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Mechanical Behaviour of Salt Affected Alluvial Soils

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ABSTRACT

The mechanical behavior of salt affected sandy loam to loam soils of Sultanpur (Gurgaon District, Haryana) was evaluated through soil strength, estimated with cone penetrometer and direct shear apparatus was found to be highly influenced by pH, moisture content, bulk density and salt content. Depending upon the physiographic conditions, at some places accumulation of clay has taken place rendering the soil towards heavy texture. These minor variations in texture have played a decisive role in mechanical behaviour of the soil. Hence, it is suggested that to characterize the mechanical behaviour of the salt affected soil, it is not only evaluation of salinity status at specific sites but also collateral information with regard to texture and moisture content are essential. With increase in pH the mechanical behaviour as judged from penetration resistance and shear strength got worsened and had high values (upto 139.5 J/cm) rendering it hard. Soil management practices like addition of gypsum may be essential to stop further degradation of the soils making them congenial to plant growth.

Introduction

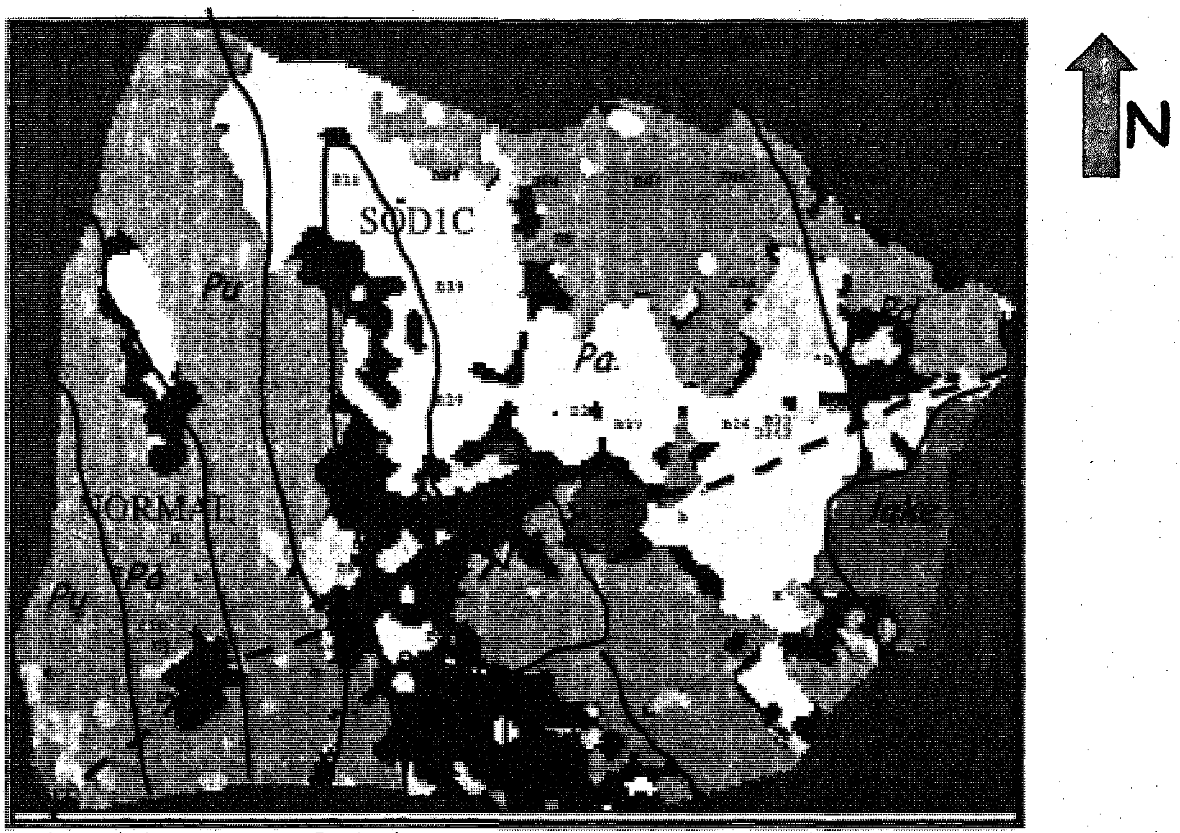
Land resources are finite. Per capita availability of land in India got reduced from 0.89ha during 1950 to 0.15 during 2001-2003 (Survey of Indian Agriculture, 2001), mainly due to increasing population on one hand and land degradation processes on the other. Among the two major degradation processes, soil erosion and salinity, the later accounts for 10.1 mha % of the total geographical area of the country. Root zone soil physical environment of these salt affected soils, not only hinders the water availability to plants for their metabolic activity, their mechanical behaviour also pose problems in soil management during land preparation, seedling emergence and root growth in general (Zhang *et al.*, 2001).

Soil mechanical behavior is highly dependent on soil moisture content and is evaluated through indices like penetration resistance, shear strength, modulus of rupture (Bradford and Gupta, 1986; Petro Vaz *et al.*, 2001). The inter relationship between soil compaction (as judged from bulk density), soil moisture content and the mechanical behavioral indices are critical factors in determining soil and crop management practices (Raghavan, 1976). As soil strength increases, root elongation rate decreases due to the increasing resistance of the soil particles to displacement. High strength soil can be a serious problem in agriculture as it can restrict access of the root system to water and nutrients, and thereby decreasing crop yields. As soils loose water during drying, the effects of soil strength on plant growth therefore will be greater than the direct effect of low matric potential (Clark *et al.*, 2003).

However, this information with regard to salt affected alluvial soils under semi arid climatic conditions is very little and in-situ studies taking into consideration their spatial variability are meager. The present investigations are undertaken with the objective of assessing the mechanical behavior of salt affected soils with a special reference to their spatial variability.

Materials and methods

The field studies were conducted at Sultanpur village, Gurgaon district of Haryana State. Sultanpur village lies between $28^0 27'4''$ to $28^0 29'45''$ N latitude and $75^0 53'45''$ to $76^0 50''$E longitude, belonging to semiarid Agro-Ecological Zone 3 of the Indo-Gangetic plains (NBSSLUP Publ. 24.). The soils of the area vary from sandy loam to loam in the uplands and clayey in relatively low lying areas. (Fig. 1, Table 1). The soils are



Pu sandy loam Pa clay loam PaS1 clay loam salt affected,
Pd transverse dunal plains

Fig. 1. Soil map of Sultanpur (Gurgaon District, Haryana)

Table 1. Physiographic units and soil classes of Sultanpur village

Physiographic unit	Symbol	Soil series	Dominant soils	Associated soils
Plain with Aeolian cover	Pa	Nai	Typic ustorthents, clay loam	Typic ustipsaments/ ustochrepts' clay loams
Plain with Aeolian cover	PaS1	Rewasan	Typic ustocrepts, (salt affected) (moderatesaline alkali)	Typic ustorthents clay loams Typic ustipsaments
Sandy slightly undulated plains	Pu	Jamalpur	Typic ustipsaments	Typic ustorthents clay loams/ ustochrepts
Tranverse dunal plains	Pd	Jamalpur	Typic ustipsaments	Typic ustorthents, clay loams
Seasonal water logged soils	L	Ujain	Aeric haplaquepts	Typic ustocrepts, fine loam

mostly as alluvial materials . In some of the low-lying areas soil crusting was observed (Fig.2) affecting the crop growth. The wheat fields were more severely affected than the mustard fields.

Fig. 2. Alkaline patch in the study area

The village topography comprises of sand dunes, dunal foot slopes, inter-dunal plains and basins. Poor drainage in this area is the causative agent for soil degradation, mainly salinity / alkalinity and water logging.. Out of 1700 ha of the geographic area 1590 ha has been selected for intensive sampling for the evaluation of salinity/ alkalinity and mechanical behaviour in a grid of 610 m (20"). The sampling was done during rabi 2003 and continued through summer.

GARMIN's GPS 12 Personal Navigator was used for collecting site-specific data i.e. positioning the grid points latitude - longitude values and altitude values. Soil samples from 0-5 cm and 5-10 cm soil depth were collected. The soil pH was measured in 1:2.5 soil water suspensions and the Electrical Conductivity (EC) in the clear extract.

The penetration resistance (soil impedance) was measured using the impact cone penetrometer, in which a weight of 1 kg is placed in the sleeve of the tripod. The length of the cylinder permitted sufficient free fall of the weight to impart energy when the weights fall. Cumulative strokes of 5, 10, 15, 20, 25, 30, 35, 40, 50, 70 were given. The potential energy of each stoke was 4.9 joules.

The shear strength was measured using direct shear apparatus. The apparatus has a rotating screw of 20 TPI in combination with a proving ring and a shear box. The direct shear tests were conducted at normal loads of 5, 8, 10 kg on metallic circular plate amounting to 0.25, 0.41 and 0.516 kg/cm^2. Angle of internal friction and soil cohesion were calculated using the Coulomb's law of sliding friction.

$$t = c + \sigma \tan \phi$$

Where,

t = Tangential/shearing stress
c = Soil cohesiveness
σ = Normal stress
ϕ = Angle of internal friction

Collateral information with regard to gravimetric soil moisture and bulk density was also obtained.

Results And Discussion

Two most important soil physiochemical properties affecting other soil physical properties in this area are EC and pH. The measured values of EC (dSm^{-1}) ranged from 0.01 dSm^{-1} to 3.03 dSm^{-1}. To account for spatial variability of these soil parametric values the spatial statistical procedure ' kriging' was employed (Warrick *et al.*, 1980 and Webster, 1985). Kriging is a weighted interpolation method, which is similar to inverse distance in that it weights the surrounding measured values to derive a prediction for each location. However, the weights are based not only on the distance between the measured points and the prediction locations but also on the overall spatial arrangement among the measured points. To use the spatial arrangement in the weights the spatial autocorrelation must be quantified. The goal of interpolation is to minimise prediction error. Ordinary kriging makes certain assumptions about the model such as intrinsic stationary, and that the true mean of the data is not only constant (there is no trend) but also contains an unknown random error with spatial dependence (e.g. anisotropy). To obtain the krigged contour map of various parameters Golden graphics software package 'surfer 32' was employed. Kriged contour map of Soil Strength is given in Fig. 6.

The EC values ranging between 2 to 2.5 were marked as saline soil in the soil map (Fig. 1). The EC values reported earlier in the same study area were as high as 5 or 6 dSm^{-1} around 10 years ago.

(Sharma, 1993). During this period, enhanced cultivation practices with irrigation might have provided better drainage there by leaching the salts and hence the lower EC values. Very high EC (> 2 dSm^{-1}) inhibits good blooms of crop. In areas with high silt and clay contents, crusty salt patches were observed (Fig. 2 and Fig 3)

Another important physiochemical property that influences the soil mechanical behaviour is soil pH. The pH ranged from 6.9 to 9.83. Out of total 76 sampling sites in the study area samples with pH between 8 to 8.5 comprised of 26 samples and pH 8.5 to 9 comprised of 20 where as 9 samples of pH above 9 (Table 2.). The earlier studies have shown the pH value to be below 9.5. The local people were aware of higher salt content but they tend to have paid little attention to high alkalinity (high pH) values. Irrigation of the fields leached the excess salts of calcium and magnesium thereby reduced higher EC values but sodium might have been retained in the soil profile, which exhibited into higher pH values. The higher sodium in the soil deteriorated the soil physical properties to a great extent.

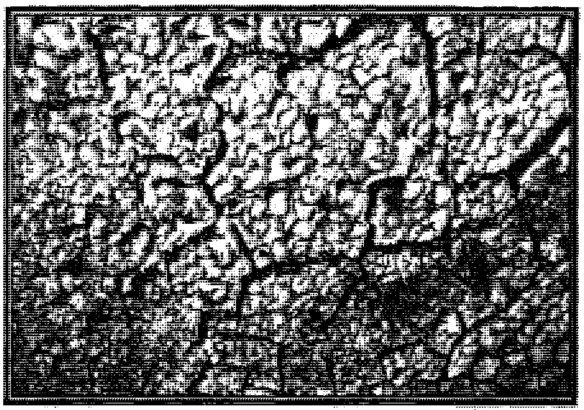


Fig. 3. Closer view of crusted soil

The soil moisture (%) ranged from 0.6 to 25.2 for topsoil layer at the time of field determination of mechanical properties of soil and it was observed that at higher pH sites (Fig. 4) higher in moisture had a buffering effect on soil strength. In the subsurface layer the moisture ranged from 0.92 to 21.2%. Fine silty loam soil has high degree of dispersion and breaking of aggregates under heavy kinetic impact of rain drops followed by high evaporation leads to surface crusting exhibiting higher penetration resistance.

Table 2. Distribution of samples in various categories of salt affected soils and their respective pH

Category	pH	EC dSm^{-1}	No. of samples
Nearly normal	6.5-8.0	<1	13
Moderately alkaline	8.0-8.5	<1	26
Highly alkaline	8.5-9.0	<1	20
Severely alkaline	>9.0	<1	9
Saline alkali	>8.0	>1	8
Total no. of samples	76		

The penetration resistance of the soil is characterized by penetration depth of the instrument's cone into the soil, at a given impact (number of strokes). The rate of penetration, which denotes the penetration resistance, is obtained from the linear plot of number of strokes vs. the penetration depth. The penetration resistance of the study area ranged from 7.84 to 121.88 J/cm for upper soil layer. This penetration resistance increased with lowering of soil moisture. The moisture content was very low (0.66%) in certain areas resulting in high strength values. The penetration resistance of the soil in the deeper layer, ranged from 14.55 to 139.54 J/cm and the strength values were found to be higher in the subsurface as natural conditions prevailed there. Generally due to compaction subsurface layers possessed higher densities relative to surface layers. (1.54 to 1.72 g/cc)

Soil shear strength by direct shear apparatus was studied at sampling sites. The soil cohesiveness, which is a direct measure of the ease of soil to be sheared, was found to be influenced by soil moisture, bulk density and soil pH. Soil pH was found to be highly correlated and explained for most of the variability in cohesiveness. A stepwise multiple regression analysis revealed that of the total variability in soil strength, soil pH contributed to 35%, EC 7%,

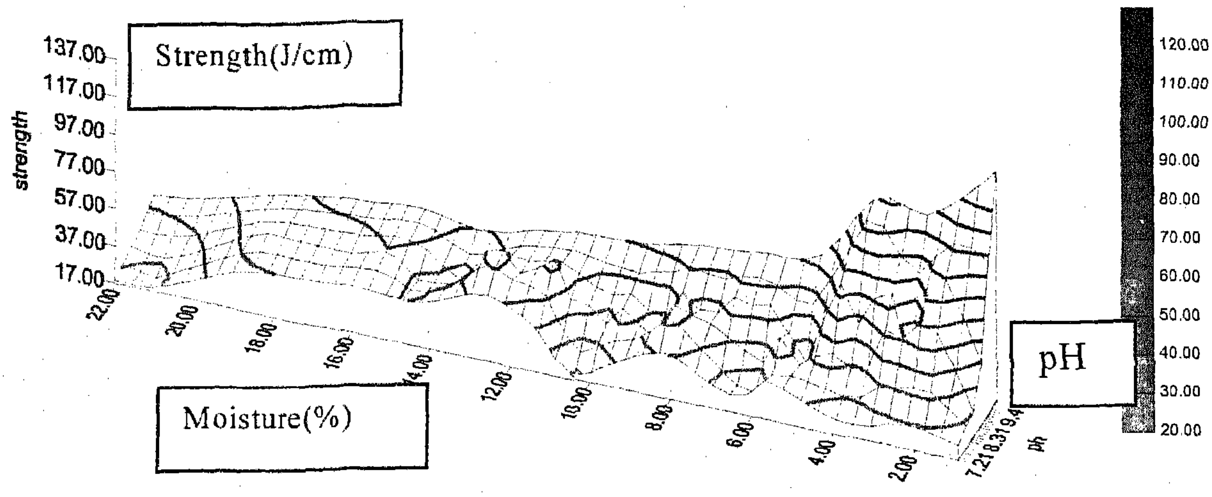


Fig. 4. Plot of soil strength, moisture and pH

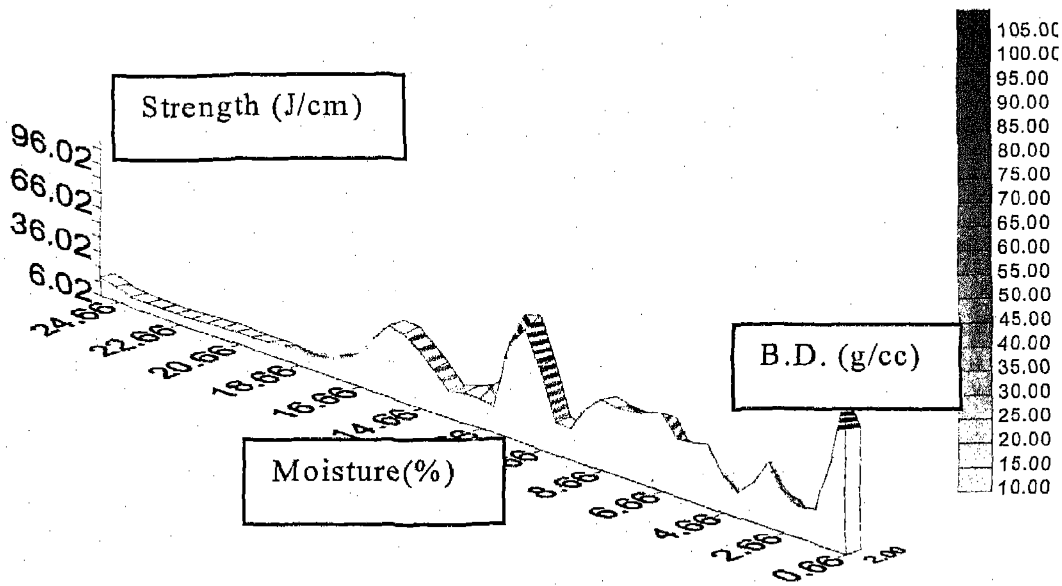


Fig. 5. Plot of soil moisture, strength and density

moisture 6%, bulk density 1% while the rest might be due to textural influences. Lower values of cohesiveness for soils with higher pH might be attributed to the increased sodium levels tend to have a dispersing influence for the clay particles to move away from each other resulting in lower values of cohesiveness. Increase in moisture levels in case of clay loam soils (fine texture) decreased the cohesiveness values close to zero. Moisture, pH, EC, bulk density could explain about 0.66 correlation and around 55% variation in strength. Rest of the variation could be attributed to texture.

Conclusion

Based on this study it can be concluded that mechanical behaviour of soils is highly dependent on soil moisture, bulk density, texture, EC (salinity) and pH. During a decade cultivation practices without addition of any amendments resulted higher pH. With increase in pH the mechanical behaviors as judged from penetration resistance and shear strength got worsened. Soil management practices

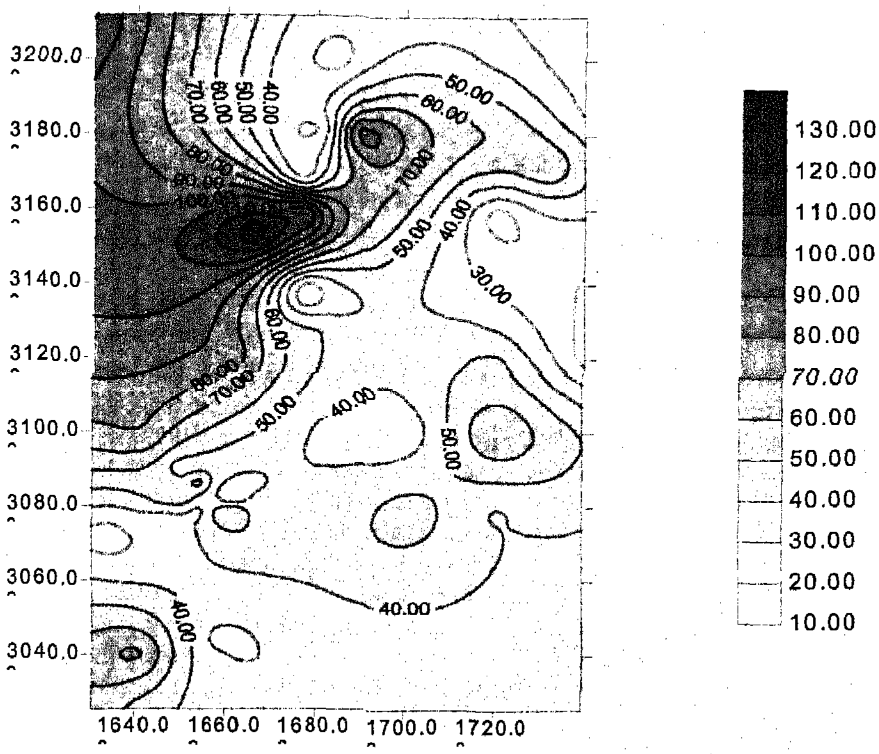


Fig. 6. Spatial distribution of soil strength (J/cm)

like addition of gypsum is required to keep the soil mechanical behaviour congenial to plant growth. . However minor variation in texture seem to play a decisive role in mechanical behaviour of the soil. Hence, it is suggested to characterize the mechanical behaviour of the salt affected soil, it is not only evaluation of salinity status at specific sites but also collateral information with regard to texture should be determined of surface as well as subsurface layers.

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