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# Soil charactreristic mapping for irrigation planning of command of Hanumansagar reservoir

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**ABSTRACT :** A study was conducted to assess the characteristics of soils for irrigation planning of command of Hanumansagar reservoir. Physio-chemical properties of soils of the command were assessed at grid of 2.4 x 2.4 km from 0-30 cm depth. The soils of command are classified into four-soil types *i.e.* clay, clay loam, silty clay loam and silty clay. The most of the soils of command area were clayey (about 77%). Clay, sand and silt content in the soil ranged from 36.32 to 57.70 per cent, 4.75 to 27.25 per cent and 18.6 to 49.29 per cent, respectively. The bulk density and hydraulic conductivity of soils of command was found varying from 1.48 to 1.81 g $cm^{-3}$ and 1.1 to 13.9 mm $hr^{-1}$, respectively. The water retention of soil at 0.33 bar varied from 23.77 to 35.63 per cent and at 15 bar varied from 13.30 to 26.30 per cent. The soils of command area were found moderately to strongly alkaline in reaction as pH varied from 7.63 to 8.78. Electrical conductivity of soils was observed ranging from 0.23 to 0.93 dS $m^{-1}$. Calcium carbonate of these soils varied from 6.25 to 23.5 per cent indicating that the soils are highly calcareous. Thus, the soils of command area are not suitable for horticultural plantation specifically belonging to citrus family. The contour profiles of determined soil properties were prepared as ready reckoner maps.

**KEY WORDS :** Bulk density, Hydraulic conductivity, FC, PWP

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Irrigation water scarcity is vital both for livelihood and food security. While India has made large investments in augmentation of water supply, there have been no commensurate efforts in the management of demand and in the promotion of efficient and economic water use. In spite of large investments, the performance of many irrigation systems is significantly below potential due to variety of shortcomings. Major reasons includes wide gap between supply and demand, inappropriate governance arrangements and poor management practices. Agriculture, being the major water user, it's share in the total water use is bound to decrease from the present 83 per cent to 74 per cent due to more pressing and competing demands from other sectors by 2025 A.D. and as such, the question of improving the present level of water use efficiency in general and for irrigation in particular assumes a great significance in perspective water resource planning (Anonymous, 2006).

The population of India is increasing at alarming rate *i.e.*19.5 per cent (Census, 2011). The soil and water become shrinking resources due to increased population. At the same time, more food and water is required for increased population. The food requirement is projected to be increased from 210 Mt to 420 Mt by 2025 (Anonymous, 2006).

The crop production is a function of soil, water and climate. The amount of irrigation water to be applied is a function of soil characteristics, stage of crop growth and the climate. Information on soil characteristics is thus become essential for planning of irrigation schedule for optimum crop production. Crop production requires knowledge of soil parameters like soil type, pH, electrical conductivity and calcium carbonate content whereas scheduling of irrigation requires knowledge of bulk density, hydraulic conductivity, field capacity and permanent wilting point.

In Akola district of Maharashtra state there are five irrigation projects. The Hanumansagar reservoir project at Wan is major project having capacity of 83 $Mm^3$. The irrigation potential of this project is 151 $km^2$ but presently it is irrigating only 40 $km^2$, though it is filling to its full capacity almost every year. Considering the need of prerequisite information required for irrigation planning a study was undertaken during the year 2011-12 with the objective to assess the soil characteristics mapping of command of Hanumansagar reservoir.

## ■ METHODOLOGY

The study area is command of Hanumansagar reservoir at Wan in Telhara block of district Akola. The command of the reservoir is situated in subtropical zone and spread over about 225.25 km$^2$ having an average annual rainfall of 790 mm.

### Collection and processing of soil samples for analysis :

The command area is divided into the grids of 2.4 x 2.4 km. The four representative soil samples were collected from each grid with the help of screw auger from 0-30 cm depth. Soil samples were then dried in oven. The oven-dried samples were carefully and gently grind with wooden pestle to break the soil lumps (clods). The grind soil samples were passed through sieve of 2 mm size. The sieved samples were then mixed thoroughly to make one composite sample for each grid. The composite samples were used for subsequent analysis. The physio-chemical properties were determined by using standard procedure in the laboratory.

### Determination of physical properties of soil :

*Particle size distribution (PSD)* :

The particle size distribution was determined as per the Bouyoucos hydrometer method using ASTM 151H hydrometer (Means and Parcher, 1965). Using treated soil samples with hydrometer,

clay and silt per cent were determined by using following formula.

$$WD = \frac{100}{Ws} x \frac{Gs}{Gs - 1} x (RH + mT + Cm - Cd)$$

where,

WD = Per cent of suspension (%)
Ws = Weight of soil (g)
Gs = Density of soil (g cm$^{-3}$)
RH = Hydrometer reading
mT = Temperature correction (0.13 per °F)
cm = Meniscus correction (0.4)
Cd = Density correction (2)

Sand per cent was determined by using 0.05 mm (53 micron) sieve. The textural class was determined using the USDA textural triangle.

*Bulk density (BD)* :

Bulk density was determined by dry clod coating technique as described by Blake and Harge (1986). The bulk density was determined using following formula.

$$\text{Bulk density } (gcm^{-3}) = \frac{\text{Oven dry weight of clod}}{\text{Volume of soil clod}}$$

*Hydraulic conductivity (HC)* :

Saturated hydraulic conductivity was determined by constant head permeameter (disturbed soil) method as described by Israelsen and Hansen (1962). The volume of percolate from permeameter was measured until the constant volume was obtained. The hydraulic conductivity was determined by using following relationship.

$$K = \frac{VxL}{A x h x t}$$

where,

K = Hydraulic conductivity, cm hr$^{-1}$
V = Collected volume of water, cm$^3$
L = Length of soil column, cm
A = Cross section area of the soil column, cm$^2$
h = Hydraulic head, cm
t = Time required to get 'V' volume

*Soil moisture retention* :

The soil moisture retention at 0.33 bar to 15 bar was determined using oven dried soil sample with pressure plate and pressure membrane apparatus as per method outlined by Richards (1947). Available water capacity (AWC) was also estimated. Available water capacity (AWC) is the difference between moisture content at 0.33 and 15 bar.

### Determination of chemical properties of soil :

Chemical properties of soil like Ph, EC and $CaCO_3$ content were determined using following methods.

*Soil pH*

Hydrogen ion activity expressed as pH was measured with pH meter using 1:2.5 (soil: water) suspension (Jackson, 1973).

*Electrical conductivity (EC)* :

Electrical conductivity of soil is a measure of salts in the soil solution. The clear supernatant obtained from the soil suspension used for pH was utilized for EC measurement using a conductivity meter (Jackson, 1973).

*Calcium carbonate content* ($CaCO_3$) :

Rapid titration method was used to determine the calcium carbonate content in soil as described by Jackson (1973). Calcium carbonate was determined by using following formula.

$$CaCo_3 = (B - T) \text{ x N of NaOH x} \frac{50}{10} \text{ x } 0.05 \text{ x} \frac{100}{\text{weight of soil}}$$

where,

B = Volume of standard NaOH required to neutralize 10 ml of HCL (Blank), ml
T = Volume of standard NaOH required to neutralize 0.5 N of HCL, ml

### Preparation of contour maps :

The soil texture map for the command was prepared using determined soil separates. The contour profiles of bulk density, hydraulic conductivity, field capacity, permanent wilting point, pH, EC and calcium carbonate content of the soils of command of Hanumansagar reservoir were plotted using surfer software.

## RESULTS AND DISCUSSION

The results of the present study as well as relevant discussions have been presented under following sub heads:

**Particle size distribution (PSD) :**

The results of particle size distribution analysis were used to classify the soils into different soil textures. According to the USDA textural classification, the soils of command area was classified into the four-soil textures clay, clay loam, silty clay loam and silty clay. The grid wise classification of soil is presented in Table 1. Most of the soils in the command were clayey (Fig.1). Clay, sand and silt content varied from 36.32 to 57.70 per cent, 4.75 to 27.25 per cent and 18.6 to 49.29 per cent, respectively, over the command. Sand content was found positively correlated with clay content with $r^2$=0.98 (Fig. 4). Using the results of PSD, soil texture map of the command was prepared (Fig. 3).

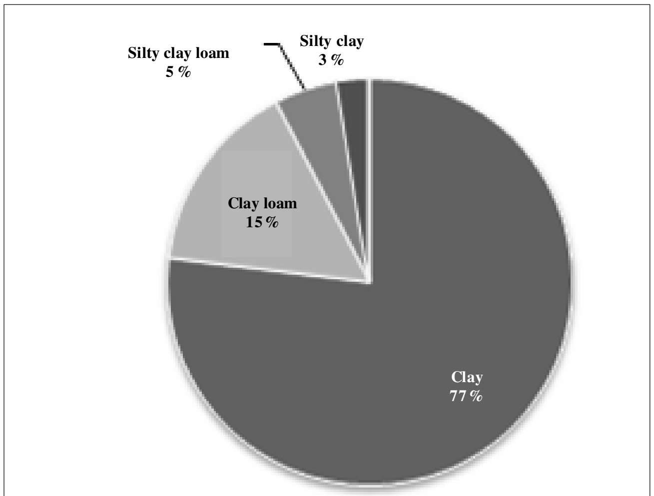



**Fig. 1: Destribution of soils**

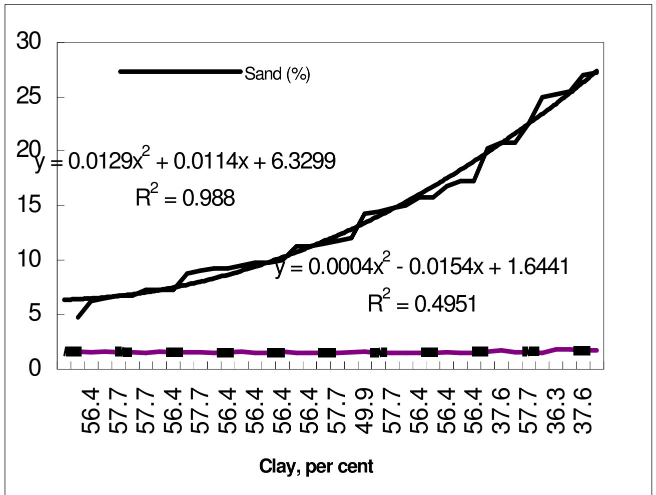



**Fig. 2 : Effect of clay content on map of command**

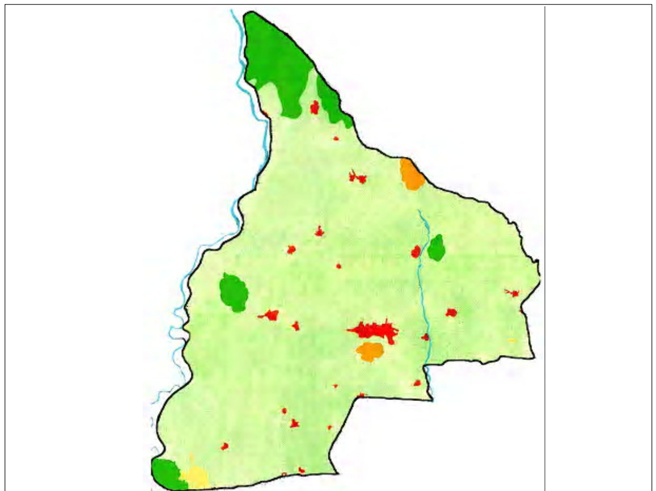


**Fig. 3 : Soil texture sand content and bulk density**

**Bulk density (BD) :**

Bulk density of soil is an index of physical condition of soil. The grid wise values of bulk density are presented in Table 1. The bulk density of soil varied from 1.48 to 1.81 g cm$^{-3}$. The bulk density was found to be slightly decreased with increase in clay content in the soil (Fig. 2). The results are in conformity with Nimkar (1990) who reported bulk density of soils of purna valley as 1.6 to 2 g cm$^{-3}$.

**Hydraulic conductivity (HC) :**

Hydraulic conductivity is a measure of drainage characteristics of soil. High hydraulic conductivity of soils ensures good drainage and aeration, and low water holding capacity. The grid wise saturated hydraulic conductivity of soil is presented in Table 1. The saturated hydraulic conductivity of soil varied from 1.1 to 13.9 mm hr$^{-1}$ over the command. The hydraulic conductivity of silty clay soil was found as 3.7 mm hr$^{-1}$, whereas the hydraulic conductivity for silty clay loam, clay loam and clay soil was found varying from 12.9 to 13.9 mm hr$^{-1}$, 2.2 to 9.9 mm hr$^{-1}$ and 1.1 to 9.5 mm hr$^{-1}$, respectively. It was also observed that the hydraulic conductivity decreased with increase in silt plus clay content while it was increased with increase in sand content (Fig 4). The results confirmed the findings of Sharma (1972).

**Table 1 : Physio-chemical properties of soils of command**

| Grid No. | PSD | | | | Physical properties | | | | Chemical properties | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sand (%) | Silt (%) | Clay (%) | Texture | $K_s$ (mm $hr^{-1}$) | $P_b$ (g $cm^{-3}$) | 0.33 bar *i.e.* FC (%) | 15 bar *i.e.* PWP (%) | pH | EC ($dSm^{-1}$) | $CaCO_3$ (%) |
| 1 | 25.25 | 38.43 | 36.32 | Clay loam | 9.6 | 1.81 | 28.84 | 17.42 | 8.31 | 0.35 | 6.53 |
| 2 | 25.50 | 36.88 | 37.62 | Clay loam | 9.2 | 1.80 | 28.65 | 16.71 | 7.63 | 0.37 | 6.87 |
| 3 | 15.75 | 27.85 | 56.40 | Clay | 6.2 | 1.51 | 27.07 | 18.19 | 8.01 | 0.27 | 7.12 |
| 4 | 25.00 | 18.60 | 56.40 | Clay | 7.8 | 1.50 | 29.83 | 16.67 | 8.11 | 0.29 | 7.37 |
| 5 | 22.50 | 19.80 | 57.70 | Clay | 7.5 | 1.53 | 33.95 | 17.36 | 8.21 | 0.44 | 7.50 |
| 6 | 27.25 | 36.43 | 36.32 | Clay loam | 9.9 | 1.73 | 27.70 | 17.52 | 8.63 | 0.36 | 7.87 |
| 7 | 6.75 | 35.55 | 57.70 | Clay | 1.4 | 1.57 | 35.42 | 24.60 | 8.23 | 0.27 | 7.87 |
| 8 | 11.50 | 32.10 | 56.40 | Clay | 7.7 | 1.52 | 31.65 | 17.78 | 8.31 | 0.28 | 17.25 |
| 9 | 4.75 | 37.55 | 57.70 | Clay | 2.4 | 1.59 | 35.63 | 26.06 | 7.73 | 0.27 | 18.60 |
| 10 | 14.39 | 49.29 | 36.32 | Silty clay loam | 12.9 | 1.48 | 27.07 | 13.63 | 8.51 | 0.23 | 12.25 |
| 11 | 12.00 | 30.30 | 57.70 | Clay | 4.9 | 1.54 | 25.77 | 15.90 | 8.42 | 0.41 | 15.87 |
| 12 | 7.25 | 35.05 | 57.70 | Clay | 5.9 | 1.51 | 29.11 | 18.32 | 8.28 | 0.43 | 15.62 |
| 13 | 6.75 | 35.55 | 57.70 | Clay | 5.9 | 1.53 | 29.66 | 21.37 | 8.41 | 0.40 | 17.50 |
| 14 | 9.75 | 33.85 | 56.40 | Clay | 6.1 | 1.49 | 23.77 | 16.67 | 8.01 | 0.30 | 18.50 |
| 15 | 9.25 | 34.35 | 56.40 | Clay | 5.9 | 1.50 | 27.99 | 17.98 | 8.66 | 0.39 | 17.12 |
| 16 | 27.00 | 35.38 | 37.62 | Clay loam | 9.8 | 1.71 | 28.90 | 18.13 | 8.05 | 0.45 | 19.00 |
| 17 | 9.50 | 34.10 | 56.40 | Clay | 1.1 | 1.59 | 31.36 | 20.00 | 8.46 | 0.29 | 17.25 |
| 18 | 7.25 | 35.05 | 57.70 | Clay | 3.4 | 1.58 | 29.12 | 18.45 | 8.16 | 0.37 | 9.00 |
| 19 | 11.75 | 30.55 | 57.70 | Clay | 8.9 | 1.52 | 28.63 | 17.78 | 8.39 | 0.45 | 16.50 |
| 20 | 20.75 | 41.63 | 37.62 | Clay loam | 8.3 | 1.69 | 31.16 | 19.56 | 8.40 | 0.33 | 16.37 |
| 21 | 8.75 | 34.85 | 56.40 | Clay | 3.7 | 1.57 | 25.67 | 16.80 | 8.34 | 0.40 | 17.87 |
| 22 | 9.00 | 33.30 | 57.70 | Clay | 1.5 | 1.56 | 35.57 | 26.30 | 8.43 | 0.93 | 13.12 |
| 23 | 11.25 | 31.05 | 57.70 | Clay | 8.5 | 1.51 | 26.75 | 17.90 | 8.43 | 0.93 | 20.62 |
| 24 | 7.25 | 36.35 | 56.40 | Clay | 3.7 | 1.57 | 33.98 | 22.96 | 8.51 | 0.24 | 12.00 |
| 25 | 9.25 | 34.35 | 56.40 | Clay | 4.6 | 1.56 | 28.90 | 19.29 | 8.26 | 0.41 | 14.37 |
| 26 | 17.25 | 26.35 | 56.40 | Clay | 5.9 | 1.51 | 25.51 | 16.60 | 8.27 | 0.45 | 19.87 |
| 27 | 6.25 | 37.35 | 56.40 | Clay | 4.3 | 1.56 | 34.33 | 22.58 | 8.07 | 0.31 | 7.87 |
| 28 | 6.50 | 35.80 | 57.70 | Clay | 2.2 | 1.59 | 29.01 | 20.00 | 8.09 | 0.47 | 19.50 |
| 29 | 15.75 | 46.63 | 37.62 | Silty clay loam | 13.9 | 1.50 | 26.03 | 13.30 | 8.39 | 0.65 | 18.12 |
| 30 | 17.25 | 26.35 | 56.40 | Clay | 5.9 | 1.50 | 26.95 | 16.53 | 8.24 | 0.36 | 23.50 |
| 31 | 16.75 | 26.85 | 56.40 | Clay | 5.7 | 1.53 | 27.16 | 16.67 | 8.48 | 0.34 | 20.00 |
| 32 | 10.00 | 33.60 | 56.40 | Clay | 2.3 | 1.59 | 29.34 | 20.95 | 8.25 | 0.32 | 12.12 |
| 33 | 20.25 | 23.35 | 56.40 | Clay | 1.8 | 1.59 | 28.80 | 17.93 | 8.24 | 0.29 | 6.25 |
| 34 | 14.25 | 35.86 | 49.89 | Clay | 2 | 1.58 | 25.53 | 15.03 | 8.78 | 0.33 | 19.12 |
| 35 | 15.00 | 27.30 | 57.70 | Clay | 9.5 | 1.51 | 31.25 | 21.43 | 8.11 | 0.32 | 19.62 |
| 36 | 14.75 | 27.55 | 57.70 | Clay | 9.3 | 1.50 | 27.48 | 16.69 | 8.26 | 0.24 | 19.12 |
| 37 | 20.75 | 41.63 | 37.62 | Clay loam | 3.3 | 1.57 | 28.69 | 16.83 | 7.77 | 0.30 | 18.50 |
| 38 | 9.75 | 40.36 | 49.89 | Silty clay | 3.7 | 1.48 | 27.02 | 16.78 | 8.36 | 0.32 | 16.62 |
| 39 | 11.25 | 32.35 | 56.40 | Clay | 7.7 | 1.50 | 27.62 | 15.97 | 8.47 | 0.30 | 15.00 |
| Average | 13.88 | 33.58 | 52.55 | Clay | 6.0 | 1.56 | 29.15 | 18.48 | 8.27 | 0.38 | 14.75 |

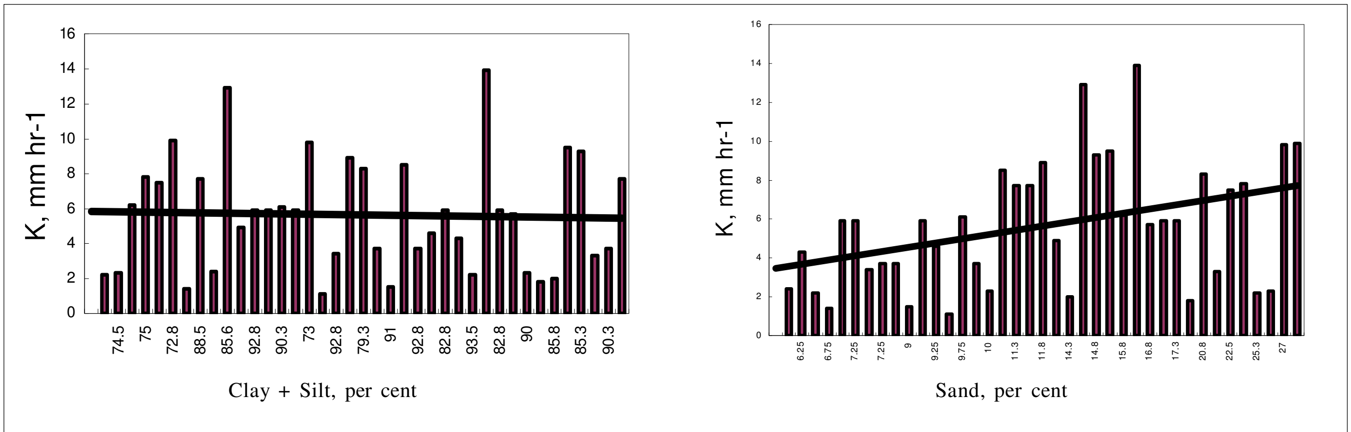



**Fig. 4 : Effect of sand, silt and clay content on hydraulic conductivity**

**Soil moisture retention :**

The grid wise soil moisture retention at 0.33 and 15 bar, and available water capacity is presented in Table 1. The water retention of soil at 0.33 bar varied from 23.77 to 35.63 per cent and at 15 bar varied from 13.30 to 26.30 per cent, over the command. The water retention of silty clay, silty clay loam, clay loam and clay soil at 0.33 bar varied from 27.02, 26.03 to 27.07, 38.32 to 45.26 and 25.51 to 35.63 per cent, respectively and at 15 bar varied from 16.78, 13.30 to 13.63, 20.06 to 24.32 and 15.03 to 26.06 per cent, respectively. The soil moisture content increased at both 0.33 bar and 15 bar with increase in silt plus clay content in the soil. The variation in water retention was relatively high under low tension and low under high tensions (Fig. 5). The results confirmed the prediction of Shinde (1985).

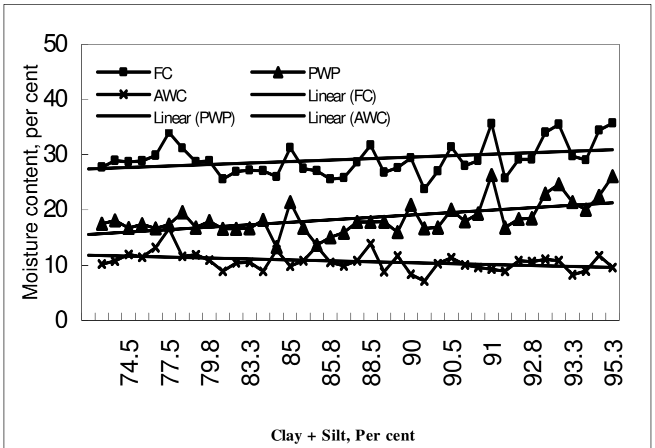



**Fig. 5 : Effect of clay plus silt content on water retention at 0.33 (FC) and 15 bar (PWP), and AWC**

**Available water capacity (AWC) :**

Soil moisture holding capacity is important to predict the time to irrigate and amount of water needed to replenish the moisture that has been removed from the root zone. Grid wise available water capacity of soil over the command is presented in Table 1. Available water capacity of soils varied from 7.1 to 16.59 per cent. Available water capacity decreased with increase in silt plus clay per cent (Fig. 5).

**Soil reaction (pH) :**

Grid wise pH values for soils of command are presented in Table 1. The soils of command area were found moderately to strongly alkaline in reaction as pH varied from 7.63 to 8.78. The results are in conformity with those reported by Padole *et al* .(1998).

**Electrical conductivity (EC) :**

Soil EC correlates the soil properties like moisture content, soil texture, soil organic matter and salinity that affect the crop productivity. Grid wise electrical conductivity values for soils of command are presented in Table 1. EC was found to be varied from 0.23 to 0.93 dS $m^{-1}$. The observed values of EC are well within acceptable limit (< 2 dS $m^{-1}$) designated for normal soils.

**Calcium carbonate content ($CaCO_3$) :**

Grid wise calcium carbonate content values for soils of command area are presented in Table 1. Calcium carbonate content of soils varied from 6.25 to 23.5 per cent. The soils of command were classified as highly calcareous. It confirmed the findings of Sagare *et al.* (1991). It is observed that as calcium carbonate content increases available water capacity of soil decreases (Fig. 6) and therefore, frequent irrigations would be required to these soils. Calcareous soils contain high amounts of free lime ($CaCO_3$). Higher concentration of calcium carbonate may not severely restrict the water movement but adversely affect the root penetration. The presence of excessive $CaCO_3$ reduces the availability of phosphorus and micronutrient (Kharkar *et al.,* 1991). Thus,

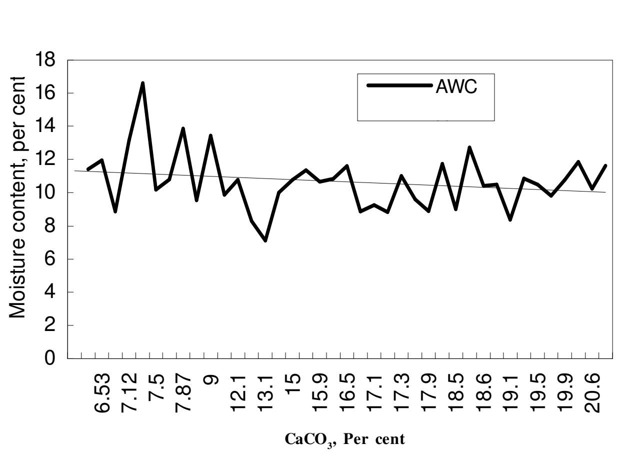



**Fig. 6 : Effect of $CaCO_3$ content on AWC**

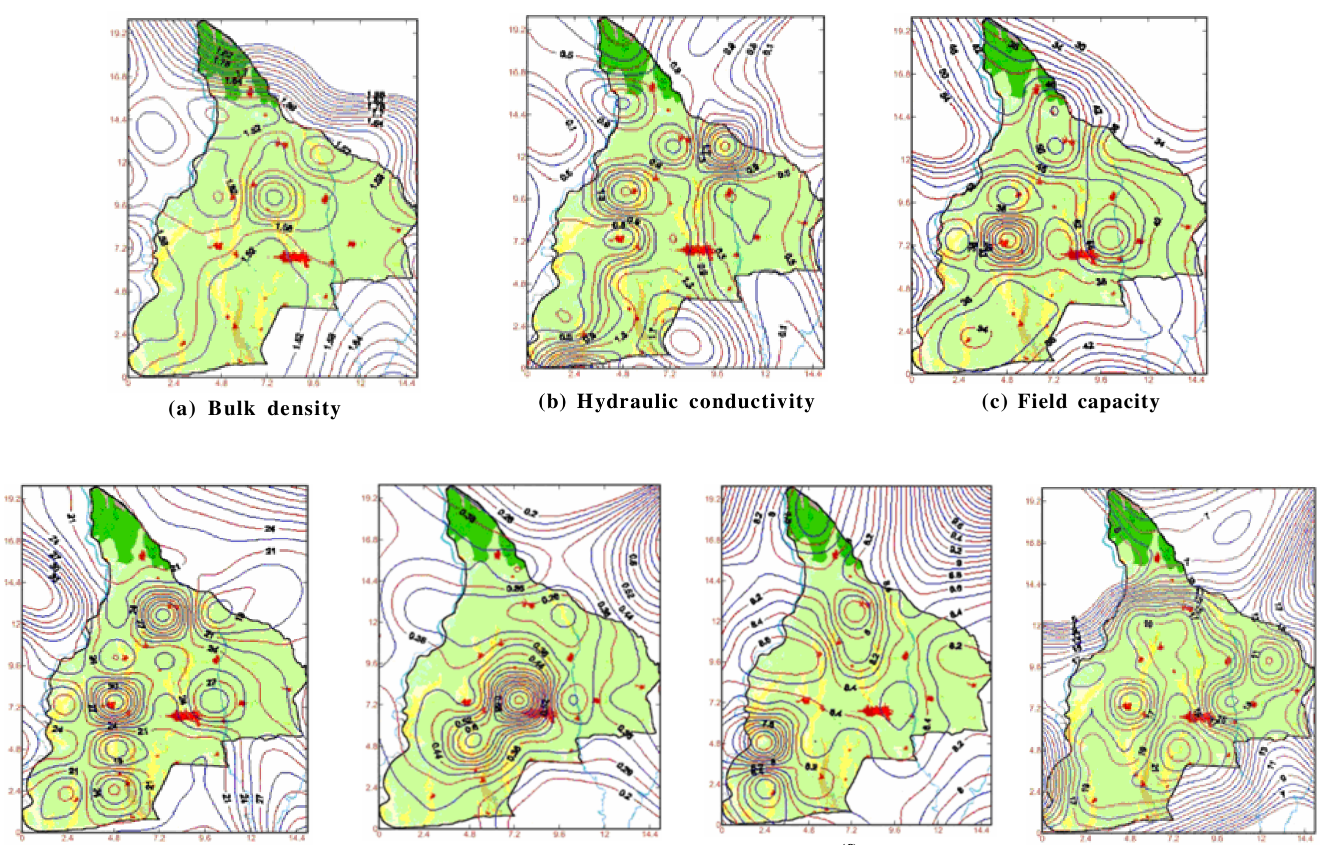
the soils of command are not suitable for horticultural plantation specifically belonging to citrus family.

**Preparation of contour maps :**

Contour maps of various properties of soil were plotted using SURFER software. Fig. 7 (a, b, c, d, e, f, g) depicted the contour profiles superimposed on soil texture map of command area for the soil properties *viz.,* bulk density, hydraulic conductivity, field capacity, permanent wilting point, pH, EC and $CaCO_3$ content. Contour maps serve as ready reckoner of soil characteristics for further analysis like determination of irrigation depth.

**Conclusion :**

As most of soils in the command are clayey, and average values of soil properties like bulk density (1.56 g cm$^{-3}$), hydraulic conductivity (6 mm hr$^{-1}$), pH (8.27), electric conductivity (0.38 dSm$^{-1}$) are well in limit, the soils of command are suitable to grow all crops, except horticultural crops of citrus family due to high $CaCO_3$ content (14.74 %). On the basis of soil properties, the command is classified under soil irrigability class 'A'.



(a) Bulk density (b) Hydraulic conductivity (c) Field capacity

(d) PWP (e) pH (f) EC (e) $CaCO_3$ content

**Fig. 7: Contour profiles of soil properties**

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