162 ± 4.072
	Combined 0-45	Mean	25.598 ± 2.776	23.608 ± 2.259	17.000 ± 2.739	23.664 ± 1.841	26.178 ± 2.027
		Range	7.263 to 63.811	7.878 to 51.601	0.312 to 51.540	0.339 to 56.129	7.268 to 70.460
Microaggregate (%)	0-15		6.777 ± 1.106	3.895 ± 0.501	4.225 ± 1.609	5.326 ± 0.469	5.544 ± 0.725
	15-30		8.821 ± 1.318	2.827 ± 0.554	4.147 ± 1.000	3.971 ± 0.330	5.880 ± 1.081
	30-45		8.300 ± 1.294	4.321 ± 0.676	3.003 ± 1.111	2.947 ± 0.287	6.012 ± 0.711
	Combined 0-45	Mean	7.966 ± 0.714	3.681 ± 0.341	3.792 ± 0.723	4.082 ± 0.224	5.812 ± 0.490
		Range	0.307 to 22.618	0.279 to 9.833	0.153 to 31.717	0.041 to 17.447	0.279 to 23.271

Tabla 2. Descripción de la textura del suelo y agregados en diferentes lugares y profundidades. Se proporcionan la media y rango, por separado, para profundidades de 0-45 cm; tamaño de agregados del suelo en mm.

Table 2. Description of soil texture and aggregate at different sites and soil depths. Separate mean and range is given for 0-45 cm depth; size of soil aggregate in mm.

Vegetation analysis at different sites

For herbs maximum species richness (Table 4) was found at site four (22) followed by site three while minimum at site two (five). Total density was found to be maximum (17.018 plants m^{-2}) at site four followed by site one (9.588 plants m^{-2}). Minimum density was found at site two and five (2.771 and 2.721 plants m^{-2}). For shrubs/trees maximum species richness was found at site three and four (8 species each) followed by site two and five. Density was maximum at site one and four ((8.875 and 8.617 plants $10m^{-2}$) while minimum at site two and five (4.688 and 4.719 plants $10m^{-2}$).

Inter-relation of Soil and Vegetation

Species richness and density for herbs and shrubs/tree was high at site four, with high amount of OC (0.684 %), OM (1.179 %), N (0.059 %), P (42.338kg ha^{-1}), Ca (170.732 mg kg^{-1}) and Fe (32.016 mg kg^{-1}) however low amount of clay (33.654 %), EC (9.441 dSm^{-1}) and Na (68.699 mg kg^{-1}) was found.

Density of herbs and shrubs/trees was low at site two and five with high amount of clay (44.160 and 44.131 %), Na (166.149 and 141.128 mg kg^{-1}) and EC (14.031 and 10.466 dSm^{-1}) while low amount of Ca (51.989 and 91.120 mg kg^{-1}) and Fe (19.577 and 25.740 mg kg^{-1}). Density of herbs and shrubs/trees with clay (-0.857 and -0.903) and sodium (-0.815 and -0.822) were negative correlated (Fig. 3) while positive correlated with calcium (0.861 and 0.952).

	Soil Depth		Site 1	Site 2	Site 3	Site 4	Site 5
pH	0-15		9.095 ± 0.247	7.828 ± 0.327	8.098 ± 0.072	7.685 ± 0.131	7.754 ± 0.155
	15-30		9.215 ± 0.203	7.817 ± 0.400	8.254 ± 0.033	7.811 ± 0.129	7.769 ± 0.174
	30-45		8.799 ± 0.039	8.442 ± 0.473	8.295 ± 0.042	7.977 ± 0.148	7.864 ± 0.187
	Combined 0-45	Mean	9.036 ± 0.103	8.029 ± 0.212	8.216 ± 0.034	7.824 ± 0.077	7.796 ± 0.093
		Range	8.557 to 9.977	7.297 to 9.253	7.860 to 8.403	7.047 to 9.060	7.297 to 9.253
EC (dSm^{-1})	0-15		9.640 ± 0.965	12.228 ± 1.979	14.193 ± 3.051	10.436 ± 1.741	10.523 ± 2.240
	15-30		9.380 ± 1.040	14.225 ± 3.074	13.453 ± 1.352	9.641 ± 1.786	10.837 ± 2.387
	30-45		12.327 ± 0.895	15.642 ± 1.224	11.867 ± 0.547	8.246 ± 1.686	10.037 ± 2.196
	Combined 0-45	Mean	10.449 ± 0.590	14.031 ± 1.145	13.171 ± 1.010	9.441 ± 0.971	10.466 ± 1.220
		Range	5.333 to 15.067	5.133 to 18.067	7.800 to 25.067	0.593 to 21.000	2.800 to 19.033
OC (%)	0-15		0.643 ± 0.140	0.549 ± 0.043	0.632 ± 0.021	0.662 ± 0.018	0.658 ± 0.051
	15-30		0.580 ± 0.160	0.643 ± 0.053	0.517 ± 0.022	0.706 ± 0.017	0.704 ± 0.026
	30-45		0.595 ± 0.113	0.622 ± 0.025	0.672 ± 0.041	0.684 ± 0.019	0.637 ± 0.006
	Combined 0-45	Mean	0.606 ± 0.075	0.605 ± 0.024	0.607 ± 0.019	0.684 ± 0.010	0.667 ± 0.019
		Range	0.130 to 0.945	0.358 to 0.836	0.360 to 0.868	0.348 to 1.043	0.554 to 1.966
OM (%)	0-15		1.109 ± 0.241	0.947 ± 0.074	1.090 ± 0.037	1.141 ± 0.030	1.135 ± 0.088
	15-30		1.000 ± 0.277	1.108 ± 0.091	0.890 ± 0.038	1.217 ± 0.029	1.214 ± 0.044
	30-45		1.026 ± 0.194	1.072 ± 0.043	1.158 ± 0.071	1.180 ± 0.034	1.099 ± 0.010
	Combined 0-45	Mean	1.045 ± 0.129	1.042 ± 0.041	1.046 ± 0.034	1.179 ± 0.018	1.149 ± 0.033
		Range	0.225 to 1.629	0.618 to 1.442	0.620 to 1.496	0.599 to 1.798	0.955 to 3.389
N (%)	0-15		0.055 ± 0.012	0.047 ± 0.004	0.055 ± 0.002	0.057 ± 0.002	0.057 ± 0.004
	15-30		0.050 ± 0.014	0.055 ± 0.005	0.045 ± 0.002	0.061 ± 0.001	0.061 ± 0.002
	30-45		0.051 ± 0.010	0.054 ± 0.002	0.058 ± 0.004	0.059 ± 0.002	0.055 ± 0.001
	Combined 0-45	Mean	0.052 ± 0.006	0.052 ± 0.002	0.052 ± 0.002	0.059 ± 0.001	0.057 ± 0.002
		Range	0.011 to 0.081	0.031 to 0.072	0.031 to 0.075	0.030 to 0.090	0.048 to 0.169
P ($kg\ ha^{-1}$)	0-15		40.975 ± 3.353	40.587 ± 0.770	37.723 ± 0.942	38.461 ± 0.437	32.381 ± 0.529
	15-30		38.123 ± 3.539	43.026 ± 0.975	42.376 ± 1.083	43.151 ± 0.468	37.162 ± 0.657
	30-45		39.324 ± 3.411	40.775 ± 0.525	46.178 ± 0.717	45.403 ± 0.712	38.551 ± 0.979
	Combined 0-45	Mean	39.474 ± 1.863	41.463 ± 0.462	42.092 ± 0.738	42.338 ± 0.396	36.031 ± 0.512
		Range	27.767 to 49.530	37.523 to 48.029	32.270 to 51.031	33.020 to 53.283	28.517 to 45.028
K ($mg\ kg^{-1}$)	0-15		877.466 ± 15.727	728.838 ± 106.434	773.005 ± 69.673	54.129 ± 0.871	717.305 ± 54.315
	15-30		882.108 ± 11.418	838.064 ± 19.635	792.488 ± 77.586	53.071 ± 0.879	753.111 ± 51.682
	30-45		861.443 ± 22.200	789.876 ± 23.467	610.926 ± 17.324	52.154 ± 1.401	779.561 ± 25.362
	Combined 0-45	Mean	873.672 ± 8.837	785.592 ± 33.337	725.473 ± 36.830	53.118 ± 0.608	749.992 ± 24.930
		Range	773.471 to 907.223	425.546 to 918.522	568.939 to 932.192	35.767 to 59.391	416.334 to 918.522
Ca ($mg\ kg^{-1}$)	0-15		169.811 ± 5.451	69.182 ± 20.355	122.220 ± 10.572	162.786 ± 7.882	84.735 ± 4.039
	15-30		177.788 ± 7.357	43.934 ± 7.883	116.490 ± 6.732	173.251 ± 7.050	88.849 ± 4.256
	30-45		165.169 ± 1.643	42.849 ± 1.762	109.025 ± 6.160	176.161 ± 8.869	99.777 ± 5.071
	Combined 0-45	Mean	170.923 ± 2.997	51.989 ± 6.993	115.912 ± 4.270	170.732 ± 4.486	91.120 ± 2.681
		Range	155.689 to 192.701	27.110 to 127.851	86.060 to 146.466	98.544 to 214.569	65.544 to 124.200
Na ($mg\ kg^{-1}$)	0-15		74.612 ± 4.975	166.062 ± 4.472	69.784 ± 8.435	70.332 ± 4.572	142.578 ± 11.472
	15-30		74.228 ± 4.368	171.318 ± 5.684	79.993 ± 4.166	67.587 ± 5.143	139.814 ± 10.798
	30-45		68.300 ± 2.376	161.067 ± 7.893	77.222 ± 7.368	68.179 ± 4.386	140.990 ± 10.268
	Combined 0-45	Mean	72.380 ± 2.164	166.149 ± 3.209	75.667 ± 3.629	68.699 ± 2.613	141.128 ± 5.815
		Range	63.417 to 92.001	147.232 to 182.733	46.523 to 98.072	37.597 to 105.781	108.669 to 201.986
Zn ($mg\ kg^{-1}$)	0-15		7.363 ± 1.856	25.194 ± 1.428	21.503 ± 0.714	19.429 ± 1.770	22.361 ± 2.368
	15-30		8.678 ± 1.677	25.366 ± 1.257	25.370 ± 1.503	19.824 ± 1.779	22.383 ± 2.321
	30-45		5.638 ± 0.348	25.894 ± 2.205	22.926 ± 1.595	19.924 ± 1.799	19.810 ± 2.553
	Combined 0-45	Mean	7.227 ± 0.796	25.485 ± 0.817	23.266 ± 0.779	19.726 ± 0.987	21.518 ± 1.313
		Range	1.473 to 13.422	20.126 to 30.791	20.172 to 28.839	3.660 to 30.521	6.105 to 32.521
Cu ($mg\ kg^{-1}$)	0-15		20.623 ± 0.070	17.085 ± 1.737	20.549 ± 3.761	20.865 ± 2.469	16.523 ± 2.573
	15-30		20.630 ± 0.103	17.694 ± 1.136	20.977 ± 3.675	23.086 ± 1.855	19.773 ± 3.173
	30-45		20.620 ± 0.064	19.404 ± 1.102	25.854 ± 1.599	23.017 ± 2.263	17.913 ± 2.744
	Combined 0-45	Mean	20.625 ± 0.041	18.061 ± 0.711	22.460 ± 1.704	22.323 ± 1.232	18.069 ± 1.541
		Range	20.222 to 20.785	14.642 to 22.237	6.975 to 31.285	4.852 to 43683	2.519 to 34.555

Tabla 3 *(sigue)*. Descripción de propiedades químicas del suelo en diferentes lugares y profundidades. EC= Conductividad eléctrica, OC= Carbono orgánico, OM= Materia orgánica, N= Nitrógeno total, P= Fósforo disponible, K= Potasio, Ca= Calcium total, Na= Sodio, Zn= Zinc, Cu= Cobre, Fe= Hierro, Pb= plomo, Mn =Manganeso; se proporcionan la media y rango, por separado, para profundidades de 0-45 cm.

Table 3 *(continues)*. Description of chemical properties of soil at different sites and soil depths. EC= Electrical conductivity, OC= Organic carbon, OM= Organic matter, N= Total nitrogen, P= Available phosphorous, K= Potassium, Ca= Total calcium, Na= Sodium, Zn= Zinc, Cu= Copper, Fe= Iron, Pb= Lead, Mn =Manganese; separate mean and Range is given for 0-45 cm depth.

	Soil Depth		Site 1	Site 2	Site 3	Site 4	Site 5
Fe (mg kg^{-1})	0-15		25.868 ± 0.504	17.201 ± 0.766	46.517 ± 5.933	33.344 ± 2.923	26.845 ± 3.577
	15-30		27.184 ± 1.760	20.735 ± 4.645	46.255 ± 5.450	31.367 ± 2.802	25.995 ± 3.217
	30-45		24.983 ± 0.296	20.796 ± 3.428	51.386 ± 5.506	31.336 ± 2.610	24.382 ± 2.948
	Combined 0-45	Mean	26.012 ± 0.584	19.577 ± 1.692	48.053 ± 2.890	32.016 ± 1.545	25.740 ± 1.754
		Range	24.428 to 34.200	15.083 to 34.496	32.212 to 60.896	11.501 to 53.327	10.031 to 40.819
Pb (mg kg^{-1})	0-15		40.476 ± 6.987	43.486 ± 6.597	51.053 ± 13.867	46.008 ± 4.266	51.691 ± 8.524
	15-30		49.732 ± 5.648	43.396 ± 6.384	37.323 ± 6.685	43.507 ± 5.023	44.202 ± 4.837
	30-45		40.280 ± 5.390	47.640 ± 6.118	40.421 ± 8.638	47.849 ± 5.051	50.635 ± 7.048
	Combined 0-45	Mean	43.496 ± 3.233	44.840 ± 3.129	42.932 ± 5.326	45.788 ± 2.666	48.843 ± 3.783
		Range	27.198 to 60.218	24.287 to 59.659	24.524 to 97.829	16.336 to 94.303	13.425 to 99.869
Mn (mg kg^{-1})	0-15		36.012 ± 3.056	31.093 ± 6.066	38.164 ± 1.929	24.637 ± 2.342	32.430 ± 3.035
	15-30		30.667 ± 3.158	30.124 ± 5.687	40.139 ± 1.195	25.970 ± 2.011	31.548 ± 2.691
	30-45		31.363 ± 1.792	37.253 ± 2.133	37.392 ± 2.873	23.791 ± 2.213	30.786 ± 2.740
	Combined 0-45	Mean	32.681 ± 1.499	32.823 ± 2.553	38.565 ± 1.100	24.799 ± 1.221	31.588 ± 1.518
		Range	24.330 to 47.057	13.353 to 41.704	31.154 to 46.250	7.825 to 40.343	13.353 to 41.704

Tabla 3. Descripción de propiedades químicas del suelo en diferentes lugares y profundidades. EC= Conductividad eléctrica, OC= Carbono orgánico, OM= Materia orgánica, N= Nitrógeno total, P= Fósforo disponible, K= Potasio, Ca= Calcium total, Na= Sodio, Zn= Zinc, Cu= Cobre, Fe= Hierro, Pb= plomo, Mn =Manganeso; se proporcionan la media y rango, por separado, para profundidades de 0-45 cm.

Table 3 *(continued)*. Description of chemical properties of soil at different sites and soil depths. EC= Electrical conductivity, OC= Organic carbon, OM= Organic matter, N= Total nitrogen, P= Available phosphorous, K= Potassium, Ca= Total calcium, Na= Sodium, Zn= Zinc, Cu= Copper, Fe= Iron, Pb= Lead, Mn =Manganese; separate mean and Range is given for 0-45 cm depth.

Discussion

Plant species differ in their sensitivity or tolerance to salts (Brady and Weil 1996). According to Roy *et al.* (1973) in the soil of Thar Desert of Rajasthan (India) clay content varies from 2 to 6 % in the surface soil and 4 to 8 % in the sub soil. Organic carbon content is very low, ranging from 0.08 to 0.20 % in the surface layer. Moisture retention capacity is very low and the soils are highly pervious. The surface, however, has a tendency to form a crust resulting in reduced infiltration. In this region calcium carbonate increases with the depth. In present study average clay content (38.303 %) was higher than silt (31.249 %) and sand (30.283 %) content. Organic carbon content ranges from 0.130 to 1.966 % and mean value were 0.633 %, this shows that saline (Little Rann of Kutch) and Thar Desert are not similar in soil texture and chemical constitutes.

At earlier study it was found that temperature and rainfall affects the salinity and vegetation of the soil (Pilania & Panchal 2013) of an area. Monsoon has a positive effect on the vegetation and soil properties. While natural hardy vegetation near the surface soil dries up in the dry season, deeper parts of its roots are sustained by moisture supply from the deep soil and with the first rains of the monsoon the desert springs up into life. Ramakrishna *et al.* (1966) have discussed in detail about the annual moisture regime variability and its impact on agriculture in Rajasthan desert.

Carbon and nitrogen decreases with the depth which shows conformations with the findings of Charley and West (2010) at semi desert of Utah; because more litter is added from the canopy and surface roots to the surface soil.

In this study plant density was found to be low with respect to high bulk density. The increase of soil bulk density is considered as an important early indicator of ecosystem degradation (Rubio and Bochet 1998) because it leads to further alteration of soil properties such as soil water infiltration and retention (Salihi and Norton 1987). In this area BD and PD were found to be high due to high content of clay and sodium. Highly saline and sodium induced soil reduces amount of water to pass through the root zone regardless of the amount of water actually in the root zone. The high Na concentration of a sodic soil not only injures plants directly but also degrades the soil. Due to salinity fine particles bind into aggregates. Due to high concentration of sodium in soil, clay platelet, soil dispersion and aggregate swelling takes place. This soil dispersion causes clay particles to close soil pores, which results to reduce soil permeability. Soil dispersion hardens soil and blocks water infiltration, making it diffi-

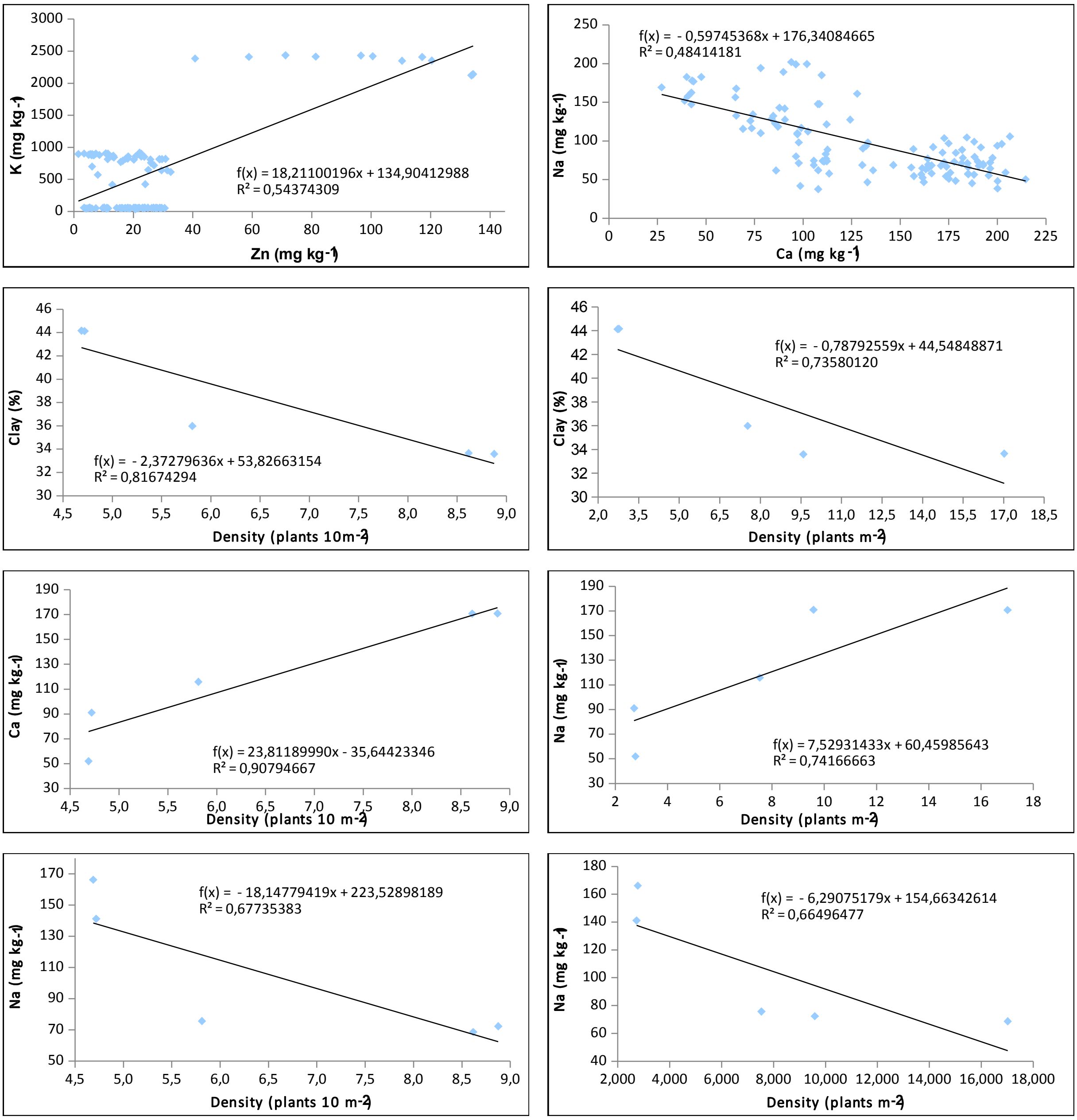

Figura 3. Correlación entre diferentes parámetros del suelo y vegetación en el Pequeño Rann de Kutch *i.e.* desierto salino.

Figure 3. Correlation between different parameters of soil and vegetation at Little Rann of Kutch *i.e.* saline desert.

cult for plants to establish and grow (Pilania *et al.* 2014c)

EC is the outcomes of the ions and it rises according to the content of soluble salts. EC is directly related to the soluble salts concentration of the soil like Na and Mg (Maiti 2003). High value of EC and high percentage of clay affects vegetation negatively and are harmful for vegetation (Pilania & Panchal 2014) and the same type of negative effect were found during this study. Panchal & Pandey (2002) mentioned that soil salinity increases with soil degradation 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. Parejiya *et al.* (2015) found approx 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

	Site 1	Site 2	Site 3	Site 4	Site 5
Herbs					
Total Density (plants m^{-2})	9.588 ± 1.23	2.771 ± 1.37	7.531 ± 0.65	17.018 ± 0.86	2.721 ± 0.78
Total Species	6	5	9	22	8
Shrubs / Trees					
Total Density (plants 10m^{-2})	8.875 ± 0.65	4.688 ± 0.4	5.813 ± 0.48	8.617 ± 0.88	4.719 ± 0.34
Total Species	3	11	2	5	2

Tabla 4. Análisis de la vegetación en los distintos lugares del Pequeño Rann de Kutch *i.e.* desierto salino.
Table 4. Vegetation analysis at different sites of Little Rann of Kutch i.e. Saline Desert.

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 one and four high concentration of Ca (170.923 and 170.732 mg kg^{-1}) and low Na (72.380 and 68.699 mg kg^{-1}) was found with maximum plant density, which suggests that Na have negative effects on salinity. The application of gypsum has long been considered a common exercise in reclamation of saline sodic and sodic soils (Marschner 1995). The addition of calcium to the soil (as lime or gypsum) 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. Moreover, an improved Ca/Na ratio in the soil solution enhances the capacity of roots to restrict Na^+ influx (Marschner 1995). Importance of interaction between Na and Ca was recognized after LaHaye and Epstein (1969) reported that exogenously supplied calcium may significantly alleviate detrimental effects of Na^+ on the physiological performance of hydroponically grown plants.

Conclusion

Soil with low concentration of OC, OM, N, P, Fe, Ca and high concentration of clay, Na and EC cause low species richness and density. Emergent of native and dominant species like *Cressa cretica* Linn., *Capparis deciduas* (Forsk.) Edgew., *Acacia nilotica* (Linn.) Del, etc. at fringe vicinity with furnishing necessary nutrients can facilitate to enhance green belt, improve soil structure and help to control the extension of desert condition.

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