SOIL-PLANT DEGRADATION AND THEIR INTER-RELATION AT SALINE DESERT ECOSYSTEM.

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Abstract

High salinity is contributing significantly to environmental degradation. Saline desert (Little Rann of Kutch of 4860 ha) was selected to study soil and vegetation. Soil was analyzed at different depth 0-15, 15-30 and 30-45cm. Maximum salinity was 24.033dSm⁻¹. Mean values for FC, WHC, OC, N, P, Ca, K and Na were 20.456%, 28.250%, 0.344%, 0.030%, 103.293mg kg⁻¹, 841.276mg kg⁻¹ and 144.395mg kg⁻¹. Calcium and herbaceous density (153.601mg kg⁻¹ and 0.646plants m⁻²) was maximum and sodium (65.490mg kg⁻¹) was minimum (site two). Results suggest that calcium have beneficial effect to overcome salinity and minimise the effect of sodium in the soil.

Introduction:

Salinity is one of the harshest environmental factors restraining the productivity of the land. Most vegetation is responsive to salinity caused by high concentrations of salts in the soil. Worldwide, it is estimated that nearly two billion hectares of biologically productive land have been rendered unproductive due to irreversible degradation (Vilanculos, 1994). The present rate of land degradation is estimated at 5 to 7 million hectares per year, suggesting that 0.3 to 0.5% of the world’s arable land is lost annually due to soil degradation (FAO, 1983; Vilanculos, 1994). So it is must to spotlight on the soil properties on a desert area so that the productivity can be improved.

The chief effect of salts on vegetation is, during increased osmotic pressure plants find it gradually more difficult to haul out water from the soil. This is the main cause of vegetative demur on saline areas, leading to many of the adverse environmental consequences of salinization of desert. Change in vegetation, either 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 and root zone salt levels varying according to rainfall pattern and the occurrence of periods of drying weather (Charman and Junor, 1989).

Soil characteristics manipulate the availability of water for plant use by controlling the infiltration and percolation of water (McAuliffe 2003). Such as, sandy soils allow for quick and deep movement of water (Walter 1979, Noy-Meir 1973, Sala et al., 1996, McAuliffe 1994, 2003). However, clay-rich soils have higher water holding capacity in shallow layers but tend to confine deep percolation (McAuliffe 1994, 2003). The deep percolation and storage of moisture in coarse-textured soils will supply a source of soil moisture for plants that is more importunate through time than the source of soil moisture that is found on fine-textured soil. The spatial and temporal distributions of soil moisture strongly influence vegetation composition, structure and productivity in arid and semiarid regions (McAuliffe 2003). The characteristics of divergent soil types are significant for plant carbon and water exchange (Smith et al.,1995; Hamerlynck et al., 2000, 2002, 2004; Huxman et al.,2004b,c) and at last ecosystem processes.
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(Huxman et al., 2004b, c; Potts et al., 2006). Soil and vegetation are mutually supporting each other. Diverse aspects of soil influence vegetation of any vicinity (Pilania and Panchal, 2014). Little Rann of Kutch is a salt marshland with soaring salinity (Gupta and Ansari, 2012). The key objectives of this research were to analyse the soils with different physical and chemical properties and their influence on vegetation.

Material and Methods:-

Study Area

The study was conducted in India at Little Rann of Kutch known as “The Wild Ass Sanctuary”, named after endangered Ghudkhur (Equus hemionus khur). It is situated between 22° 55’ to 24° 35’ North latitudes and 70° 30’ to 71° 45’ East longitudes.

Soil Analysis

Field analysis and collection of samples were done in the months of summer i.e. March, April May and half of June. Soil samples were randomly collected from 108 places from four different sites for three depths, namely, 0-15 cm, 15-30 cm and 30-45 cm.

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. For the analysis of bulk density (BD) a pit of 10 cubic cm was dug and soil was taken out and oven dried to a constant weight. Soil weight in unit volume was computed to determine bulk density. Particle density (PD) was measured by method given by USDA, 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°C temperature).

Analysis of Chemical Properties of Soil

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

Vegetation analysis

For each site the vegetation data were quantitatively analyzed for density following Curtis and McIntosh (1950) to identify the correlation between different parameters of soil.

Results:-

Characterization of soil properties at different depths

The results of soil test designated that the property varies from depth to depth (Table 1). The result is comprised from 0-15, 15-30, 30-45 cm as well as 0-45 cm depth to estimate a value for this region. The regional mean values for BD, PD, PO, FC and WHC were 2.097 g/cc, 2.994 g/cc, 26.854%, 20.456% and 28.250% respectively. BD, PD and FC (2.181 g/cc, 3.085 g/cc and 21.375%) were found maximum at 30-45 cm soil depth while PO (31.862%) was found to be maximum at upper layer of soil (0-15cm). The inherent soil texture change very slowly with depth. The average clay content (35.926%) was higher than silt and sand content (29.205 and 34.869%). However major difference was not obtained between these variables at different soil depths. Variables of soil aggregate show a major difference at various depths. Maximum values obtained for aggregate size greater than 2mm and 0.212 to 1mm. Fourteen different variables for chemical characters of soil at different soil depths were studied. More than 55% shows maximum values at upper layer of soil (0-15cm) while only 28% have maximum values at lower depth of soil (30-45cm). The regional mean value for EC, OC, N, P, Ca, K and Na were 12.322 dSm⁻¹, 0.344%, 0.030%, 9.428%, 0.038%, 0.012%, and 0.025% respectively.
Characterization of soil and vegetation properties at different sites
The average herbaceous density was maximum (0.646 plants m$^{-2}$) at site two while minimum (0.221 plants m$^{-2}$) at site four but species richness was maximum (23) at site three and minimum (3) at site two. The average tree/shrub density was maximum (1.839 plants 10m$^{-2}$) at 4 while minimum (0.600 plants 10m$^{-2}$) at site two but in case of trees species richness was maximum (6) at site four and minimum (3) at site three. The density of *Prosopis juliflora* (Sw.) was found to be 0.250, 0.688, 2.063 and 3.458 plants 10m$^{-2}$ at site one to four respectively.

A physical and chemical variable varies at different sites. High BD (2.191 g/cc$^{-1}$) and low porosity (25.169%) highly affects the herbaceous vegetation at site four. High PD (3.118 g/cc$^{-1}$), low FC and WHC (15.619 and 24.372%) negatively affects the tree’s density at site two. Sand (48.157%) and clay (44.057%) was found maximum at site two and four respectively while minimum values at vice versa. This suggests that soil texture affects the density of herbs and trees, as herbaceous or fibrous roots cannot penetrate deep inside the soil due to clustering of clay particles while tuberous or tap roots of trees may penetrate inside the soil.

Ca (153.601 mg kg$^{-1}$) and herbaceous density (0.646 plants m$^{-2}$) was maximum at site two and Na (65.490 mg kg$^{-1}$) was minimum, which suggests that Ca have beneficial effect to overcome salinity as well as on sodium content of the soil.

64% of the chemical variables at site three obtained greater values then others sites (site one, two and four). OC, OM, N, P, Zn, K, Cu, Fe, Na (0.368%, 0.635%, 0.032% and 25.541 kg ha$^{-1}$, 142.863, 939.921, 25.197, 111.884 and 227.407 mg kg$^{-1}$) were found to be maximum at site three. Maximum species richness (23) at site three obtained greater values then others sites (site one, two and four). Minimum species richness was maximum (6) at site four and minimum (3) at site three. The density of *Prosopis juliflora* (Sw.) was found to be 0.250, 0.688, 2.063 and 3.458 plants 10m$^{-2}$ at site one to four respectively.

EC (14.685 dSm$^{-1}$) was maximum at site four with lowest herbaceous density and highest tree density which indicates that total salinity effects more negatively to herbs than to trees. Positive correlation between Fe with density (0.993) was found at the study area.

Discussion:-
Saline soil (physical and chemical properties) and their influence on vegetation at saline desert of western India (Little Rann of Kutch) were studied. Physical and chemical value of soil varies depth as well as site wise (horizontally) and the soil factors affect the vegetation. Salinization of soil is more common in arid and semi-arid regions than in humid ones. The high salt content lowers osmotic potential of soil water and consequently the availability of soil water to plants. The salt-induced water deficit is one of the major constraints for plant growth in saline soils (Ramoliya *et al.* 2004). EC and Na were found to be as high as 24.033 dSm$^{-1}$ and 310.820 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 segment of the soil and the concentration and composition of solutes in the soil solution manage the activity of the nutrient ion. Soil solution pH influences the speciation and thus availability of firm nutrients (Patel *et al.* 2011).

Maximum Ca (153.601 mg kg$^{-1}$) and herbaceous density was obtained at site two, which suggests that Ca have detrimental effects on salinity. Application of gypsum has long been considered a common practice in reclamation of saline-sodic and sodic soils (Marschner 1995). Addition of calcium to the soil (as gypsum or lime) displaces Na$^+$ from clay particles. This prevents the clay from swelling and dispersing (Summer 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

kg ha$^{-1}$, 103.293 mg kg$^{-1}$, 841.276 mg kg$^{-1}$ and 144.395 mg kg$^{-1}$ respectively. EC and Na were found to be high (24.033 dSm$^{-1}$ and 310.820 mg kg$^{-1}$) due to the saline characteristics of the land. EC, OC, N, K and Na (14.291dSm$^{-1}$, 0.361%, 0.031%, 854.578 mg kg$^{-1}$ and 147.744 mg kg$^{-1}$) were found to be maximum at upper layer of soil (0-15 cm) depth. saline characters of soil is represented by high median and mode values of EC (11.000 and 21.000 dSm$^{-1}$) which is the combine effect of different salts of Na, Mn, K etc. Mn and Ca, Na and Ca, Ca and K show negative correlation of 0.448, 0.562 and 0.578 (Figure 1). K and Zn, Na and K show positive correlation of 0.961 and 0.923.
calcium may significantly alleviate detrimental effects of Na\(^+\) on the physiological performance of hydroponically grown plants.

In this study WHC, FC, OC and N were 28.250, 20.456, 0.344 and 0.030\% while Panchal and Pandey (2002) found that in Gujarat near Little Rann of Kutch (Saurashtra Region) WHC, FC, OC and N were 26.4, 20.2, 0.43 and 0.008\%. Some slight variations are found in these values due to environment, climatic conditions and topography of the soil. 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, geomorphological 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. The study conducted arid desert of Iran, shows that BD, Clay and Silt (1.18 g cm\(^{-1}\), 37.02\% and 44.02\%) by Motaghian \textit{et al.} 2008. Another study arid region (Azimzadeh \textit{et al.} 2008) of Iran shows that pH, EC, sand, silt, clay and OM (7.7, 2.5 dSm\(^{-1}\), 70\%, 18\%, 12\%, and 0.3\%) varies with the results of earlier scientists. This suggests that from site to site the results of soil variables at regional level.

In present study at different depth the soil variables vary and out of fourteen chemical variables more than 55\% shows maximum values at upper layer of soil (0-15 cm) while only 28\% have maximum values at lower depth of soil (30-45 cm).

OC, OM (0.368\%, 0.635\%) were found to be maximum at site three with high species richness (23) for herbs and low density. This observation shows that positive effect of OC and OM was minimised by salts of Na, K \textit{etc} and it was also found that Ca was also lowest at this site (91.839 mg kg\(^{-1}\)). According to Singh \textit{et al.} (1989) organic substances stimulate immobilization of nutrients in the soil biomass. Consequently, with depletion of organic substances, the conservation of nutrients is also reduced which results in the decline of nutrient status of soil. Nitrogen is added in the soil by decomposition of organic matter and nitrogen fixation by microbes. The reduction of organic substances may adversely influence the microbial activity with degradation of land. It is considered that the soil organic matter is the major pool of carbon and nutrients, and regulates to a large extent the physical, chemical and biological properties of soil (Miller, 1990; Gupta and Malik, 1996).

The concentration of salts of Na, K and Mg increases in soil with degradation. High concentration of salts in soil, in general, causes detrimental effects on plant growth (Bernstein, 1967; Kramer, 1983; Pandey and Thakrar, 1997; Mer \textit{et al.} 2000). As per Donahue \textit{et al.} (1983), excessive concentrations of salts may kill growing plants. Salinity appears to affect two plant processes \textit{i.e.} water and ionic relations (Cramer and Nowak, 1992). During the revelation to salinity, the plants experience water stress and during long-term revelation to salinity, the plants experience osmotic effects related to ionic effects. However, plant species differ in their sensitivity or tolerance to salts (Troech and Thompson, 1993). At earlier study small plots were studied at Little Rann of Kutch and it was found that high EC, pH and high percentage of clay affects vegetation negatively and are harmful for the growth of the vegetation (Pilania and Panchal 2014) and the same result was found during this recent study.

Temperature and rainfall affects the soil as well as vegetation (Pilania and Panchal, 2013b) of an area. Due to less rainfall and high temperature the salinity of the soil increases. The main reason behind less number of species and density of plants is that excess salinity in soil water can decrease plant available water and cause plant stress. Maximum salinity during dry periods which lowers the osmotic potential of soil water (Hirpara \textit{et al.} 2005) may also cause loss of vegetation in the saline area. Due to high concentration salinity reduces nitrogen accumulation in plants and imbalance of the uptake of the essential nutrients (Feigin 1985, Garg \textit{et al.} 1993). According to Zare \textit{et al.} (2011) increase in soil depth leads to increase in amount of sand, lime, gypsum, BD and soil hydraulic conductivity while EC, clay, silt, OM, FC, K and N decreased. Soil texture doesn’t show conformation with the findings of Zare \textit{et al.} (2011) but in case of EC, OM, K and N was found to be highest at the upper layer and shows conformations.

\textbf{Conclusion:-}

Species richness and density of herbs was found inversely proportionate. High density of \textit{Prosopis juliflora} (Sw.) and concentration of Na may allow to germinating plant but are not able to sustain therefore species richness was high and low density. On other hand low species richness and high density found due to less density of \textit{P. juliflora} and low concentration of Na and high concentration of Ca which allow germination of few species with sustainable growth as per niche pre-emption hypothesis and severe competition among species.
Table 1: Descriptive of Soil (Physical and Chemical variables) at different soil depths. (BD=Bulk density, PD=Particle density, PO=Porosity, FC=Field capacity, WHC=Water holding capacity, EC=Electrical conductivity, OC=Organic carbon, OM=Organic matter, N=Total nitrogen, P=Available phosphorous, Ca=Total calcium, Zn=Zinc, K=Potassium, Cu=Copper, Fe=Iron, Na=Sodium, Pb=Lead, Mn=Manganese, Size of soil aggregate is given in mm)

| Parameters | Soil Depth (cm) | Combined data from 0-45 cm soil depth |
|------------|----------------|-------------------------------------|
|            | 0-15           | 15-30                               | 30-45                               | Minimum | Maximum | Mean | Median | Mode |
| PHYSICAL PROPERTIES |                  |                                     |                                     |         |         |     |        |      |
| BD (gcc⁻¹) | 2.04 ± 0.05    | 2.06 ± 0.05                         | 2.18 ± 0.12                        | ± 0.02  | 2.84 ± 0.07 | ± 0.06 | ± 0.05 | 2.06   |
| PD (gcc⁻¹) | 3.03 ± 0.09    | 2.85 ± 0.06                         | 3.08 ± 0.05                        | ± 0.05  | 4.92 ± 0.29 | ± 0.09 | ± 0.10 | 2.89   |
| PO (%)     | 31.8 ± 1.3     | 26.3 ± 1.0                          | 27.7 ± 1.1                         | ± 0.12  | 58.62 ± 0.7  | ± 0.14 | ± 0.17 | 25.4   |
| FC (%)     | 20.0 ± 0.8     | 19.9 ± 0.7                          | 21.3 ± 0.8                         | ± 0.14  | 42.92 ± 0.4  | ± 0.18 | ± 0.22 | 18.0   |
| WHC (%)    | 27.9 ± 0.4     | 28.5 ± 0.6                          | 28.3 ± 0.8                         | ± 0.16  | 56.48 ± 0.3  | ± 0.2  | ± 0.26 | 25.8   |
| SOIL TEXTURE (%) |              |                                     |                                     |         |         |     |        |      |
| Sand (%)   | 35.2 ± 1.4     | 34.7 ± 1.4                          | 34.6 ± 1.5                         | ± 0.15  | 35.09 ± 0.9  | ± 0.2  | ± 0.3  | 34.9   |
| Clay (%)   | 35.8 ± 1.3     | 35.9 ± 1.3                          | 35.9 ± 1.3                         | ± 0.13  | 35.9 ± 1.3   | ± 0.13 | ± 0.15 | 34.0   |
| Silt (%)   | 28.8 ± 0.4     | 29.3 ± 0.6                          | 29.4 ± 0.4                         | ± 0.08  | 29.2 ± 0.4   | ± 0.09 | ± 0.28 | 27.9   |
| SOIL AGGREGATE (%) |         |                                     |                                     |         |         |     |        |      |
| >2         | 39.1 ± 0.6     | 36.8 ± 0.7                          | 31.3 ± 0.7                         | ± 0.14  | 35.8 ± 0.7   | ± 0.4  | ± 0.7  | 10.1   |
| 1-2        | 12.8 ± 0.5     | 11.3 ± 0.6                          | 13.4 ± 0.7                         | ± 0.19  | 35.9 ± 0.7   | ± 0.19 | ± 0.9  | 1.22   |
| 4-10       | 0.212 ± 0.2    | 0.30 ± 0.3                          | 0.34 ± 0.4                         | ± 0.08  | 36.4 ± 0.4   | ± 0.18 | ± 0.29 | 40.7   |
| 0.125-0.212  | 0.34 ± 0.3    | 0.91 ± 0.5                          | 0.76 ± 0.7                         | ± 0.07  | 2.01 ± 0.7   | ± 0.13 | ± 0.44 | 38.5   |
| 0.063-0.125 | 0.67 ± 0.7    | 0.91 ± 0.9                          | 0.32 ± 0.3                         | ± 0.03  | 9.16 ± 0.2   | ± 0.48 | ± 0.56 | 7.56   |
| <0.025     | 1.69 ± 0.4     | 1.67 ± 0.6                          | 1.26 ± 0.8                         | ± 0.16  | 7.21 ± 0.5   | ± 0.17 | ± 0.21 | 7.21   |
| CHEMICAL PROPERTIES |          |                                     |                                     |         |         |     |        |      |
| pH         | 8.24 ± 0.0     | 8.39 ± 0.0                          | 8.42 ± 0.0                         | ± 0.0   | 7.93 ± 0.1   | ± 0.0  | ± 0.0  | 7.93   |
| EC (dS/m)  | 14.2 ± 0.3     | 11.1 ± 0.1                          | 11.5 ± 0.1                         | ± 0.0   | 12.3 ± 0.1   | ± 0.0  | ± 0.0  | 21.0   |
| OC (%)     | 0.36 ± 0.0     | 0.32 ± 0.0                          | 0.35 ± 0.0                         | ± 0.0   | 0.92 ± 0.1   | ± 0.0  | ± 0.0  | 0.33   |
| OM (%)     | 0.62 ± 0.0     | 0.55 ± 0.1                          | 0.60 ± 0.0                         | ± 0.0   | 1.59 ± 0.1   | ± 0.0  | ± 0.0  | 0.58   |
| N (%)      | 0.03 ± 0.0     | 0.02 ± 0.0                          | 0.03 ± 0.0                         | ± 0.0   | 0.08 ± 0.0   | ± 0.0  | ± 0.0  | 0.02   |
| P (kg ha⁻¹) | 19.1 ± 0.5    | 23.6 ± 0.8                          | 25.3 ± 0.6                         | ± 0.2   | 36.02 ± 0.3  | ± 0.3  | ± 0.3  | 24.0   |
| Ca (mg)    | 102 ± 2.0      | 104 ± 2.5                           | 103 ± 2.7                          | ± 2.7   | 42.773 ± 8.11 | ± 2.4  | ± 2.4  | 51.9   |
| kg⁻¹ | 154 | 75 | 259 | 42 | 466 | 64 | 1 | 293 | 60 | 51 | 10 |
|------|-----|----|-----|----|-----|----|---|-----|----|----|----|
| Zn (mg kg⁻¹) | 77.1 ± 0.5 | 77.6 ± 0.7 | 77.5 ± 0.7 | 1.158 | 148.93 | 77.4 ± 0.6 | 42.8 | 66 | 30.0 | 06 |
| K (mg kg⁻¹) | 854. ± 2.5 | 841. ± 2.5 | 828. ± 2.3 | 50.159 | 1194.3 | 841. ± 2.4 | 867. | 792. | 811 |
| Cu (mg kg⁻¹) | 21.0 ± 1.3 | 21.9 ± 1.3 | 22.4 ± 1.2 | 2.519 | 45.966 | 21.8 ± 1.3 | 20.7 | 15.2 | 05 |
| Fe (mg kg⁻¹) | 82.8 ± 1.0 | 67.4 ± 1.8 | 69.4 ± 1.0 | 18.211 | 519.35 | 73.2 ± 1.2 | 63.0 | 43 | 47.5 | 30 |
| Na (mg kg⁻¹) | 147. ± 1.1 | 143. ± 1.0 | 141. ± 1.5 | 39.046 | 310.82 | 144. ± 1.2 | 99.4 | 80 | 55.3 | 78 |
| Pb (mg kg⁻¹) | 61.3 ± 2.1 | 60.3 ± 1.7 | 61.4 ± 1.2 | 26.723 | 134.07 | 61.0 ± 1.7 | 57.8 | 51.7 | 88 | 68 |
| Mn(mg kg⁻¹) | 35.3 ± 1.3 | 34.3 ± 1.2 | 33.5 ± 0.9 | 17.114 | 45.926 | 34.4 ± 1.1 | 36.6 | 20 | 36.9 | 16 |
### Table 2: Descriptive of Soil (Physical and Chemical variables) and Vegetation analysis at different sites.

| Parameters               | Site 1            | Site 2            | Site 3            | Site 4            |
|--------------------------|-------------------|-------------------|-------------------|-------------------|
| **Herbs**                |                   |                   |                   |                   |
| Average Density          | 0.309 ± 0.298     | 0.646 ± 1.130     | 0.371 ± 0.637     | 0.221 ± 0.219     |
| (plants m$^{-2}$)        |                   |                   |                   |                   |
| Total species            | 8                 | 3                 | 23                | 13                |
| **Trees**                |                   |                   |                   |                   |
| Average Density          | 1.453 ± 0.616     | 0.600 ± 0.222     | 0.840 ± 0.798     | 1.839 ± 0.676     |
| (plants 10m$^{-2}$)      |                   |                   |                   |                   |
| Total species            | 4.000 ± 0.925     | 5.000 ± 0.462     | 28.806 ± 0.388    | 30.050 ± 1.896    |
| **Physical Properties**  |                   |                   |                   |                   |
| Bulk Density (gcc$^{-1}$)| 2.025 ± 0.020     | 2.152 ± 0.030     | 2.097 ± 0.029     | 2.191 ± 0.030     |
| Particle Density (gcc$^{-1}$) | 2.747 ± 0.042   | 3.118 ± 0.107     | 3.102 ± 0.077     | 2.933 ± 0.030     |
| Porosity (%)             | 25.477 ± 1.084    | 30.132 ± 1.982    | 30.714 ± 1.146    | 25.169 ± 1.077    |
| FC (%)                   | 20.588 ± 1.105    | 15.619 ± 0.848    | 20.993 ± 0.473    | 24.272 ± 2.124    |
| WHC (%)                  | 28.664 ± 0.925    | 24.372 ± 0.462    | 28.806 ± 0.388    | 30.050 ± 1.896    |
| **Soil Texture**         |                   |                   |                   |                   |
| Sand (%)                 | 31.823 ± 1.622    | 48.157 ± 0.424    | 34.166 ± 0.623    | 27.302 ± 0.283    |
| Clay (%)                 | 39.520 ± 1.637    | 24.252 ± 0.463    | 35.707 ± 0.417    | 44.057 ± 0.120    |
| Silt (%)                 | 28.657 ± 0.383    | 27.591 ± 0.583    | 30.127 ± 0.383    | 28.642 ± 0.235    |
| **Soil Aggregate**       |                   |                   |                   |                   |
| >2                       | 16.620 ± 1.325    | 39.212 ± 2.672    | 52.031 ± 1.499    | 5.758 ± 1.496     |
| 1to2                     | 20.122 ± 1.402    | 14.130 ± 3.541    | 5.722 ± 0.103     | 22.520 ± 2.044    |
| 0.212to1                 | 35.033 ± 1.327    | 32.567 ± 1.806    | 26.972 ± 4.644    | 42.773 ± 1.064    |
| 0.125to0.212             | 12.121 ± 0.739    | 8.992 ± 3.400     | 6.138 ± 1.920     | 11.249 ± 0.710    |
| 0.063to0.125             | 10.470 ± 0.667    | 3.374 ± 0.776     | 6.728 ± 2.215     | 10.132 ± 0.888    |
| 0.025to0.063             | 3.264 ± 0.291     | 0.829 ± 0.297     | 1.484 ± 0.390     | 4.420 ± 0.396     |
| <0.025                   | 2.371 ± 0.116     | 0.896 ± 0.463     | 0.924 ± 0.211     | 3.148 ± 0.420     |
| **Chemical Properties**  |                   |                   |                   |                   |
| pH                       | 7.711 ± 0.089     | 9.902 ± 0.178     | 8.437 ± 0.018     | 7.438 ± 0.049     |
| EC (dSm$^{-1}$)          | 12.940 ± 1.511    | 9.103 ± 0.250     | 12.435 ± 0.644    | 14.685 ± 1.222    |
| OC (%)                   | 0.362 ± 0.037     | 0.248 ± 0.012     | 0.368 ± 0.008     | 0.323 ± 0.020     |
| OM (%)                   | 0.624 ± 0.064     | 0.427 ± 0.021     | 0.635 ± 0.014     | 0.556 ± 0.034     |
| N (%)                    | 0.031 ± 0.003     | 0.021 ± 0.001     | 0.032 ± 0.001     | 0.028 ± 0.002     |
| P (kg ha$^{-1}$)         | 17.868 ± 0.812    | 21.201 ± 1.028    | 25.541 ± 0.635    | 23.904 ± 1.116    |
| Ca (mg kg$^{-1}$)        | 98.107 ± 11.09     | 153.60 ± 3.960    | 91.839 ± 3.563    | 97.907 ± 16.56    |
| Zn (mg kg$^{-1}$)        | 22.237 ± 2.521    | 3.695 ± 0.451     | 142.86 ± 0.904    | 20.930 ± 3.554    |
| K (mg kg$^{-1}$)         | 722.62 ± 68.84    | 748.11 ± 57.50    | 939.92 ± 13.88    | 814.87 ± 15.21    |
| Cu (mg kg$^{-1}$)        | 18.266 ± 2.093    | 15.709 ± 1.275    | 25.197 ± 1.515    | 23.530 ± 3.983    |
| Fe (mg kg$^{-1}$)        | 43.009 ± 4.936    | 26.201 ± 1.074    | 111.88 ± 11.39    | 38.978 ± 2.881    |
| Na (mg kg$^{-1}$)        | 68.690 ± 4.984    | 65.490 ± 2.274    | 227.40 ± 3.442    | 66.524 ± 7.089    |
| Pb (mg kg$^{-1}$)        | 66.610 ± 5.112    | 56.130 ± 2.670    | 57.358 ± 1.247    | 70.650 ± 14.54    |
| Mn (mg kg$^{-1}$)        | 31.782 ± 1.345    | 30.351 ± 2.132    | 38.611 ± 0.721    | 27.878 ± 2.628    |
**Figure 1:** Correlation between different soil parameters and vegetation.

- **Correlation between Mn and Ca**
  - $y = -0.080x + 43.82$
  - $r=0.448$, $n=81$ ($p>0.001$)

- **Correlation between K and Zn**
  - $y = 11.53x + 570.1$
  - $r=0.961$, $n=81$ ($p>0.001$)

- **Correlation between Na and Ca**
  - $y = -1.175x + 281.7$
  - $r=0.562$, $n=81$ ($p>0.001$)

- **Correlation between Na and K**
  - $y = 0.099x - 0.978$
  - $r=0.923$, $n=81$ ($p>0.001$)

- **Correlation between Ca and K**
  - $y = -11.22x + 2775$
  - $r=0.578$, $n=81$ ($p>0.001$)

- **Correlation between Density and Na**
  - $y = -6.355x + 82.14$
  - $r=0.986$, $n=4$ ($p<0.01$)

- **Correlation between Density and Fe**
  - $y = 12.46x + 5.748$
  - $r=0.993$, $n=4$ ($p<0.001$)
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