Study on Soil Properties and Their Influence on Vegetation in Western Region of Gujarat State in India

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Abstract: Four ecosystems, namely, forest, grassland, degraded land and desert land encompassing semi-arid to arid ecoclimate were selected for the study in the western region of Gujarat state in India. Vegetation analysis was performed and physical and chemical properties of soil were analyzed for each ecosystem. Reduction of clay content, water holding capacity, field capacity, organic carbon and available phosphorus exhibited positive correlation with reduction of number of perennial plant species and their density, whereas increase in exchangeable calcium, magnesium and sodium exhibited negative correlation with reduction of herbaceous biomass with deterioration of ecosystems. Total nitrogen, exchangeable manganese and iron decreased, whereas electrical conductivity, pH, exchangeable potassium and zinc increased with the deterioration of ecosystem.
Keywords : ecosystem, perennial species, biomass, physical and chemical properties of soil

1 Introduction

India, with its growing population, increasing demands for cultivable land, fuel, fooder need for its growing industries, and its large area within the dry lands, is very much threatened by problems of land degradation. Bormann and Likens (1979) and Pandey and Singh (1985) reported that recovery of damaged forest ecosystems suggest restoration of nutrient status of soil. Sand dune stabilization of in Thar desert of India progresses by restoring relative proportion of nutrients in soil (Pandey and Rokad, 1992).

According to report of ICAR, 187.7 million hectares (57.1%) of the geographical area has been affected by various type and degree of land degradation in India (Faroda and Singh, 1997). About 25% area of the western zone (Saurashtra) of Gujarat state is now degraded land or looks like desert and forest cover including open canopy is restricted to only 6% area. with this alarm we are now focused to look at soil properties and their influence on vegetation at different ecosystems. Four types of ecosystems, namely, forest, grassland, degraded land and desert land encompassing semi-arid to arid ecoclimate were selected for the study in the western region of Gujarat state in India. In the present paper analysis of physical and chemical properties of soil and their influence on herbaceous vegetation and biomass are discussed.

2 Material and methods

Details of the study sites regarding their location, rainfall, temperature and types of ecoclimate, as well as methods for analysis of physical and chemical properties of soil, presented in our previous paper (Panchal and Pandey, 2002).

3 Vegetation analysis

The size and the number of the quadrats were determined, respectively, by the species area curve (Mishra, 1968) and the running mean method (Kershaw, 1973). For herbaceous vegetation, fifty quadrats of 1 m×1 m were placed at random at each research site of all ecosystems. Number of individuals for each species was recorded to calculate density. Biomass was determined at the peak growth of the vegetation, *i.e.*, during third week of September, 1998. Ten monoliths of the 25 cm×25 cm×30 cm with intact plants were excavated randomly at each site. Plant fractions were oven dried at 60℃ to a constant weight.

4 Results

The values of different physical and chemical properties of soil are given in table 1 for forest, grassland, degraded land and desert land ecosystems. Clay particles, water holding capacity, field capacity, organic carbon, total nitrogen, available phosphorus, exchangeable manganese and iron decreased and exchangeable potassium, calcium, magnesium, sodium and zinc increased with the deterioration of ecosystem. pH and electrical conductivity of soil increased with the deterioration of ecosystem. In other words, soil salinity develops with degradation of soil or desertification. C:N ratio was maximum at desert ecosystem, due to the lowest value of total nitrogen.

Table 1 Vegetation analysis and physical and chemical properties of soil at different types of ecosystems (± 1 SE)

Parameters	Forest		Grassland		Degraded land		Desert land	
Dominant Herbaceous plant species	*Eragrostis cilliaris* (*L.*) *R..Br.* *Cenchrus setigerus Vahl.* *Dactyloctenium aegyptium*(*L.*) *P.Beauv.*		*Aristida adscensionis L.* *Sehima nervosum* (*Rottl.*) *Stapf.* *Zornia diphylla auct.* *Borreria hispida* (*L.F.*) *K. Schum*		*Aristida adscensionis L.* *Indigofera cordifolia Heyne ex Roth* *Melanocenchris jacquemontii J & S.* *Glossogyne pinnatifida DC.*		*Cyperus bulbosus Vahl.* *Cressa cretica L.* *Aeluropus lagopoides* (*L*) *Trin.ex Thw.*	
Herbaceous plant density	177.23 plants m^{-2}	± 28.50	634.55 plants m^{-2}	± 67.277	360.21 plants m^{-2}	± 34.306	101.41 plants m^{-2}	± 24.815
Clay (%)	13.8	± 1.70	12.5	± 1.30	7.2	± 0.70	4.3	± 0.50
Water holding capacity (%)	48.7	± 3.10	45.3	± 2.40	29.8	± 1.00	26.4	± 1.10
Filed capacity (%)	35.9	± 0.50	33.3	± 0.90	22.5	± 1.10	20.2	± 0.80
Organic carbon (%)	0.93	± 0.005	0.93	± 0.023	0.56	± 0.043	0.43	± 0.012
Total nitrogen (%)	0.022	± 0.001	0.022	± 0.0010	0.015	± 0.0010	0.008	± 0.0003
C : N ratio	42.80	± 1.489	42.700	± 2.229	38.10	± 0.513	56.90	± 2.379
Available phosphorus (%)	0.0020	± 0.00003	0.0020	± 0.00010	0.0016	± 0.00005	0.0011	±0.00012
Exchangeable potassium (%)	0.021	± 0.00000	0.021	± 0.00029	0.021	± 0.00030	0.023	± 0.00110
Exchangeable calcium (%)	0.65	± 0.018	0.69	± 0.027	1.71	± 0.064	4.21	± 0.047
Exchangeable magnesium (%)	0.050	± 0.006	0.050	± 0.006	0.100	± 0.002	1.720	± 0.048
Exchangeable sodium (%)	0.006	± 0.0004	0.006	± 0.0008	0.010	± 0.0006	0.201	± 0.005
Exchangeable zinc (ppm)	0.31	± 0.033	0.33	± 0.016	0.66	± 0.023	0.35	± 0.054
Exchangeable manganese (ppm)	14.08	± 0.371	13.20	± 0.283	12.70	± 0.129	12.50	± 0.173
Exchangeable Iron (ppm)	12.25	± 0.155	11.25	± 0.050	11.20	± 0.124	11.10	± 0.100

Reduction of clay particles, water holding capacity, field capacity, organic carbon, available phosphorus and total nitrogen exhibited a positive correlation with density of perennial plant species according to following expressions:

Clay :

$$y = 6.119 + 11.16\, x \ (r = 0.709,\ n = 15,\ p < 0.01)$$

Water holding capacity:

$$y = 37.045 + 3.963\, x \ (r = 0.665,\ n = 15,\ p < 0.01)$$

Field capacity:

$$y = -39.786 + 5.419\,x \; (r = 0.612,\; n = 15,\; p < 0.01)$$

Organic carbon:

$$y = -3.897 + 162.855\,x \; (r = 0.606,\; n = 15,\; p < 0.01)$$

Available phosphorus:

$$y = -27.539 + 81923.077\,x \; (r = 0.540,\; n = 15,\; p < 0.05)$$

Total nitrogen:

$$y = 18.477 + 5485.484\,x \; (r = 0.558,\; n = 15,\; p < 0.05)$$

where, x is clay, water holding capacity, field capacity, organic carbon, available phosphorus and total nitrogen and y is density of perennial plant species.

Similarly, reduction of clay particles, water holding capacity, field capacity, organic carbon and available phosphorus exhibited a positive correlation with number of perennial plant species according to following expression :

Clay :

$$y = 1.694 + 0.435\,x \; (r = 0.755,\; n = 15,\; p < 0.01)$$

Water holding capacity:

$$y = 0.764 + 0.134\,x \; (r = 0.616,\; n = 15,\; p < 0.01)$$

Field capacity:

$$y = 0.574 + 0.187\,x \; (r = 0.577,\; n = 15,\; p < 0.05)$$

Organic carbon:

$$y = 2.283 + 4.967\,x \; (r = 0.505,\; n = 15,\; p < 0.05)$$

Available phosphorus:

$$y = 0.547 + 3096.154\,x \; (r = 0.557,\; n = 15,\; p < 0.05)$$

where, x is clay, water holding capacity, field capacity, organic carbon and available phosphorus and y is number of perennial plant species.

While, exchangeable potassium, sodium, calcium and magnesium show negative trend with the density and number of perennial plant species.

Total herbaceous aboveground biomass was positively correlated with the concentration of organic carbon (Fig. 1), total nitrogen (Fig. 2) and available phosphorus (Fig. 3), whereas it was negatively related with exchangeable calcium (Fig. 4), exchangeable magnesium (Fig. 5) and exchangeable sodium (Fig. 6) in surface soil (0-10cm depth).

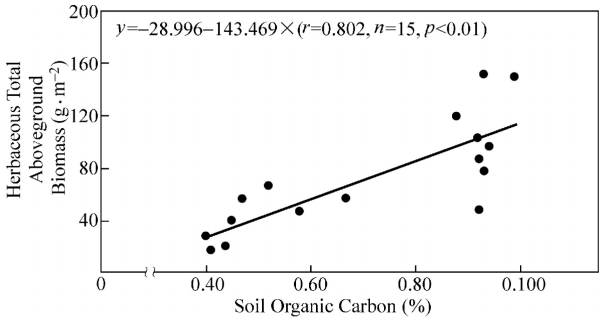

Fig.1

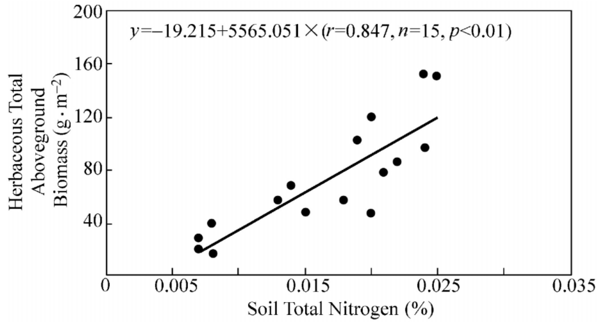

Fig.2

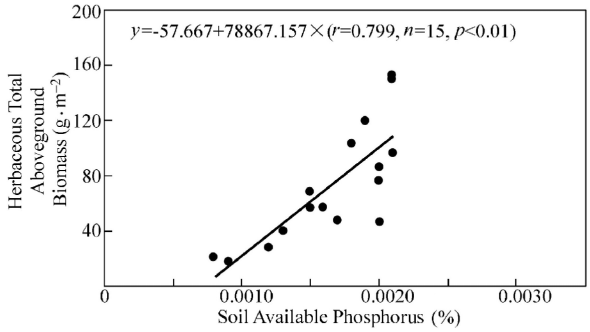

Fig.3

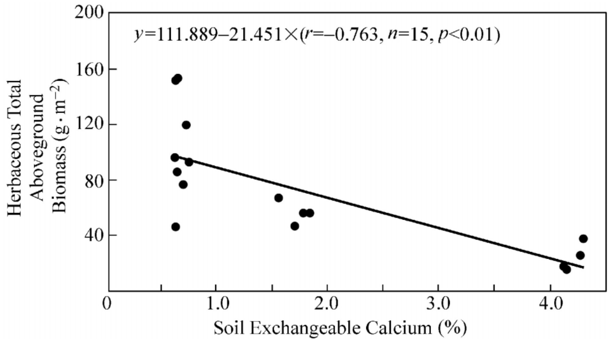

Fig.4

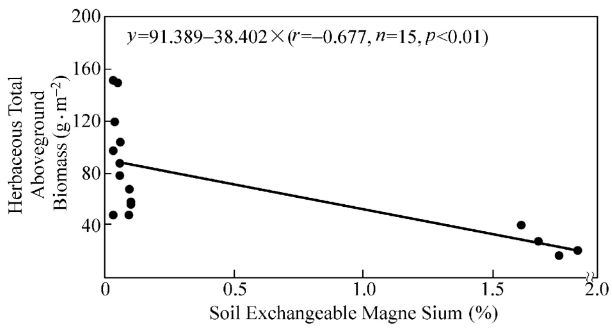

Fig.5

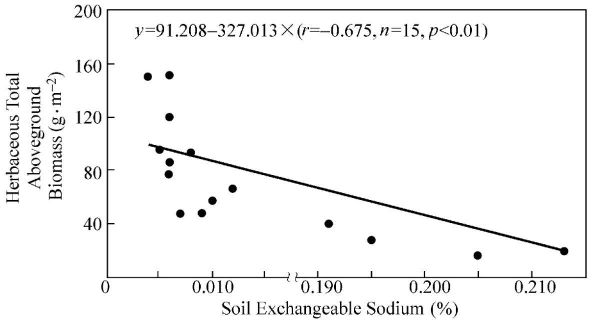

Fig.6

Fig.1—6 Relationship between soil nutrients (%) and herbaceous total above ground biomass (g • m^{-2})

5 Discussion

In the present study dominance shifted from perennial species at forest grassland and open grassland to annual species at degraded land with the degradation of soil condition. Annuals and fast-growing short-lived perennials gradually occupied the space left by the disappearing perennials over time. The life history of annual and short-lived perennials is considered an adaptation to survive on degraded lands in dry regions. Two annual grasses, viz., *A. adscensionis* and *M. jacquemontii* grow abundantly on degraded lands. These are the air loving plants and the grounds with distinct mild slopes and thin soil layer are the better habitats for these annual grasses since rain water runs off down the slopes. Eventually, pore space in soils is not greatly filled up with water causing depletion of air. The microenvironment of the degraded land ecosystem becomes gradually hostile for perennial plant species and favourable for annual or short-lived species as the soil becomes thin and divested of its nutrients over time. Abundance of perennial species is reported to have correlation with the increasing thickness of soil (Pandey and Singh, 1991). Eventually, entire absence of perennial plants can result in decline in species diversity as degradation of soil condition progresses.

Decline in herbaceous biomass with the land degradation can be attributed to the life history traits of the plants occurring along the degradation gradient, reduction of fine soil particles and soil fertility, increase of salt concentration in soil and increase of soil aridity. Perennial grasses and herbs accumulate greater biomass than the annual plants. Consequently, biomass exhibited a decreasing trend along the trajectory, from grassland to desert land ecosystem. Pandey and Singh (1991) worked on grazinglands located on the Vindhyan Plateau in Sonbhadra, Uttar Pradesh, India, and found that biomass was highest at the ungrazed grazinglands and decreased with increasing grazing intensity (disturbance). Also, on long term of grazing perennial grasses were replaced by annual grasses. Results of the present investigation are in conformity with the above findings.

The decline of water holding capacity and field capacity of soil, resulted from depletion of clay particles of soil with the deterioration of ecosystem causes progressive drier condition of soil and reduction in plant density. According to Singh *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). Decline of concentration of available phosphorus with the deterioration of ecosystem can be attributed to a depletion of clay particles and organic substances. Clay micelles with adsorbed nutrients form complexes with organic substances, which prevent loss of nutrients.

Nitrogen and phosphorus are essential elements for plant growth and decline of these nutrients with land degradation can cause poor growth of plants. The concentration of salts of sodium, potassium, calcium and magnesium increases in soil with degradation. High concentration of salts in soil, in general, causes detrimental effects on plant growth (Bernstein, 1967; Kramer, 1983; Pandey & Thakarar, 1997; Mer *et al.* 2000). According to Donahue *et al.* (1983), excessive concentrations of salts may kill growing plants. Salinity appears to affect two plant processes: water and ionic relations (Cramer and Nowak, 1992). During the initial exposure to salinity, the plants experience water stress, and during long-term exposure 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). Mer *et al.* (2000) conducted a green house experiment on barley, wheat, gram and mustard crop plants in the western region of Gujarat State, India, to assess their responses to increasing levels of soil salinity. Of the four crop plants tested, barley appeared to be the most tolerant to salinity with regard to seed germination and early growth of plants. Wheat, gram and mustard were tolerant only to low soil salinity. However, high salt concentrations in the soil reduced the absorption of nitrogen and phosphorus by young plants. The imbalance of mineral nutrients resulted in a reduction or an inhibition of plant growth. Consequently, decrease in biomass of herbaceous plants can be attributed to the degradation of soil condition and ultimately lead to deterioration of ecosystem.

Changes in flora and vegetation were brought about by the degradation of soil condition, ultimately, lead to deterioration of ecosystem. Dominant plant species changed from trees at forest ecosystem to perennial grasses and herbs at forest grassland and open grassland ecosystem to annual plant species at degraded land ecosystem. At desert ecosystem, salt tolerant herbaceous plant species were dominant. Plant density, the number of perennial plant species and herbaceous biomass decreased with the deterioration of ecosystem can be attributed to the life history traits of the plant occurring along the degradation gradient, reduction of fine soil particles and soil fertility, increase of salt concentration in soil and increase of soil aridity

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