

**CHARACTERIZATION OF SELECTED TANK  
COMMAND AREA SOILS IN CENTRAL DRY  
ZONE (ZONE-IV) OF KARNATAKA**

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BANGALORE

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**CHARACTERIZATION OF SELECTED TANK  
COMMAND AREA SOILS IN CENTRAL DRY  
ZONE (ZONE-IV) OF KARNATAKA**

**N. RAMESH**

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**DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY  
UNIVERSITY OF AGRICULTURAL SCIENCES  
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**CERTIFICATE**

This is to certify that the thesis entitled, “**CHARACTERISATION OF SELECTED TANK COMMAND AREA SOILS IN CENTRAL DRY ZONE (ZONE-IV) OF KARNATAKA**” Submitted by **Mr. RAMESH, N.** for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE) in SOIL SCIENCE** to the University of Agricultural Sciences, GKVK, Bangalore, is a record of *bona-fide* research work done by him during the period of his study in this University under my guidance and supervision. The data of this thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

Bangalore  
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*Place : Bangalore*

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# **INTRODUCTION**

## I INTRODUCTION

The early inhabitation of mankind were on the river banks with assured water supply. The civilizations namely ; Babylon, Indus valley civilization and others, perished due to their inability to utilize water efficiently and also due to accompanying problems of soils, arising out of poor water management. Man, realising importance of assured water supply, has ever since built large reservoirs, dams, tanks and other, accross rivers and streams to offset problems of water scarcity during crop growth period and hence continuously utilized land for the crop production.

The stress on land to produce more to meet the requirements of growing population has instigated man to use water indiscriminately. This indiscriminate use of stored water in the reservoirs, tanks and other has of course increased the water table and hence it has induced soil problems such as soil salinity and sodicity. Among most important aspects of soils and water management in irrigated agriculture is the prevention of undue increase in soil sodicity or salinity. Prerequisite to the development of satisfactory management procedures is broad basic knowledge of the complex factors that contribute to salinity and sodium hazards. Control of soil salinity requires application of enough water to leach excess salts and provision for removal of concentrated drainage effluent. Presuming that adequate drainage occurs, the main component of salinity hazard of irrigation water is the total salt content. Water quality appraisal from the point of view of sodium /salinity hazard becomes a necessity to evade possible ill effects on soil health.

In Karnataka large dams, namely Thunga Bhadra Project, Krishnaraj Sagara, Vanivilas Sagara, Krishna valley project and Bhadra reservoir have potential to

irrigate large areas. It is still inadequate and tank irrigation is still in vogue, in various parts, accounting nearly 30 per cent of the total irrigated area. In central dry zone [zone 4] 25.56 per cent of total irrigated area (39,903 ha) is under tank irrigation (Anonymous, 1990). Hence it becomes necessity to appraise the water quality of these tanks and its subsequent effect on soil quality parameters. It would also help in developing measures to maintain soil health. Hence the study to characterise tank command area soils of central dry zone IV of Karnataka was taken up with the following objectives.

1. To study the ionic population in water exchangeable and water soluble positions in tank bed irrigated soils of central dry zone(zone- IV) of Karnataka.
2. To derive ion exchange equation that would adequately describe sodicity hazards in soils consequent to tank irrigation.
3. To study the effect of irrigation by tank water on physical properties of soil
4. To determine the effect of anions on exchangeable sodium percentage in the soils.

# **REVIEW OF LITERATURE**

## **II REVIEW OF LITERATURE**

The history of irrigated agriculture in India dates back to the pre-Aryan period, as could be seen from the excavation of Mohanjadaro and Harappa in the Indus valley. Nevertheless several countries have practiced irrigation for a number of centuries

In recent times great impetus has been given to irrigation to boost the production of food for the teeming million. The introduction of irrigation in dry areas and the attendant havocs of salt affliction of soils, water logging etc. as a result of faulty management practices have been the main reasons for reduction in crop production and a number of studies have been made else where in India.

The relevant literature is reviewed briefly under the following headings

### **2.1 Chemical properties**

#### **2.1.1 Soil reaction (pH)**

The sodic soils in the Indo Gangetic alluvium in Uttar Pradesh have high pH and the pH of the surface soils of North-Eastern regions varied from 8.9 to 9.4 (Agarwal and Yadav, 1956).

Kanwar and Sehgal (1962) reported that the pH of the sodic soils of Karnal increased with depth and the values were 9.2, 9.2, 9.3 and 9.5 at 0 to 20 cm, 20 to 40 cm, 40 to 60 cm and 60 to 100 cm depth respectively. The increase in pH may be due to fluctuating water table and higher concentration of sodium.

Kanwar *et al.* (1963) have indicated that pH could be taken as an index of exchangeable sodium in saline-sodic soils. They obtained a significant correlation between these two parameters and between pH and soluble carbonate percentage.

About 13 per cent of the area in Vishveswaraya canal tract in Mandya district is affected by salinity. The pH of the surface soil ranged from 7.7 to 9.6 and increased with depth (Ambadas Rao, 1969).

The pH of surface soils of the Western Uttar Pradesh ranged from 9.8 to 10.3 (Agarwal and Tripathi, 1974). The surface sodic soils of Punjab and Haryana varied from pH 8.7 to 10.6 (Mahajan and Kanwar, 1974).

Bhadrapur and Seshagiri Rao (1979) reported an increase in pH with depth in black cotton soils in Tungabhadra project area irrigated for 33 years.

Tiwari *et al.* (1983) reported that the sodic soils in Kanpur region of Uttar Pradesh have high pH. The pH of the soils varied from 8.5 to 10.3, such high pH of the soils is due to the presence of soluble sodium carbonates and bicarbonates.

More *et al.* (1988) observed that salt affected soils of Purna command area in Maharashtra state have pH ranging from 8.1 to 10.7 and did not show any specific trend. The pH of Katneshwar and Pimpalgam profiles was relatively higher as compared to other soil profiles.

Electrolytes and SAR increased soil pH of Entisols and Vertisols significantly while Alfisols were resistant to change in soil pH (Satish Rao, 1989).

Bharambe *et al.* (1990) reported that pH of Jayakwadi command area soils in Maharashtra were neutral to alkaline and higher pH values at lower layers may be due to high calcium carbonates.

Ved Prakash *et al.* (1995) reported that the salt affected soils of Sultanpur district of Uttar Pradesh have pH ranging from 8.8 to 10.6 and decreased with increasing depth, indicating the process of alkalization had started at the surface and proceeded in down ward direction.

Walia and Rao (1997) reported that the pH of Khraund soils are slightly acidic (pH 6.0) and gradually increased with depth due to leaching of bases from surface. The alkaline reaction (pH 7.9 to 8.3) of other soils is attributed to base rich alluvium and presence of free carbonates.

### **2.1.2 Electrical conductivity of soils**

The presence of excess soluble salts constitute the most important liming factor for crop growth. The conductivity of the surface soils of Indo-Gangetic alluvium ranged from 3.0 to 5.6  $\text{d Sm}^{-1}$  (Agarwal and Yadav, 1956).

Barde and Gowaikar (1965) reported that the electrical conductivity of North Gujarat soils increased with depth and the values were 0.19, 1.21, 1.8, 2.10 and 3.0  $\text{d Sm}^{-1}$  at 0 to 20 cm, 20 to 40 cm, 40 to 60 cm and 60 to 100 cm depth respectively.

The soils of Sutlej river basin in Punjab had conductivity lesser than one m mho/cm which decreased with depth (Seghal *et al.* 1968).

Gupta and Abichandani (1970) noticed that the use of irrigation water containing predominantly divalent cations caused higher accumulation of salts in the subsurface layers.

Sodic soils have low electrical conductivity because of precipitation of Ca and Mg as their carbonates (Poonia and Bhumbra, 1973).

Bhargava *et al.* (1973) reported that the electrical conductivity decreased with depth in Tungabhadra catchment area soils. Similar results were obtained by Bhadrapur and Seshagiri Rao (1979).

In some of the salt affected soils of Harsi command area of Madhya Pradesh, electrical conductivity of soils ranged from 1.2 to 13.9 m mhos/cm as a result of excessive accumulation of salts. An increasing trend of electrical conductivity in the profile stratum indicated that prevailing conditions facilitated excessive accumulation of salts in the surface horizons and also that leaching of salts had not taken place from top to lower layers (Mediratta *et al.*, 1985).

Raj Pal *et al.* (1985) observed that there was fair agreement between the predicted and observed values of electrical conductivities in various soil layers obtained from the model based on miscible displacement. This technique was to predict leaching and accumulation of total soluble salts in sandy loam profile.

Ahmed and Shafiqur Rahaman (1986) reported that, electrical conductivity and sodium adsorption ratio of irrigated soil decreased down the profile in light textured soils but in heavier textured soils these parameters did not decrease very much.

Electrical conductivity of some of the salt affected soils of Purna command area of Maharashtra ranged from 0.8 to 19.0 d Sm<sup>-1</sup> at 25°C. An increasing trend of electrical conductivity in the upper layers of profile indicates that the prevailing conditions facilitated excessive accumulation of salts in the surface horizons (More *et al.*, 1988).

Chandrasekharan *et al.*, (1994) obtained non-significant correlation between EC and some sodicity indices like ESP and SAR may be due to lower levels of exchangeable sodium.

Ved Prakash *et al.* (1995) reported that the salt affected soils of Sultanpur district of Uttar Pradesh have EC ranging from 0.6 to 16.8 d Sm<sup>-1</sup> and it decreased with increasing depth, indicating that the process of alkalization had started at the surface and proceeded in down ward direction.

### **2.1.3 Organic carbon**

Continuous cultivation of cereal crops under irrigation has little influence on the humus content of soils, where as under Lucerne there was an increase in humus content (Boltania, 1959).

Sobornikova (1959) reported that the irrigation of chernozem soils of the Rostor region of U.S.S.R. for 4 years did not affect the total humus, but irrigation for 18 years decreased the humus content in the surface one meter by eleven per cent. Irrigation also caused temporary and shallow leaching of soluble humus.

Suchkov (1962) recorded that prolonged irrigation and systematic fertilization of serozems increased the organic matter content and soil

productivity. In meadow soils the same practice decreased the content of organic matter but did not decrease productivity.

Kenchanna Gowda (1977) reported a slight increase in organic carbon content in TBP area soils upon irrigation.

Tiwari *et al.* (1983) indicated that the irrigated sodic soils of Kanpur are low in organic matter content due to poor vegetation and rapid decomposition and mineralization under prevailing sub-tropical climatic conditions.

Gupta *et al.* (1985) observed that the high dispersibility of soils treated with humic substances is related to soil pH which in turn influenced the CEC and physico-chemical properties of salt affected soils.

Organic carbon content of Purna command area in Maharashtra was medium to high in surface layers and it decreased down the depth of soil profile (More *et al.*, 1988).

#### **2.1.4 Alkaline earth carbonates**

Kulkarni *et al.* (1963) reported that in irrigated soils of North Karnataka, alkaline earth carbonates content increased with depth may be due to movement of calcium to lower horizons upon irrigation and precipitated as calcium carbonate with increase in carbonate and bicarbonate concentration in the soil solution.

Barde and Gowaikar (1965) indicated that the per cent calcium carbonate in North Gujarat soils increased with depth due to accumulation of precipitated calcium carbonate in lower layers.

Kenchanna Gowda (1977) reported in his work on TBP soils, calcium carbonate content get reduced upon irrigation markedly through out the profile.

In sodic soils of Kanpur region of Uttar-Pradesh the calcium carbonate accumulation in lower layers was visible but the trend was not consistent may be due to fluctuation in water table (Tiwari *et al.*, 1983).

### 2.1.5 Cation exchange capacity of soils

Kenchanna Gowda (1977) in his work on TBP soils reported that irrigation did not alter much of the CEC of the soils and it followed closely with the pattern of accumulation of clay in horizons.

Gupta *et al.* (1985) observed that alkali soils formed under the influence of sodium carbonate salts have high ESP and pH. They also observed CEC of these soils increased with pH. However the development of negative charge and pH is more in calcareous salt affected soils.

CEC of some of the salt affected soils of the Purna command area in Maharashtra ranged from 8.0 to 45.0 c mol (P<sup>+</sup>) kg<sup>-1</sup>, CEC of surface soils was high and it was low at lower depths of soils profile, due to high organic matter at surface region (More *et al.*, 1988).

The CEC is positively correlated with exchangeable sodium ( $r = 0.9513$ ) in salt affected soils of Challakere (Gangappa, 1989).

Srivastava and Srivastava (1993) studied the relation between CEC and pH in some salt affected soils of Uttar Pradesh and reported that CEC was found

to be positively and significantly correlated with pH and CEC increased at a rate of  $3.7 \text{ c mol (P}^+) \text{ kg}^{-1}$  per unit increase in soil pH.

Sen *et al.* (1997) reported that in some soils of Barak valley in Assam, inspite of fairly high clay content, low CEC of these soils may be due to preponderance of low activity clay minerals however the CEC of surface soil was high might be due to higher content of organic matter.

Walia and Rao (1997) reported that the CEC of Trans-Yamuna plain soil varied from 10.9 to 28.4  $\text{c mol (P}^+) \text{ Kg}^{-1}$  soil and the surface soil have low CEC in comparison with underlying horizons obviously due to decrease in clay content.

### **2.1.6 Exchangeable cations**

The exchangeable calcium and sodium in north Gujarat soil increased with depth and their values were 12.4, 13.6, 14.9, 16.2 and 17.2, 18.3, 18.3, 21.4 and 26.3  $\text{me}/100\text{g}$  soil at 0 to 20 cm, 20 to 40, 40 to 60 cm and 60 to 100 cm depth respectively (Barde and Gowaikar, 1965).

In Allahabad soil the calcium content was 2.1,3.8,4.2 and 6.0  $\text{me}/100\text{g}$  and it increased with depth. The sodium content increased with depth values were 6 and 11  $\text{me}/100\text{g}$  at surface and lower depth respectively (Misra and Sharma, 1968).

Sehgal *et al.*,(1968) reported that the exchangeable calcium and magnesium content in Punjab soils of Sutlej river basin have decreased with depth and the values were 6.6 and 2  $\text{me}/100\text{g}$  and 2.26 and 0.4  $\text{me}/100\text{g}$  soils respectively at surface and one meter depth.

The status of exchangeable cations, exchangeable sodium percentage of a soil depends upon various factors like status of soluble cations, concentration of electrolytes, type of mineral and other factors. In tropical soil exchangeable calcium and magnesium were found in excess over exchangeable sodium or exchangeable potassium (El Swaify and Swindale, 1970).

Srinath (1979) observed an increased content of sodium, calcium and magnesium at lower horizons in most of the salt affected soils studied.

Bhadrapur and Seshagiri Rao (1979) have reported that exchangeable sodium increased with depth in salt affected soil of Ghataprabha and Malaprabha command area.

Tiwari *et al* (1983) reported in their work on Jayakwadi command area soils that calcium was dominant cation, all soil are highly base saturated and exchangeable sodium decreased with depth

Sharma and Jha (1989) indicated that in some salt affected soils, the cationic predominance was  $Na > (Ca + Mg) > K$ , where as in normal soils, the sequence was  $[Ca + Mg] > Na > K$ .

Bharambe *et al*, (1990) reported in their work on Jayakwadi command area soils that calcium was dominant cation, all soils are highly base saturated and exchangeable sodium decreased with depth.

Parvathappa *et al*, (1990) in the study on impact irrigation water quality on soil properties in semiarid tropics reported that exchangeable calcium and magnesium were dominant in exchange complex while ESP was greater than 15 in a few soils.

Walia and Rao (1997) reported that in soils of Trans -Yamuna plain, exchangeable calcium is the dominant base followed by magnesium in all pedons and these two cations constitute the bulk of bases in all pedons, the abundance of sodium is invariably higher than potassium.

### **2.1.7 Exchangeable sodium percentage**

Several workers reported an increase in ESP with depth upto the zone of maximum accumulation of clay, may be due to increase in SAR values with depth (Jain and Saxena, 1970 and Bhadrapur and Seshagiri Rao, 1977).

Patak and Patel (1980) indicated that exchangeable sodium percentage (ESP) values were comparatively higher in lower layers of salt affected areas of Kaira district, Gujarat.

In some salt affected soils of purna command area of Maharashtra, the ESP was in the range of 10 to 40 at varying depths, being relatively higher in upper horizons (More *et al*, 1988). Similar trend in ESP of the soil profile was recorded by Tiwari *et al*, (1983).

Ved Prakash *et al*, (1995) reported that the ESP of salt affected soils of Sultanpur district of Uttar Pradesh ranged from 19.5 to 80.5 and decreased with increasing depth, due to down ward process of alkalization.

### **2.1.8 Water soluble cations of the soils**

Kanwar and Singh (1961) reported that the degree of sodium saturation was markedly more on light textured soils than on heavy soils. However the total amount of adsorbed cations will be always more on heavy textured soils with high

CEC values. Considerable quantity of calcium, magnesium and potassium are displaced from the exchangeable sites of clay complex, when sodium is the predominant cation due to sodium adsorption (Kanwar *et al*, 1963).

On account of evaporation the soil solution becomes concentrated and carbonates and bicarbonates tend to precipitate as Ca and Mg carbonates which are less soluble. there by increasing the activity of sodium. The adsorption of sodium was more due to carbonate ion than due to bicarbonate ion at the same level of salt concentration (Kanwar and Kanwar, 1968).

Mathur *et al*, (1968) observed that the soluble calcium content in western Rajasthan soils decreased with depth and the values were 3.9, 2.6, 2.1 and 1.8 me/l where as the values for soluble were 7, 12, 38 and 69 meL<sup>-1</sup> and increased with depth at 0 to 20 cm, 20 to 40 cm, 40 to 60 cm and 60 to 100 cm respectively.

Jain and Saxena (1970) reported that the soluble calcium plus magnesium content in Udaipur soils were 3.0, 7.5, 8.9 and 13.0 meL<sup>-1</sup> and sodium content were 1.0, 7.8, 18.7 and 25.5 me/l at 0 to 20 cm, 25 to 30 cm, 50 to 75 cm and 75 to 100 cm depth respectively and increased with depth.

Bandyopadhyaya (1973) observed that the soluble calcium and magnesium of Karnal soil decreased with depth and the values were 6.0 and 1.5 meL<sup>-1</sup> at surface and one more meter depth respectively and sodium content was 7 me L<sup>-1</sup> which remained almost same.

Poonia and Bumbla (1973) observed the predominance of sodium over other cations, among salt affected soils. Similar results were obtained by Bhadrapur and Seshagiri Rao (1977), and Srinath (1979).

Bhadrapur and Seshagiri Rao (1976) reported that sodium content of soil decreased considerably on flood irrigation compared to light irrigation. While calcium increased in both flood and light irrigation soils compared to pre-irrigated soils, after 33 years of irrigation in black cotton soils of TBP area. They further indicated that water soluble cations decrease with depth in these soils during 1975.

Landey and Feighonbaum (1977) indicated that the increased soluble sodium upon dilution was due to its replacement mainly by Ca and Mg.

Poonia and Talibudeen (1977) observed that surface soils preferred Ca more than the corresponding subsurface which was mainly attributed to their surface charge density and organic matter content.

Kotur and Seshagiri Rao (1988) reported that sodium concentration was greater than those of calcium and magnesium together in Malaprabha and Ghataprabha command area soils.

In some of the salt affected soils of purna command area of Maharashtra, sodium was dominant cation in Pimpalgaon, Satephal and Katneshwar soil profiles. There was a direct and positive relationship between pH and soluble sodium content of the soil (More *et al.*, 1988).

Parvathappa *et al.* (1990) reported that water soluble cations were higher in the surface horizon with calcium and magnesium as a dominant cations. Sodium was dominant in soils having high water table and poor drainage.

### 2.1.9 Water soluble anions

Mathur *et al.* (1968) reported that the bicarbonate and chloride contents of desert soils of western Rajasthan were 4 to 18.6 me L<sup>-1</sup> and 27 to 145 me L<sup>-1</sup> respectively.

The carbonate ion concentration in the Sutlej river basin of Punjab was negligible, bicarbonate content was 2.5, 7.0, 8.8 and 19.3 me L<sup>-1</sup>, Chloride content was low and sulphate content was 8.6, 12.3, 14.2 and 15.1 me L<sup>-1</sup> at 0 to 20 cm, 20 to 40 cm, 40 to 60 cm, and 60 to 100 cm depth. The bicarbonate content in the soils of Pali district was 2.5 and 10 me L<sup>-1</sup> and chloride content was 12.5 and 102 me L<sup>-1</sup> at 0 to 25 cm and 75 to 100 cm depth respectively (Sharma *et al.*, 1968).

Bandyopadhyaya (1973) observed that the bicarbonate content in Karnal soils decreased with depth and the values were 10, 8, 7.5 and 5 me L<sup>-1</sup> where as chloride and sulphate content reduced with depth and the values were 6.0, 4.5, 3.0 and 2 me L<sup>-1</sup> and 9, 8.5, 8.0 and 6.0 me L<sup>-1</sup> respectively.

Bhadrapur and Seshagiri Rao (1976) reported that bicarbonate, sulphate and chloride reduced considerably upon flood irrigation compared to light irrigation.

Kenchanna Gowda (1977) in his work on TBP soils reported that irrigation tended to accumulate anions like chloride, sulphate and bicarbonates but the sum total of chloride and sulphate was found invariably greater than those of bicarbonates.

In the sodic soils of Kanpur region of Uttar Pradesh, carbonate was the dominant anion followed by chloride and sulphate in all the profiles, but when bicarbonate was the dominant anion, the other ions followed are chlorides, carbonates and sulphates (Tiwari *et al.*, 1983).

Chloride was the dominant anion followed by sulphate, where as bicarbonate content exceeded other anions in sodic profiles of Purna command area of Maharashtra (More *et al.* 1988).

Gangappa (1989) in his work on some salt affected soils of Challakere, reported that carbonate was the dominant anion followed by chlorides, bicarbonates and sulphates.

Parvathappa *et al.* (1990) reported that water soluble bicarbonates was less than chloride and sulphate and increased with depth in few Vertisols.

#### **2.1.10 Sodium Adsorption Ratio (SAR)**

Paliwal and Gandhi (1976) reported that the equation for ESP prediction proposed by U.S.S.L. staff (1954) underestimates in light textured soils and overestimates in heavy textured soils at given SAR values.

Disagreement between predicted ESP (obtained from SAR) and observed ESP (obtained from CEC) values had been widely reported (El Seewi *et al.*, 1977 and Bhadrapur and Seshagiri Rao, 1977).

Oster and Sposito (1980) observed that the thermodynamic theory of cation exchange is constant with the empirical exchangeable sodium ratio and

sodium adsorption ratio in relation over the range of SAR values. This has practical importance in the management of sodium affected soils.

Kotur and Seshagiri Rao (1988) and Parvathappa (1981) indicated that the SAR values correlated for ion pair formation [ $\text{CaCO}_3$  and  $\text{CaSO}_4$ ] and ionic activity improved the prediction of sodium hazard much better in the salt affected soils.

## **2.2 Physical properties**

### **2.2.1 Particle size distribution**

There was a marked changes in the particle size distribution of soils in different horizons of soil profile due to irrigation. The processes of eluviation and illuviation were the main factors responsible for bringing about the alterations in the physical and chemical make up of the soil profile and its development (Kenchanna Gowda, 1977).

Tiwari *et al.*, (1983) reported that the sodic soils of Kanpur region of Uttar Pradesh are generally light in texture at the surface and tend to become clay in the lower layers. This may be attributed to the process of salinization that caused dispersion and downward movement of clay from the surface. The zone of maximum accumulation of clay is at 15-17 cm in Chakeri, Sachendi and Bara profiles, 30 to 100 cm in Shuklapur and 30 to 60 cm in Rosulabad. In Dalipnagar profile, however the texture of surface soil is relatively heavier than subsoil.

Parvathappa (1981) reported that clay content increased with depth mainly because of illuviation in irrigated soils of Karnataka.

In some of the salt affected soil profiles in western part of India, the clay content increased with depth (Dubey *et al.*, 1984).

Dubey and Sharma (1987) reported that salt affected soils of Surendranagar district of Gujarat, have uniform clay distribution except in the surface horizon and shows clay accumulation in subsurface horizon due to illuviation.

Walia and Rao (1997) reported that the clay content in Kharanud and Bharatkup soils varies from 15.4 to 39.8 per cent and such variations could be due to change in depositional pattern as indicated by abrupt change in sand/silt ratio.

### **2.2.2 Rheological properties of soil**

All rheological properties of soil viz., lower plastic limit (LPL), upper plastic limit (UPL), plasticity index (PI) and soil consistency limit are primarily dependent on clay content of the soil (Baver, 1930).

William *et al.* (1957) reported a close association between clay content and plasticity index. This was also confirmed by Ahmed *et al.*, (1969) and they obtained good correlation between CEC and lower plastic limit.

Odell *et al.* (1960) obtained a good correlation between each of Atterberg limit like lower plastic limit, upper plastic limit, plasticity index with cation exchange capacity, organic carbon and clay.

Raghu Kumar (1977) besides relating Atterberg limit with clay also obtained good correlation with water retention, porespace, water movement and volume expansion in red soils of south India..

Smith *et al.* (1944) have reported that salinity or sodicity would raise the liquid limit of soils.

### 2.2.3 Hydraulic conductivity

McNeal and Coleman (1966) reported that the hydraulic conductivity of Pachappa clay loam came down to 0.02 cm/hr when salt accumulation was reduced from 50 to 3 me L<sup>-1</sup>.

The hydraulic conductivity of light soils of Hawaii was not affected much by decreasing salt concentration and was maintained at 1.21 cm/hr (El Swaify and Swinadale, 1970).

Abrol and Bumbla (1968) indicated hydraulic conductivity and soil water diffusibility underwent sharp decrease when ESP was higher than 15. Dispersion and displacement of dispersed particles is thought to be the main mechanism responsible for reduction in the transmission characteristics.

Pandey *et al.* (1974) reported that the soils of Bundelkhand area have shown poor hydraulic conductivity of 0.008 cm/hr as the salt concentration decreased from 0.5 to 0.01 N. The decrease in calcium and magnesium content did not bring down the permeability below the limit.

Hamid and Mustafa (1975) observed an increase in relative hydraulic conductivity of Sudan soils from 0.11 to 2.8 cm/hr as the electrolyte

concentration increased. The reason for improved hydraulic conductivity was the compression of the diffused double layer.

Kenchanna Gowda (1977) in work on TBP soils reported that continuous irrigation brought down the hydraulic conductivity as a result of migration of finer fractions to the lower depth and reducing the poresize and sodiumization of clay complex.

In the sodic soils of central alluvial region of Uttar-Pradesh the hydraulic conductivity is generally low varying from 0.02 to 0.23 cm/hr. Subsurface samples of all the profiles showed relatively low values which may be due to their high clay content, low organic matter and salts compared to surface soils (Tiwari *et al.*, 1983).

Dixit and Mir (1985) reported that the increase in the amount of exchangeable monovalent cations at the expense of exchangeable calcium had an adverse effect on the hydraulic conductivity. The effect of exchangeable sodium was much greater as compared to that of exchangeable potassium or exchangeable ammonium. The decrease in hydraulic conductivity has been attributed to the dispersion of clay which is directly proportional to the effective ionic radii of monovalent cation.

Aggregate failure or slacking is a major cause of reduction in the size of large conducting pores and resultant decrease in hydraulic conductivity of saline soils during leaching (Abusharar *et al.*, 1987).

Yousaf *et al.* (1987) concluded that hydraulic conductivity decreased correspondingly with clay dispersion as electrolyte concentration is decreased and SAR increased over the ranges often encountered in irrigated sodic soils.

Introduction of solution of low electrolyte strength in the soil solution will have two immediate consequences.

i) The clay of the aggregate will swell especially if it is smectic type and weaken bonds.

ii) Osmotic bursting of aggregate will occur as the high concentration gradient created between the dilute external solution and the more concentrated solution within the aggregate (Keren and Singh, 1988).

Rao and Parvathappa (1993) reported a marked decrease in hydraulic conductivity and relative hydraulic conductivity values with an increase in SAR level at both surface and subsurface horizons.

#### **2.2.4 Water stable aggregates**

Hydrogen was more effective in aggregate stabilization than calcium and sodium. Chesters *et al.* (1957) indicated that the clay content and aggregate stability are closely correlated ( $r = 0.8726$ ).

Bareley and Tisdell (1959) noticed that irrigation of a sodic clay loam soil with a low amount of salt did not affect the structural stability.

Edward and Bermner (1967) indicated that aggregate in soil that had high stability appeared to consist largely of clay mineral and humified organic matter and any aggregate containing sand grains had little stability and is likely to be disrupted by relatively mild process of wetting and drying.

Emmerson and Bakker (1973) reported that dispersion and swelling occurred in soil whose exchangeable sodium percentage is only 5.

Kenchanna Gowda (1977) reported that irrigation increased water stable aggregates in TBP soils

The mean weight diameter of soils decreased with increase in SAR of irrigation water and higher ESP values reduced stability of aggregates (Satish Rao, 1989). Similar results are obtained by Mruthunjaya (1991) on Cauvery command area soils.

Gangappa (1989) reported that salt affected soils of Chalakere having exchangeable sodium in the soils resulted in high dispersion Index values (25-75) and less water stable aggregates (0.25 mm).

Bharambe *et al.*, (1990) reported that Jayakwadi command area soils have low mean weight diameter and it decreased with depth.

Parvathappa *et al.*, (1992) reported that higher SAR level reduced water stable aggregates in both Alfisols and Vertisols, the pronounced decrease was observed in soil having lower CEC and calcium carbonate. Vertisols recorded higher mean weight diameter values and it might be due to higher cation exchange capacity and dominant exchangeable calcium and magnesium which are responsible for stability of aggregates through tactoid formation.

### **2.3 Quality of irrigation water**

Quality of irrigation water used to alter the properties of soil after continuous irrigation. The content of soluble salts, carbonates, bicarbonates,

sulphate, SAR and pH are the parameters, that decide the quality of water. Use of saline water may cause accumulation of salts in the soils and drastically affect the plant growth. When the quality of water is characterised by a high proportion of sodium, the use of such water may become prohibitive due to high ESP of the soil which consequently affect the plant growth. Eaton (1950) suggested that such effects may be aggravated if the water contains  $\text{HCO}_3$  in considerable amounts which cause the precipitation of Ca as  $\text{CaCO}_3$ . Landey and Murthy (1967) and Govinda Rajan *et al.* (1968) reported that water of Hagari and Tungabhadra were of moderate salinity.

Puttaswamy Gowda *et al.* (1968) analysing the well water of Bangalore district had revealed that their EC values varied from 120 micro mhos/cm to 5800 micro mhos/cm and boron content was below 0.5 ppm. Approximately 75 per cent of them showed medium to high salinity.

Perur (1971) indicated that irrigation water of Ghataprabha, Vanivilas Sagar, Tuppadhalli tank were found to be fairly high in soluble salt during summer.

Based on balanced ionic concentration of divalent and monovalent cations, the possibility of the use of saline water for reclamation of sodic soils has been suggested by several workers (Bayko and Bayko, 1966 ; Narayana *et al.*, 1966 and Badigar *et al.*, 1969). In fact the high salt water is regularly used for irrigation on sandy soils in parts of Israel.

Water from Tungabhadra and Cauvery river belongs to  $\text{C}_1\text{S}_1$  but the water from Hagari river contains sodium as high as 1670 ppm (Ramaiah, 1937). Often the water from wells, are of a lower quality than river and canal water, Barring a

few exceptions, the quality of river water in India is fairly good. Asgar and Dhawan (1947) analysed the water from Sutlej and Beas rivers and found that their waters have EC of only 350 micro mhos per cm and very low in sodium. Water from Sevgar, Kalinadi and Behta rivers in Uttar Pradesh are of medium salinity, low in sodium content and are free from residual sodium carbonates (Agarwal and Mehrotra, 1952).

Girdhar (1996) reported that the adverse effect of high RSC water became more hazardous at high SAR because of the additive adverse effect of high SAR. The lowest Hydraulic conductivity was observed when leached with waters of high RSC and SAR. The adverse effect of high RSC and low SAR on Hydraulic conductivity was practically the same as affected by low RSC and high SAR of the water.

#### **2.4 Effect of anion on exchangeable sodium percentage in soil**

The formation of ion pairs and complexes in solution is well known. Complex formation is a highly selective interaction and may greatly enhance the selectivities of ion-exchangers. Hence, ion-exchange equilibria are strongly affected by interactions of the counter ions with other components in the external solution. Helfferich (1962) discussed at length the practical importance of complex formation and ion association in solution. It is significant to note that the relations for complex equilibria in solutions hold regardless of whether or not ion-exchange substances are present.

Olsen *et al.* (1960) observed differences in solubility of calcite in  $\text{CaCl}_2$  and  $\text{CaSO}_4$  solutions. When the data was corrected for the undissociated  $\text{CaSO}_4$  however, the solubility product of calcite was same in both salts. In a further study on the effects of chloride and sulphate salts on solubility of dicalcium

study on the effects of chloride and sulphate salts on solubility of dicalcium phosphate dehydrate and the hydroxyapatite, they found that the values for solubility products in the sulphate solutions were not equal to those in the chloride system until the effect of undissociated  $\text{CaSO}_4$  was allowed for. It was only after correcting for undissociated  $\text{CaSO}_4$  that the  $\text{PCaHPO}_4$  and PHA values were essentially constant for the water, chloride and sulphate salts. Calculating the amount of  $\text{CaSO}_4$  in undissociated form from the equation.

$$K = \frac{Y^2 \pm (\text{Ca}^{++})(\text{SO}_4^{--})}{(\text{CaSO}_4)}$$

Using 0.0053 as the value of K at 25°C, Olsen *et al.* (1960) reported approximately 30 per cent of the 0.01 M  $\text{CaSO}_4$  solution in the form of undissociated molecules or associated ion-Pairs.

Two clay soils one containing free  $\text{CO}_3$  and the other almost neutral in reaction, were saturated with Ca or Mg and treated with solutions of different salts of K and Na in the laboratory by Longenecker (1960) to study the effect of soluble anions on the breaking strength of artificial soil crusts, flocculation volume of clay suspensions, cation exchange equilibria and viscosities of Ca and Mg suspensions. The strength of artificial crusts in Ca saturated soils was decreased by Cl and  $\text{NO}_3$  salts of Na. While flocculation volume in Cl and  $\text{NO}_3$  solutions differed little from those in distilled water, the volume in  $\text{SO}_4$  solutions were measurably greater.

In tests involving cation-exchange equilibria between adsorbed and soluble cations, Mg replaced by  $\text{Na}_2 \text{SO}_4$  was appreciably greater than that replaced by NaCl and  $\text{NaNO}_3$ , partially explaining the variation in crust strength

and flocculation volumes under the effect of different salts. The author attributed the difference between the action of Cl (or  $\text{NO}_3$ ) and  $\text{SO}_4$  as due to the higher hydration of  $\text{SO}_4$  in water. A more probably explanation is that the strong tendency of ion association of  $\text{CaSO}_4$  and  $\text{MgSO}_4$  caused more displacement of Ca and Mg than in chloride and nitrate systems. There by increasing the Na content and causing the adverse changes in physical properties observed by the author.

Solutions of NaCl,  $\text{Na}_2\text{SO}_4$  and  $\text{NaNO}_3$  of concentrations 0.3 to 12.2 me per 100 ml were used by Binder-Barhava and Ravikovitch (1952) with a Ca- soil and two soils containing Na at 14.1 and 30.1 per cent of the CEC to study the adsorption of Na by soils from solutions of different salts. In general the sulphate anion led to highest Na adsorption.

Dutt and Doneen (1963) salinized Ca- saturated Yolo clay loam separately with NaCl and mixture of NaCl and  $\text{Na}_2\text{SO}_4$  solutions containing equivalent amounts of Na each. After the soils has been salinized with 2, 4, 8 or 16 me of salt per 100g, soil were air dried, concentration of  $\text{Ca}^{++}$ ,  $\text{Mg}^{++}$  and  $\text{Na}^+$  in the saturation extracts were measured. In samples salinized with NaCl, concentration of both calcium and sodium increased in the saturation extract as the amount of NaCl added increased. But when the Ca- soil was salinized with mixture of  $\text{Na}_2\text{SO}_4$  and NaCl, the concentration of sodium in saturation extract was less in the Ca- soil samples which received equivalent amount of NaCl. Obviously more Na was adsorbed in  $\text{Na}_2\text{SO}_4 + \text{NaCl}$  system than NaCl system.

Bab Cock and Schultz (1963) leached samples of Yolo fine Sandy loam with two series of solutions containing Na and Ca in which the composition varied. In one series the anion was chloride and in the other it was sulphate. After

leaching the samples to equilibrium they found exchangeable Na higher in the sulphate series than the chloride series.

## **MATERIAL AND METHODS**

### III MATERIAL AND METHODS

The details regarding soil and water samples collected and laboratory analysis that were followed during the present study are described in this chapter.

#### 3.1 General description of the area

##### 3.1.1 Location and extent

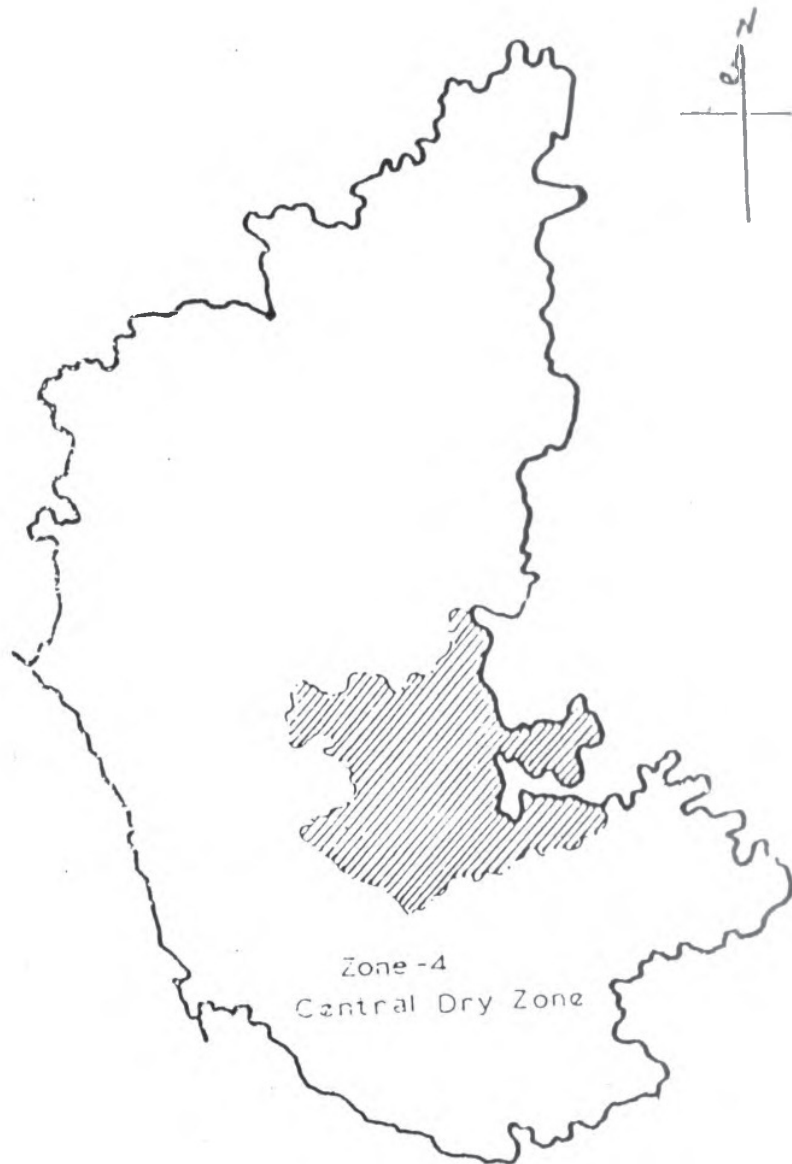
The central dry zone [Zone-IV] geographically located at 30° 57' latitude and 17° 37' longitude (Fig-1). The zone has net area of 1,55,287 hectares covered under irrigation, [out of 9,92,785 hectares sown for Agricultural crops] with net tank command area of 39,903 hectares (Anonymous, 1990).

##### 3.1.2 Climate

Agroclimatically, the central dry zone comes under arid zone with mean annual rainfall of 604.80 mm. The mean maximum monthly temperature ranges between 28°C in December to a maximum of 36.3°C in April, the mean monthly minimum temperature varies between 16.7°C in December to 22.7°C in April.

##### 3.1.3 Natural vegetation

Trees like Jack fruit, Mango, Tamarind, Neem, Wood Apple, Banyan are found in common with the shrubs like *Lantana Camara*, *Acacia Sp* and *Calotropi Sp*.



**Fig1: Map of central dry zone (zone-IV) of Karnataka.**

## **3.2 Details of Soil and Water Samples Collection**

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### **3.2.1 Soil Samples**

Representative soil samples were collected from different tank command areas representing Agro-Climatic Zone-IV of Karnataka (Fig-2). A total of 10 soil bodies were collected from two depths (0-15 and 15-30 cm) near the tank bund and a tail end of the tank.

The details regarding the soil order along with other particulars including location, number of years of irrigation, cropping pattern depth and soil texture are given in Table 1.

### **3.2.2 Irrigation water**

Representative irrigation samples were collected from different tanks representing Agro-Climatic Zone-IV of Karnataka.

## **3.3 Methods of soil analysis**

### **3.3.1 Preparation of soil samples**

Soil samples were air dried in shade, powdered gently with a wooden mallet, sieved through 2mm sieve and stored in clean polythene containers for further studies. Clods were collected for determination of mean weight diameter.

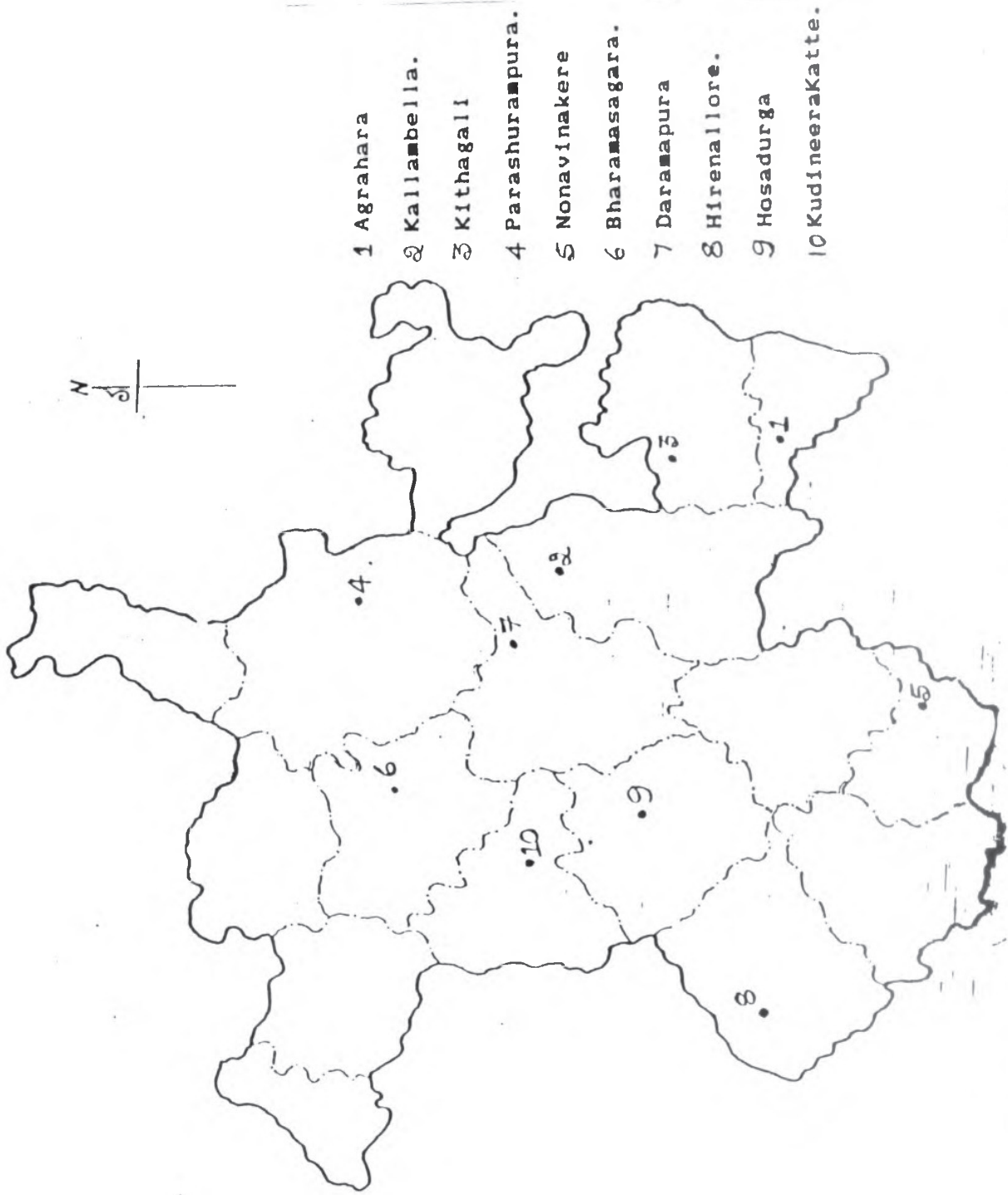


Fig2: Map of central dry zone indicating location of soil samples.

**Table 1. Details of soil samples**

Sl. No.	Order	Location	No of Years of irrigation	Cropping pattern	Depth (Cm)	Texture
1	Alfisol	Agrahara (Koratagere Taluk)	150	Paddy Ragi	* a, 0-15	L
					* b, 15-30	L
					* c, 0-15	L
					* d, 15-30	CL
2	Alfisol	Kallambella (Sira Taluk)	>175	Paddy Ground nut Ragi	a, 0-15	LS
					b, 15-30	L
					c, 0-15	L
					d, 15-30	SiL
3	Alfisol	Kithagali (Madhugiri Taluk)	100	Paddy Ground nut	a, 0-15	SL
					b, 15-30	L
					c, 0-15	SiL
					d, 15-30	SiL
4	Alfisol	Parashurampura (Challakere Taluk)	75	Paddy Ragi	a, 0-15	L
					b, 15-30	SiL
					c, 0-15	L
					d, 15-30	CL
5	Alfisol	Nonavinakere (Tiptur Taluk)	>100	Paddy Ragi	a, 0-15	L
					b, 15-30	CL
					c, 0-15	L
					d, 15-30	CL
6	Vertisol	Bharamasagara (Chitradurga Taluka)	>150	Paddy Jowar	a, 0-15	CL
					b, 15-30	CL
					c, 0-15	C
					d, 15-30	C
7	Vertisol	Daramapura (Hiriyur Taluk)	100	Paddy Ragi	a, 0-15	CL
					b, 15-30	CL
					c, 0-15	CL
					d, 15-30	CL
8	Vertisol	Hirenallore (Kadur Taluk)	>150	Paddy Jowar	a, 0-15	SiL
					b, 15-30	CL
					c, 0-15	CL
					d, 15-30	CL
9	Vertisol	Hosadurga (Hosadurga Taluk)	>75	Paddy Jowar	a, 0-15	L
					b, 15-30	CL
					c, 0-15	CL
					d, 15-30	CL
10	Vertisol	Kudineerakatte (Holakere Taluk)	>100	Paddy Ragi	a, 0-15	CL
					b, 15-30	CL
					c, 0-15	CL
					d, 15-30	CL

Note \* a & b : near tank bund  
\* c & d : tail end of tank

L - Loam

LS - Loamy sand

SiL - Silt loam

SL - Sandy loam

CL - Clay loam

C - Clay

#### **3.3.2.1 Soil reaction (pH)**

The soil pH in 1:1 soil water suspension was determined using Elico-pH meter model LT-10T (Jackson, 1973).

#### **3.3.2.2 Electrical conductivity**

The electrical conductivity (EC) of clear supernatant of 1:1 soil water suspension was measured using Elico-conductivity bridge type CM-82 T (Jackson, 1973).

#### **3.3.2.3 Organic Carbon**

Organic carbon was estimated by Walkley and Black's wet oxidation method by oxidizing the organic matter in a finely ground soil with chromic acid by making use of heat of dilution of sulphuric acid for the reaction (Jackson, 1973).

#### **3.3.2.4 Alkaline earth carbonates**

Free calcium carbonate was determined by acid neutralization method using standard hydrochloric acid as described by Piper (1966):

#### **3.3.2.5 Cation exchange capacity**

The cation exchange capacity (CEC) in alkaline soils (pH > 7.0) was determined by sodium saturation method and neutral soil by ammonium acetate

saturation method as described by U.S.S.L. Staff (1954) using digital flame photometer model CL-22D.

### 3.3.2.6 Exchangeable cations

The exchangeable cations, calcium, magnesium, sodium and potassium were extracted in 1N ammonium acetate leachate as described by Black (1965b).

Calcium and magnesium in 1N ammonium acetate extract were determined as described by Jackson (1973) in which calcium and magnesium were titrated against standard versenate solution (Ethylene diamine tetra acetic acid) using Eriochrome black-T dye indicator with  $\text{NH}_4\text{OH-NH}_4\text{Cl}$  as buffer. Another aliquot was titrated in a simple way by using calcon indicator with NaOH in order to get the value of calcium. Magnesium was calculated by the difference in non-calcareous soil. In calcareous soil, exchangeable calcium and magnesium were computed as the difference between CEC and sum of exchangeable sodium and potassium.

The exchangeable sodium and potassium content in 1N ammonium acetate extract were determined photometrically using Elico-flame photometer model CL-22D as outlined by Jackson (1973).

#### 3.3.2.6.1 Exchangeable Sodium percentage

Exchangeable sodium percentage of soils was calculated by using the exchangeable sodium and CEC of soil and by using the formula:

$$\text{ESP} = \frac{\text{Ex} - \text{Na}}{\text{CEC}} \times 100$$

### **3.3.2.7 Water soluble cations and anions**

Soil water extract (1:1) was prepared as described by U.S.S.L. Staff (1954) and the extractant was used for the determination of water soluble cations and anions as follows:

#### **3.3.2.7.1 Calcium and magnesium**

Calcium and Magnesium in soil water extract were determined as described in section 3.3.2.6

#### **3.3.2.7.2 Sodium and Potassium**

Water soluble sodium and potassium in soil water extract were estimated as described in section 3.3.2.6

#### **3.3.2.7.3 Carbonate and bicarbonate**

A known aliquat of soil water (1:1) extract was titrated against  $0.1\text{NH}_2\text{SO}_4$  using phenolphthalein as an indicator for carbonate. The titration was continued further with methyl orange indicator to detect end point for bicarbonates (U.S.S.L. Staff, 1954).

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The chlorides in the soil water extract were determined after determination of carbonates and bicarbonates by titrating a suitable amount of aliquat against standard 0.005 N silver nitrate using potassium chromate as an indicator (U.S.S.L. Staff, 1954).

**3.3.2.7.5 Sulphates**

Sulphate was precipitated as barium sulphate and the turbidity developed was measured using spectronic-20 spectrophotometer at 420 nm wave length (Black, 1965b).

**3.3.2.7.6 Sodium adsorption ratio**

Sodium adsorption ratio was calculated by knowing the concentrations of  $\text{Na}^+$  and  $\text{Ca}^{++} + \text{Mg}^{++}$  and by using the formula.

$$\text{SAR} = \frac{\text{Na}^+}{\sqrt{[\text{Ca}^{++} + \text{Mg}^{++}]/2}}$$

**3.3.3 Chemical analysis of water samples**

The representative irrigation water samples collected from tank command areas in Zone IV were collected and analysed for pH, EC, water soluble cations, anions, and boron as described by U.S.S.L. Staff, (1954) and residual sodium carbonates and SAR were calculated using water soluble cations and anions.

### **3.3.4 Physical Properties**

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#### **3.3.4.1 Particle size analysis**

Particle size of soils were determined by the International pipette method using sodium hexametaphosphate as the dispersing agent (Piper, 1966) and the results were reported as coarse sand, fine sand, silt and clay on moisture free basis.

#### **3.3.4.2 Rheological properties**

Rheological properties of soil such as upper plastic limit (UPL), lower plastic limit (LPL), plasticity-index (PI) and sticky print (SP) moisture were determined as outlined by Singh (1980).

#### **3.3.4.3 Hydraulic conductivity**

Saturated hydraulic conductivity of the disturbed soil was determined by leaching distilled water through soil columns of size 6.5 cm diameter and 18.5 cm height after attaining saturation as described by Black (1965a).

#### **3.3.4.4 Water stable aggregates**

Water stable aggregates of soil was estimated by wet sieving method as described by Black (1965a) and the results are expressed as mean weight diameter (MWD).

### 3.3.4.5 Soil moisture content

Moisture content of air dry soil was estimated as described by U.S.S.L. Staff (1954).

### 3.4 Batch equilibration of soils with NaCl and Na<sub>2</sub>SO<sub>4</sub> salt solutions

The soils (5.0g) were treated with synthesized water containing different known electrolytes at different SAR levels, shaken for one hour, centrifuged and the supernatant liquid discarded. The above processes were repeated until the equilibrium solution had the same ionic concentration as the equilibrating solution.

The treatment combinations were as follows

No	Amount of salt added g/l		Molarity of solution		Na : Ca (approx)	SAR
<b>Sulphate system</b>						
	Na <sub>2</sub> SO <sub>4</sub>	CaSO <sub>4</sub>	Na <sub>2</sub> SO <sub>4</sub>	CaSO <sub>4</sub>		
T <sub>1</sub>	2.8409	0.2722	0.02	0.002	10:1	40
T <sub>2</sub>	2.8409	0.1769	0.02	0.0013	15:1	50
T <sub>3</sub>	7.1024	0.6807	0.05	0.005	10:1	60
T <sub>4</sub>	7.1024	0.4084	0.05	0.003	15:1	80
<b>Chloride system</b>						
	NaCl	CaCl <sub>2</sub>	NaCl	CaCl <sub>2</sub>		
T <sub>1</sub>	5.8448	1.4429	0.1	0.013	8:1	40
T <sub>2</sub>	5.8448	0.8879	0.1	0.008	12:1	50
T <sub>3</sub>	5.8448	0.5549	0.1	0.005	20:1	60
T <sub>4</sub>	11.6896	1.3874	0.2	0.0125	16:1	80

After completion of equilibration, the exchangeable cations were displaced by 1.0 N  $\text{NH}_4\text{NO}_3$  solution. Sodium was determined by using Elico-flame photometer model CL-22D as described by Jackson (1973) and Calcium by titrating against standard versanate solution (Ethylene diamine tetraacetic acid) by using calcon indicator with NaOH as described by Jackson (1973). Chloride was determined after determination of carbonates and bicarbonates by titrating a suitable aliquat against standard 0.005 N silver nitrate using potassium chromate as indicator (Jackson, 1973), and sulphate was precipitated as barium sulphate and the turbidity developed measured using spectronic-20 spectrophotometer at 420 nm wave length (Black; 1965b).

### **3.5 Statistical analysis**

The results obtained from the above investigations were analysed for correlation and regression for selected soil properties (Panse and Sukhatme 1961).

# **EXPERIMENTAL RESULTS**

## **IV EXPERIMENTAL RESULTS**

The results of analysis of soils that have been irrigated for various periods and that of irrigation water used are reported in this chapter.

Scatter and bar diagrams have been drawn for the results obtained and correlations worked out for properties which indicated close conformity to a general trend. The range of values of soil and water properties studied are given in Table 2.

### **4.1 Chemical properties of soil**

The data on air dry soil moisture, soil reaction (pH), electrical conductivity, organic carbon and calcium carbonate are presented in Table 3.

#### **4.1.1 Soil Moisture**

The air dry soil moisture varies from 3.60 to 6.50 per cent. It increases with depth in all soil bodies in both Alfisols and Vertisols. The Vertisols shown higher moisture content compared to Alfisols. The air dry moisture is more at tail end of tank than nearer to tank bund.

#### **4.1.2 Soil reaction (pH)**

The pH of Alfisols ranged from 6.3 to 8.6 and in vertisol from 7.4 to 9.2 in 1:1 soil water suspension. The lowest value was recorded in surface layers of Agrahara which is nearer to the tank bund and highest was recorded in surface layers of Bharamasagara which is at tail end of the tank command area. It increased with depth in most of the soil bodies studied, while it decreased with depth in soils of Kallambella,

**Table 2. Results of analysis range of values for different soil properties**

Sl. No	Parameters	Minimum value	Maximum value
1	Soil moisture in air dry soil (%)	3.60	6.50
2	Soil reaction (pH)	6.30	9.20
3	Electrical conductivity ( $\text{d Sm}^{-1}$ )	0.06	1.24
4	Organic carbon (%)	0.36	0.93
5	Calcium carbonate (%)	1.09	3.36
6	Cation exchange capacity ( $\text{c.mol (P}^+) \text{ kg}^{-1}$ )	15.00	39.80
7	Exchangeable cations ( $\text{c.mol (P}^+) \text{ kg}^{-1}$ )		
	a) Calcium	9.40	29.80
	b) Magnesium	2.60	6.29
	c) Sodium	0.10	2.59
	d) Potassium	0.13	2.40
8	Exchangeable Sodium percentage	0.65	8.38
9	Water soluble ions ( $\text{meL}^{-1}$ )		
	a) Calcium	0.49	1.80
	b) Magnesium	0.29	1.18
	c) Sodium	2.10	28.60
	d) Potassium	0.25	2.30
	e) Carbonate	0.00	2.00
	f) Bicarbonate	1.00	14.00
	g) Chloride	0.60	12.96
	h) Sulphate	0.60	4.79
10	Sodium Adsorption Ratio	2.79	38.01
11	Particle size distribution (%)		
	Coarse sand	24.10	49.90
	Fine sand	11.03	32.20
	Silt	10.30	30.82
	Clay	11.25	40.65

Table 2 : Contd .....

SI No	Parameters	Minimum value	Maximum value
12	Rheological properties (% mositure)		
	a) lower plastic limit	5.45	13.65
	b) upper plastic limit	9.52	32.58
	c) plasticity index	4.01	19.46
	d) sticky point mositure	21.60	49.80
13	Hydraulic conductivity (cm h <sup>-1</sup> )	0.31	32.60
14	Mean weight diameter	0.71	5.91
15	Irrigation water analysis		
	a) P <sup>H</sup>	7.12	7.80
	b) Electrical conductivity (micro mhos/cm)	319.00	852.00
	c) Carbonate (me L <sup>-1</sup> )	0.00	0.00
	d) Bicarbonates (me L <sup>-1</sup> )	0.07	0.29
	e) Chloride (me L <sup>-1</sup> )	1.96	4.20
	f) Sulphate (me L <sup>-1</sup> )	0.07	0.45
	g) Sodium (me L <sup>-1</sup> )	0.42	1.18
	h) Calcium (me L <sup>-1</sup> )	1.17	2.45
	i) Magnesium (me L <sup>-1</sup> )	0.49	1.37
	j) Potassium (me L <sup>-1</sup> )	0.09	0.40
	k) Boron (ppm)	Traces	0.03
	l) Residual sodium carbonate (me L <sup>-1</sup> )	-3.52	-1.80
	m) Sodium adsorption ratio	0.39	0.85

**Table 3. Air dry soil moisture, pH, electrical conductivity, organic carbon calcium carbonate values of different soil bodies.**

Sl. No.	Soil depth (cm)	Air dry moisture (%)	pH 1:1 soil water	EC dSm-1 1:1 soil water	Organic carbon (%)	CaCO <sub>3</sub> (%)
<b>Alfisols</b>						
1	<b>Agrahara</b>					
	a, 0-15	4.70	6.30	0.40	0.64	1.09
	b, 15-30	5.50	6.70	0.06	0.60	1.13
	c, 0-15	5.16	6.50	0.12	0.93	1.15
	d, 15-30	5.70	6.90	0.06	0.80	1.25
2	<b>Kallambella</b>					
	a, 0-15	4.80	8.60	0.33	0.93	2.40
	b, 15-30	5.20	8.30	0.41	0.74	2.46
	c, 0-15	4.92	8.30	0.39	0.82	2.18
	d, 15-30	5.40	8.20	0.36	0.78	2.32
3	<b>Kithagali</b>					
	a, 0-15	4.50	7.00	0.43	0.43	1.93
	b, 15-30	4.80	7.40	0.16	0.40	2.00
	c, 0-15	4.90	7.00	0.25	0.68	1.90
	d, 15-30	5.50	7.20	0.08	0.60	1.96
4	<b>Parashurampura</b>					
	a, 0-15	3.60	7.80	0.09	0.78	2.03
	b, 15-30	4.20	7.70	0.08	0.60	2.06
	c, 0-15	4.10	8.10	0.12	0.80	2.03
	d, 15-30	4.30	7.70	0.08	0.60	2.40
5	<b>Nonavinakere</b>					
	a, 0-15	4.20	8.20	0.23	0.58	1.65
	b, 15-30	4.80	7.60	0.15	0.41	1.93
	c, 0-15	5.10	8.40	0.67	0.89	2.10
	d, 15-30	5.60	7.90	0.08	0.72	2.12

**Table 3. Contd ....**

Sl. No.	Soil depth (cm)	Air dry moisture (%) 1:1 soil	pH water 1:1 soil	EC dSm-1 water 1:1 soil	Organic carbon (%)	CaCO <sub>3</sub> (%)
<b>Vertisols</b>						
6	Bharamasagara					
	a, 0-15	5.80	8.70	0.26	0.48	3.10
	b, 15-30	6.01	8.90	0.53	0.44	3.28
	c, 0-15	5.50	9.20	1.24	0.46	3.60
	d, 15-30	6.21	8.90	1.10	0.36	3.96
7	Daramapura					
	a, 0-15	4.40	7.90	0.27	0.49	2.75
	b, 15-30	4.60	8.40	0.26	0.47	2.81
	c, 0-15	5.19	8.00	0.24	0.53	2.76
	d, 15-30	5.50	8.50	0.23	0.50	2.98
8	Hirenallore					
	a, 0-15	4.60	7.80	0.57	0.70	2.36
	b, 15-30	4.90	8.00	0.47	0.66	2.60
	c, 0-15	4.80	7.90	0.44	0.74	2.47
	d, 15-30	5.30	8.10	0.34	0.68	2.67
9	Hosadurga					
	a, 0-15	6.01	7.40	0.08	0.57	2.26
	b, 15-30	6.40	7.50	0.09	0.42	2.45
	c, 0-15	6.20	8.40	0.28	0.48	2.35
	d, 15-30	6.50	8.50	0.29	0.36	2.50
10	Kudineerakatte					
	a, 0-15	4.75	8.11	0.08	0.56	2.31
	b, 15-30	5.25	8.70	0.46	0.36	2.47
	c, 0-15	4.80	8.20	0.22	0.51	2.25
	d, 15-30	5.40	8.50	0.28	0.43	2.31

Note : \* a & b : near tank bund  
\* c & d : tail end of tank

Parashurampura, Nonavinakere and Bharamasagara (at tail end of tank command area) soils.

The Agrahara soils are found to be neutral while all other soils are alkaline in reaction. pH of the soil at tail end of tank is slightly higher than the soil near the tank bund in most of the soil bodies studied.

#### **4.1.3 Electrical conductivity**

The electrical conductivity values are low and ranged from 0.06 to 1.24 d  $\text{Sm}^{-1}$  at 25°C in 1:1 soil water suspension. The lowest value was recorded in subsurface layer of Agrahara and highest in surface layer of Bharamasagara which is far away from the tank. It decreased with depth in most of the soil bodies studied except Hosadurga, Kudineerakatte soils and soils near tank bund in case of Kallambella and Bharamasagara. Electrical conductivity values are higher in Vertisols compared to Alfisols.

#### **4.1.4 Organic Carbon**

The organic carbon (OC) content varied from 0.36 to 0.93 per cent. It decreased with depth in both Alfisols and Vertisols and increased at tail end in most of the soils studied except in Kallambella, Hosadurga and Bharamasagara soils.

#### **4.1.5 Calcium Carbonate**

The calcium carbonate content of these soils was low and varied from 1.09 to 3.96 per cent. It increased with depth and also the tail end of command area in

most of the soils studied. The lime content of soils at tail end of the tank is high as compared to soils near tank bund in most of the soils studied.

#### **4.1.6 Cation exchange capacity and exchangeable cation**

The cation exchange capacity, exchangeable cations and ESP values are presented in Table 4.

##### **4.1.6.1 Cation exchange capacity**

The cation exchange capacity values ranged from 15.0 to 39.8 c.mol (P<sup>+</sup>) kg<sup>-1</sup>. The lowest value was recorded in surface layer of Kithagali which is nearer to tank bund and highest value in subsurface layer of Hosadurga which is at the tail end of tank. It increased with depth in the soil bodies studied. The CEC values were higher in Vertisols compared to Alfisols. Cation exchange capacity of soils was higher at tail end of the tank compared to soils nearer to tank bund in most of the soil bodies studied except in Parashurampura, Bharamasagara, Hirenallore and Kudineerakatte soils.

##### **4.1.6.2 Exchangeable cations**

The exchangeable calcium values varied from 9.4 to 29.8 c.mol (P<sup>+</sup>) kg<sup>-1</sup>, minimum value was recorded in surface layer of Agrahara soil which is nearer to tank bund and maximum value was recorded in lower layer of Hosadurga soil which is at tail end of tank. It increased with depth in most of the soil bodies studied. Calcium values were higher for Vertisols compared to Alfisols.

The exchangeable magnesium content ranged from 2.60 to 6.29 c.mol (P<sup>+</sup>) kg<sup>-1</sup>, the lowest value was recorded in surface layer of Kithagali which is nearer

**Table 4. Cation exchange capacity, exchangeable cations [c mol (P<sup>+</sup>) kg<sup>-1</sup>] and exchangeable sodium percentage of different soil bodies**

Sl. No.	Soil depth (cm)	CEC c mol (p <sup>+</sup> ) kg <sup>-1</sup>	Exchangeable cations c. mol (p <sup>+</sup> ) kg <sup>-1</sup>				ESP
			Ca	Mg	Na	K	
<b>Alfisols</b>							
1	Agrahara						
	a, 0-15	15.30	9.40	3.50	0.10	0.23	0.65
	b, 15-30	20.30	14.80	3.80	0.27	0.22	1.33
	c, 0-15	16.00	9.60	3.20	0.12	0.36	0.75
	d, 15-30	22.70	15.80	3.70	0.20	0.20	0.88
2	Kallambella						
	a, 0-15	18.40	12.30	3.60	0.37	1.05	2.01
	b, 15-30	19.40	14.00	3.80	0.52	0.36	2.66
	c, 0-15	19.10	13.00	3.50	0.30	1.35	1.50
	d, 15-30	20.50	14.50	3.90	0.33	0.28	1.62
3	Kithagali						
	a, 0-15	15.00	9.60	2.60	0.12	0.13	0.80
	b, 15-30	15.50	10.30	3.40	0.19	0.13	1.23
	c, 0-15	16.80	11.00	3.00	0.14	0.48	0.83
	d, 15-30	18.50	13.30	3.70	0.23	0.31	1.24
4	Parashurampura						
	a, 0-15	20.30	15.00	3.10	0.19	0.54	0.94
	b, 15-30	21.10	15.90	3.30	0.27	0.26	1.28
	c, 0-15	16.80	10.80	3.30	0.16	0.48	0.95
	d, 15-30	19.80	12.90	3.50	0.23	0.28	1.16
5	Nonavinakere						
	a, 0-15	16.80	11.40	3.00	0.23	1.45	1.37
	b, 15-30	23.70	16.60	3.40	0.35	0.33	1.48
	c, 0-15	19.50	12.90	3.10	0.19	2.70	0.97
	d, 15-30	24.00	15.30	3.20	0.58	1.20	2.42

Table 4. Contd ....

Sl. No.	Soil depth (cm)	CEC c mol (p+) kg-1	Exchangeable cations c. mol (p+) kg-1				ESP
			Ca	Mg	Na	K	
<b>Vertisols</b>							
6	<b>Bharamasagara</b>						
	a, 0-15	29.60	19.97	5.40	0.60	1.12	2.03
	b, 15-30	33.50	22.35	6.00	1.20	0.59	3.58
	c, 0-15	26.98	19.09	5.60	1.05	0.16	3.89
	d, 15-30	30.90	19.91	6.29	2.59	0.15	8.38
7	<b>Daramapura</b>						
	a, 0-15	27.20	18.70	3.30	0.54	0.66	1.99
	b, 15-30	27.90	20.70	4.00	0.72	0.65	2.58
	c, 0-15	27.80	18.80	3.40	0.66	0.76	2.37
	d, 15-30	28.10	19.90	4.10	0.82	0.71	2.92
8	<b>Hirenallore</b>						
	a, 0-15	34.50	25.20	4.20	0.47	1.63	1.36
	b, 15-30	36.90	26.20	4.80	0.52	1.43	1.41
	c, 0-15	31.60	21.20	3.70	0.47	2.40	1.48
	d, 15-30	32.80	24.60	4.30	0.58	2.24	1.77
9	<b>Hosadurga</b>						
	a, 0-15	34.80	23.10	3.40	0.57	0.87	1.64
	b, 15-30	37.00	26.10	4.40	0.67	0.79	1.68
	c, 0-15	35.80	27.70	3.60	0.60	0.82	1.68
	d, 15-30	39.80	29.80	4.30	0.64	0.59	1.61
10	<b>Kudineerakatte</b>						
	a, 0-15	33.80	25.80	3.90	0.89	1.30	2.61
	b, 15-30	37.60	28.60	4.20	1.03	0.74	2.73
	c, 0-15	25.80	19.40	3.20	0.49	0.48	1.91
	d, 15-30	26.50	19.70	3.50	0.62	0.46	2.33

Note : \* a & b : near tank bund  
 \* c & d : tail end of tank

to the tank bund and higher value in lower layer of Bharamasagara which is at the tail end of the tank. It was found to increase with depth in all soil bodies studied. The values were higher in Vertisols compared to Alfisols.

The exchangeable sodium content was very low especially in Alfisols and varied from 0.10 to 2.59 c.mol (P<sup>+</sup>) kg<sup>-1</sup>. The lowest value was recorded in surface layer of Agrahara which is nearer to tank bund and highest in lower layer of Bharamasagara which is at tail end of the tank command area. It increased with depth in all soil bodies studied.

The exchangeable potassium content was very low compared to exchangeable calcium and magnesium in most of the soils studied. It varied from 0.13 to 2.40 c.mol (P<sup>+</sup>) kg<sup>-1</sup>. It decreased with depth in all Alfisols and Vertisols.

Among the exchangeable cations, the exchangeable calcium and magnesium were dominant in most of the soils studied followed by potassium, while exchangeable sodium was the least.

Exchangeable cations of soils at the tail end of the tank were higher compared to soils near tank bund in most of the soils studied.

#### **4.1.6.3 Exchangeable sodium percentage**

The exchangeable sodium percentage values ranged from 0.65 to 8.38. The minimum value was observed in surface layer of Agrahara which is nearer to tank bund and maximum in lower layer of Bharamasagara, which is at the tail end of the tank command area. It increased with depth in most of the soils studied. In general ESP values in both Alfisols and Vertisols are within safer limit.

Exchangeable sodium percentage of soils nearer to tank bund have lower values compared to soils at the tail end of the tank in most of the soil bodies studied except in Kallambella and Kudineerakatte soils.

#### **4.1.7 Water soluble cations and anions**

The data pertaining to water soluble cations, anions and SAR in 1:1 soil water extract are presented in Table 5 (Fig 3a - 3e).

##### **4.1.7.1 Water soluble cations**

The water soluble calcium content varied from 0.49 to 1.80 me L<sup>-1</sup>. It increased with depth in most of the soil bodies studied except in Parashurapura, Bharamasagara and Kudineerakatte soils, where it decreased with depth. The water soluble magnesium content ranged from 0.29 to 1.18 me L<sup>-1</sup>. It increased with depth in most of the soils except in Bharamasagara and soils nearer to tank bund in case of Kallambella, Kithagali and Kudineerakatte, where as in case of Nonavinakere Hirenallore and Hosadurga soils there was not much variation with depth. The sodium content varied from 2.1 to 28.6 me L<sup>-1</sup>. It decreased with depth in most of the soils studied except in Bharamasagara, Daramapura, Hosadurga soils and soils at tail end of the tank in Hirenallore and soils nearer to the tank bund in Kudineerakatte, where it increased with depth. The water soluble potassium ranged from 0.25 to 2.3 me L<sup>-1</sup>. It decreased with depth in most of the soils studied except in Agraphara soils.

Among water soluble cations in 1:1 soil water extract, sodium is dominant followed by calcium in most of the soils studied. Vertisols have more soluble cations compared to Alfisols. Water soluble cations in soils at tail end of the tank is higher compared to soils near the tank bund in most of the soil bodies studied.

**Table 5. Water soluble cations, anions (me L<sup>-1</sup>) and SAR in 1:1 soil water extract of different soil bodies**

Sl. No.	Soil depth (cm)	Water soluble cations m e L <sup>-1</sup>				Water soluble anions m e L <sup>-1</sup>				SAR
		Ca <sup>2+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup>	K <sup>+</sup>	CO <sub>3</sub>	HCO <sub>3</sub>	Cl	SO <sub>4</sub>	
<b>Alfisols</b>										
1	Agrahara									
	a, 0-15	0.78	0.29	2.60	0.26	0.00	1.00	0.90	1.50	3.49
	b, 15-30	1.57	1.18	3.40	0.77	0.00	3.00	1.25	1.80	2.92
	c, 0-15	0.58	0.29	5.90	0.51	0.00	2.00	2.34	2.11	9.02
	d, 15-30	0.59	0.30	3.80	0.53	0.00	2.00	0.60	2.00	6.15
2	Kallambella									
	a, 0-15	0.68	0.49	9.80	1.80	0.00	6.00	2.90	1.70	12.80
	b, 15-30	0.69	0.39	8.90	1.00	0.00	5.00	3.50	1.40	12.20
	c, 0-15	0.78	0.49	12.40	1.50	0.00	7.00	5.20	1.20	15.50
	d, 15-30	0.79	0.58	10.20	0.50	0.00	3.00	3.40	1.20	12.40
3	Kithagali									
	a, 0-15	0.68	0.68	4.70	0.26	0.00	2.00	1.90	1.90	5.68
	b, 15-30	0.78	0.39	2.10	0.25	0.00	1.00	1.30	0.76	2.79
	c, 0-15	0.49	0.29	5.10	0.51	0.00	2.00	1.25	0.68	8.20
	d, 15-30	0.59	0.58	2.50	0.25	0.00	2.00	0.90	0.61	3.34
4	Parashurampura									
	a, 0-15	1.37	0.39	5.56	1.02	0.00	2.00	1.60	3.50	5.92
	b, 15-30	0.90	0.88	5.56	0.77	0.00	3.00	1.45	2.90	5.89
	c, 0-15	0.78	0.29	5.13	0.76	0.00	2.00	2.90	0.73	6.90
	d, 15-30	0.59	0.30	4.28	0.75	0.00	1.00	0.60	3.16	6.40
5	Nonavinakere									
	a, 0-15	1.07	0.39	9.40	2.30	0.00	3.00	3.75	4.79	10.63
	b, 15-30	1.18	0.40	6.80	1.80	0.00	3.00	1.60	3.69	8.58
	c, 0-15	1.07	0.49	9.80	1.50	0.00	3.00	3.90	4.72	11.13
	d, 15-30	1.76	0.51	6.40	1.00	0.00	2.00	2.90	3.20	6.04

Table 5. Contd ....

Sl. No.	Soil depth (cm)	Water soluble cations m e L <sup>-1</sup>				Water soluble anions m e L <sup>-1</sup>				SAR
		Ca <sup>2+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup>	K <sup>+</sup>	CO <sub>3</sub>	HCO <sub>3</sub>	Cl	SO <sub>4</sub>	
<b>Vertisols</b>										
6	Bharamasagara									
	a, 0-15	0.88	0.39	13.70	1.00	0.00	12.00	1.75	1.02	17.16
	b, 15-30	0.78	0.29	17.50	0.80	0.00	14.00	2.05	0.89	23.90
	c, 0-15	1.27	0.69	25.70	0.80	2.00	10.00	11.45	1.78	28.68
	d, 15-30	0.88	0.39	28.60	0.50	1.00	13.00	12.96	1.65	38.01
7	Daramapura									
	a, 0-15	1.08	0.58	12.40	1.02	0.00	6.00	5.10	3.40	13.59
	b, 15-30	1.80	0.68	13.70	1.01	0.00	10.00	4.50	1.90	12.37
	c, 0-15	0.78	0.58	13.30	1.28	0.00	8.00	4.90	1.50	16.01
	d, 15-30	1.70	0.98	17.10	1.26	0.00	14.00	3.60	1.40	15.16
8	Hirenallore									
	a, 0-15	0.67	0.49	14.10	1.54	0.00	9.00	4.10	2.20	18.41
	b, 15-30	0.88	0.50	12.80	1.02	0.00	10.00	2.90	1.70	15.50
	c, 0-15	0.78	0.68	10.30	1.28	0.00	7.00	2.80	1.30	11.98
	d, 15-30	0.88	0.69	11.60	1.02	0.00	8.00	2.60	2.70	11.05
9	Hosadurga									
	a, 0-15	0.78	0.39	12.40	1.02	0.00	8.00	3.50	1.90	16.18
	b, 15-30	0.88	0.39	12.80	0.79	0.00	9.00	2.50	2.20	18.34
	c, 0-15	0.69	0.39	15.40	0.51	0.00	11.00	2.90	1.00	20.98
	d, 15-30	0.78	0.49	16.30	0.50	0.00	14.00	2.80	0.60	20.37
10	Kudineerakatte									
	a, 0-15	1.20	1.08	9.40	2.05	0.00	5.00	3.80	3.00	5.06
	b, 15-30	0.88	0.39	15.00	0.77	0.00	12.00	3.10	1.40	18.76
	c, 0-15	0.78	0.39	22.30	1.54	0.00	13.00	8.60	1.20	29.02
	d, 15-30	0.68	0.49	20.10	1.28	0.00	14.00	5.60	2.30	24.19

Note \* a & b : near tank bund

\* c & d : tail end of tank

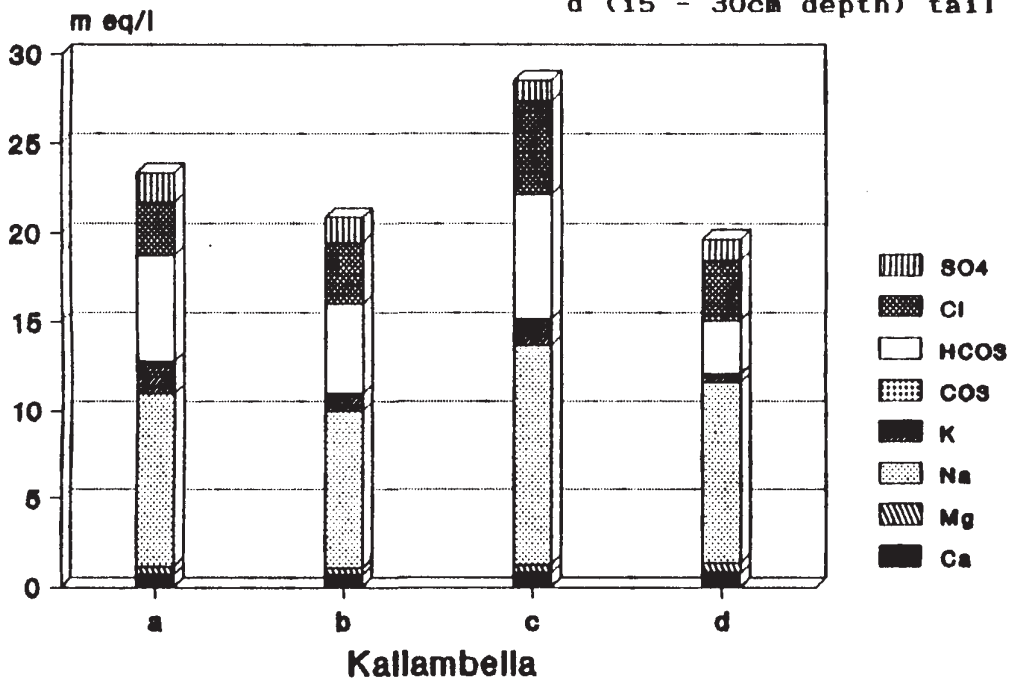
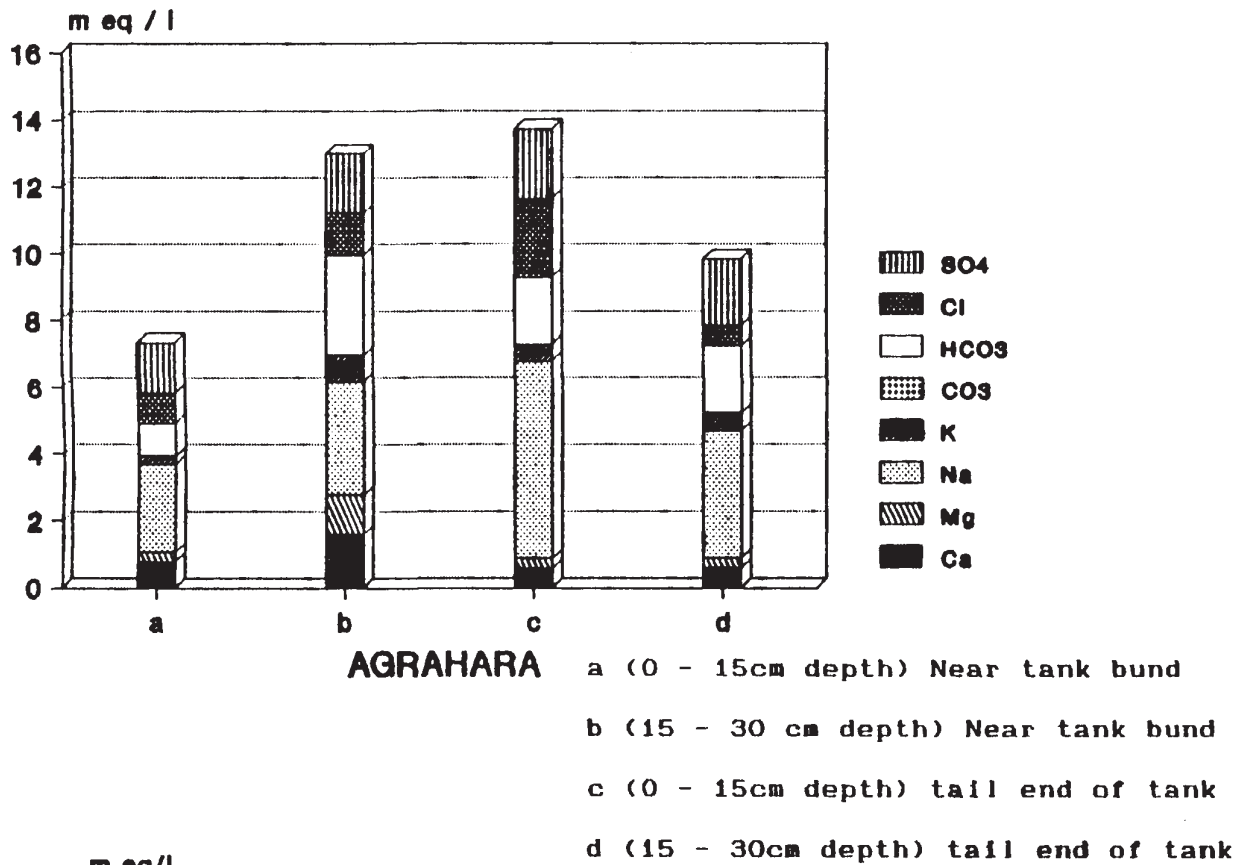


Fig.3a Water soluble ionic concentration in soils of Agrahara and Kallambella.

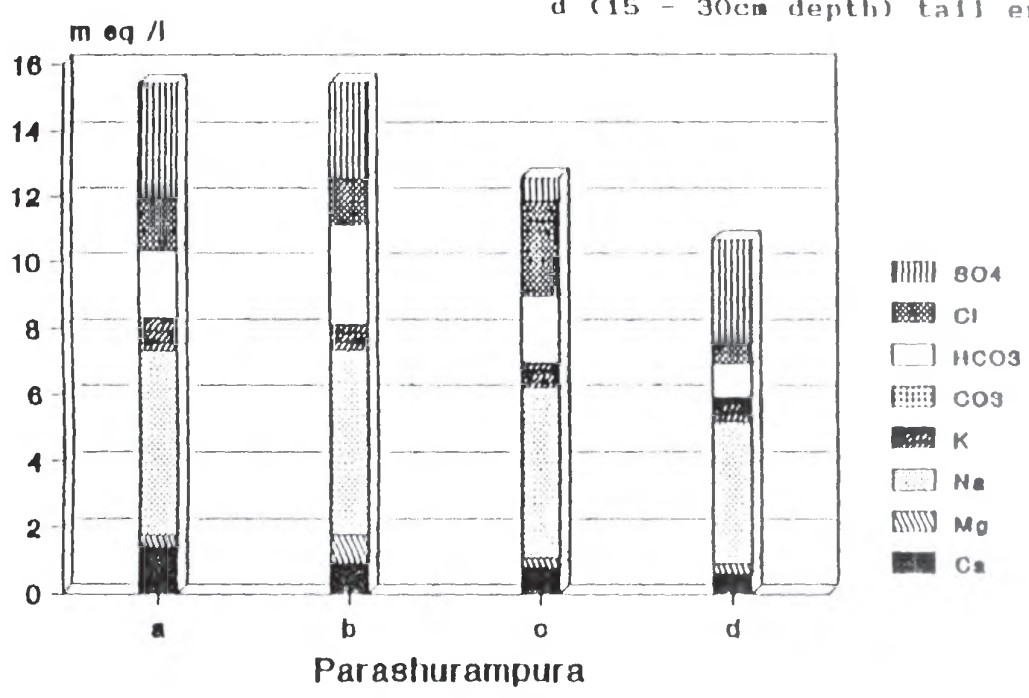
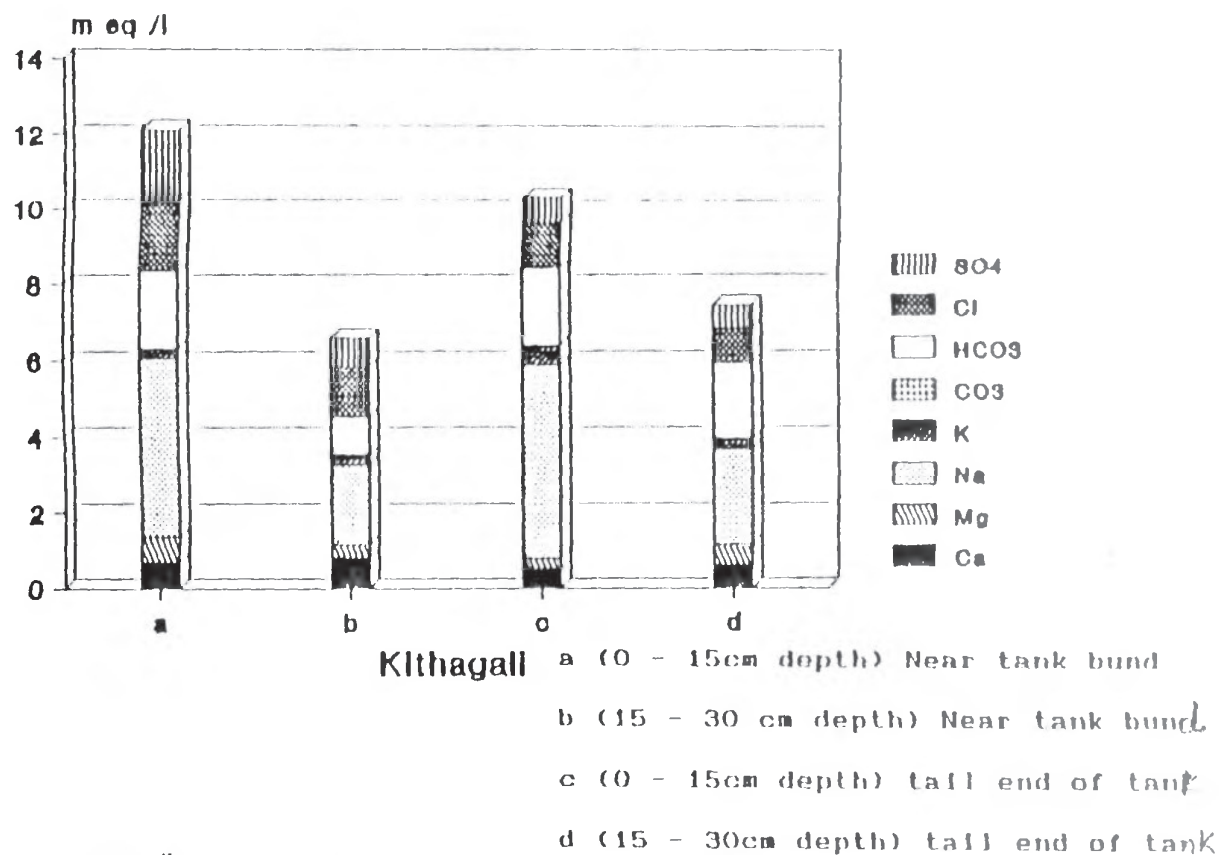


Fig.3b Water soluble ionic concentration in soils of Kithagalli and Parashurampura.

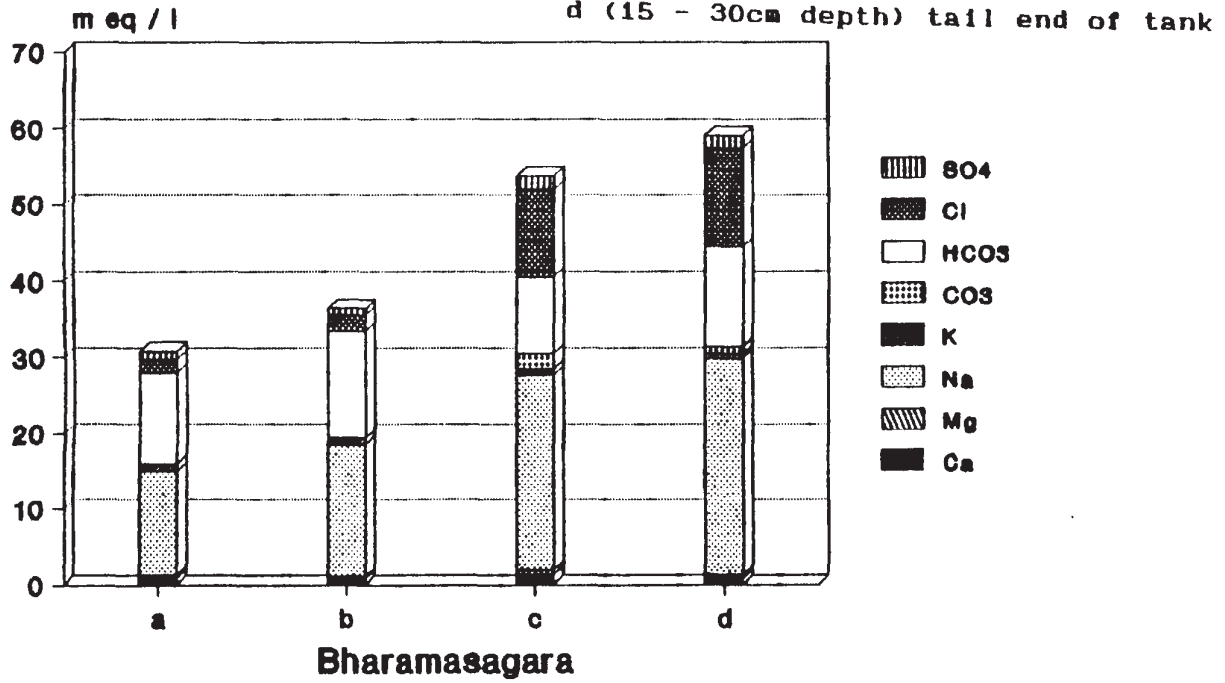
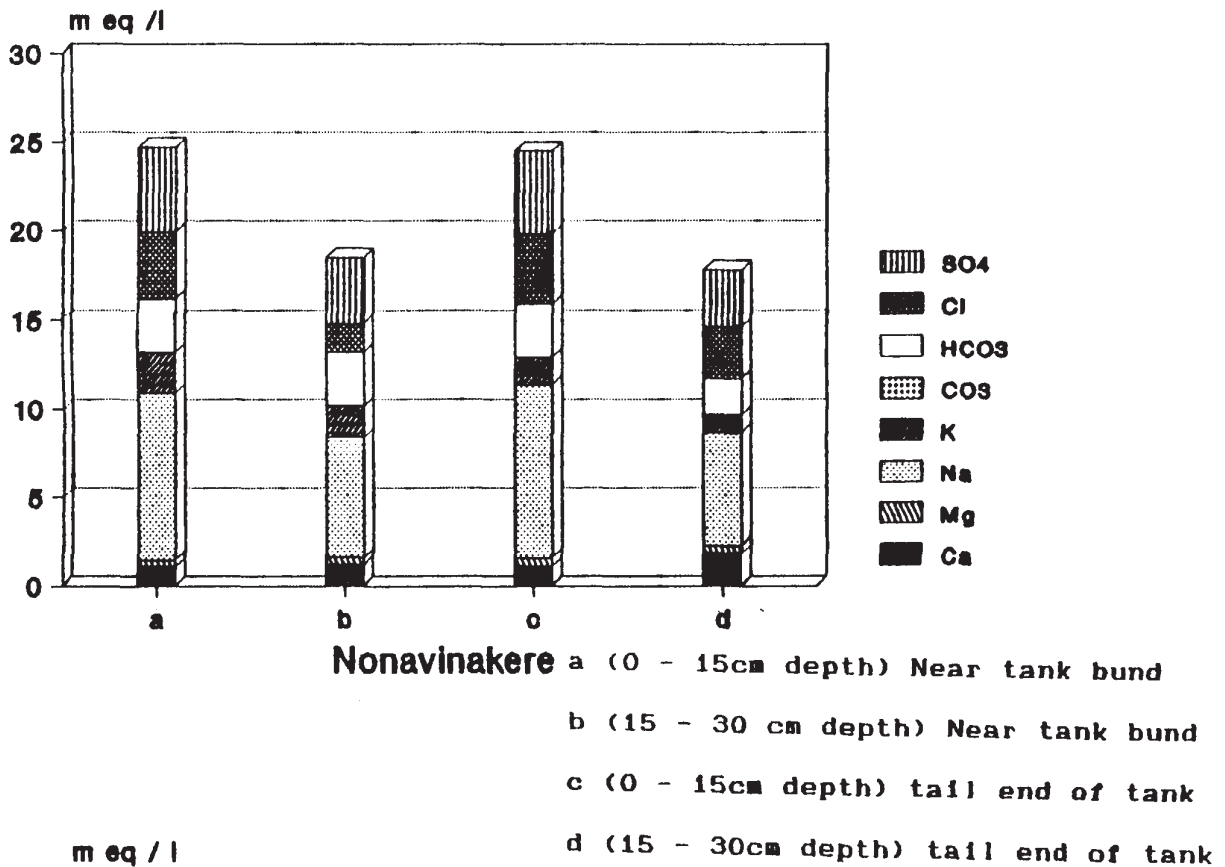


Fig.3c Water soluble ionic concentration in soils of Nonavinakere and Bharamasagara.

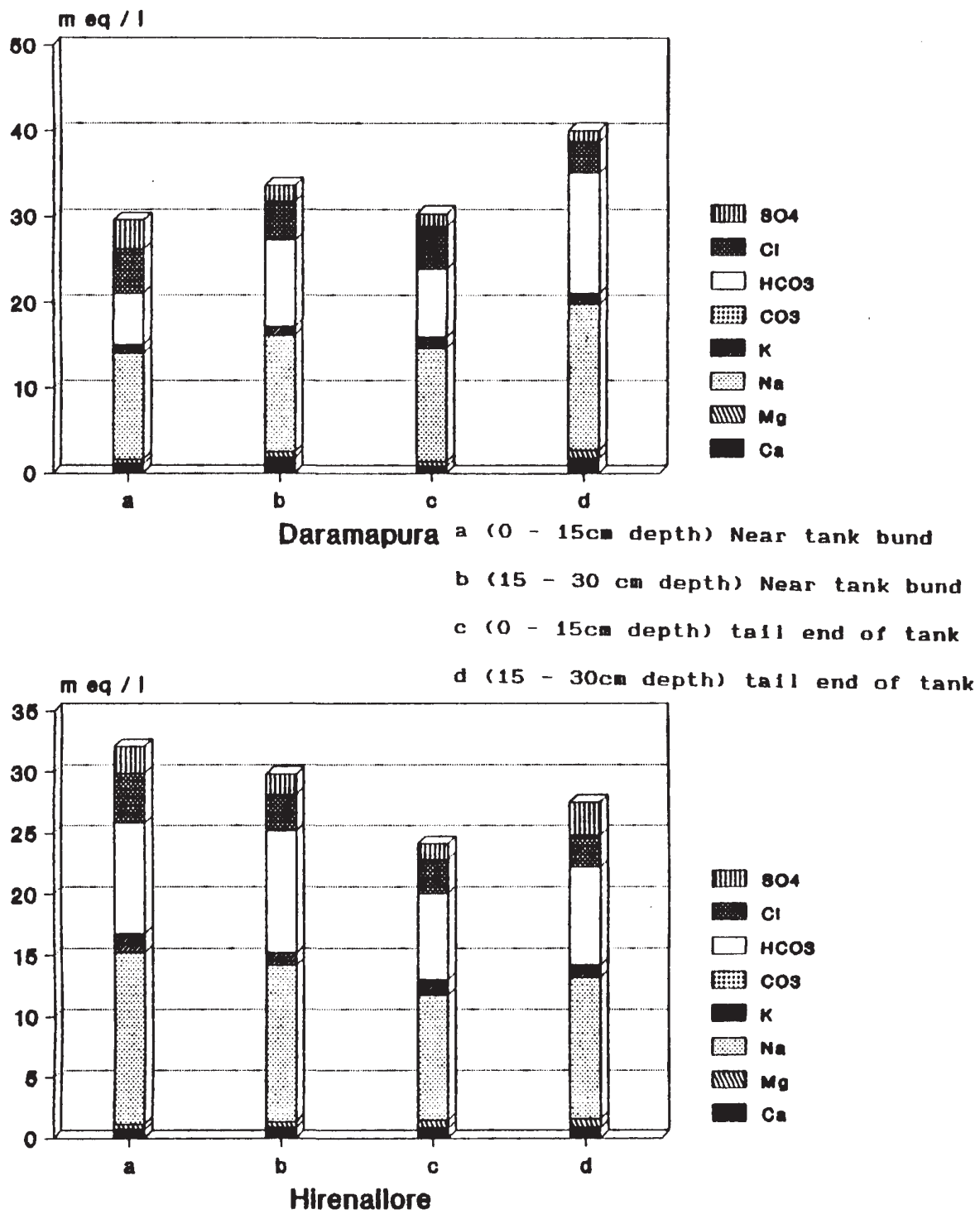


Fig.3d Water soluble ionic concentration in soils of Daranmapura and Hirenallore.

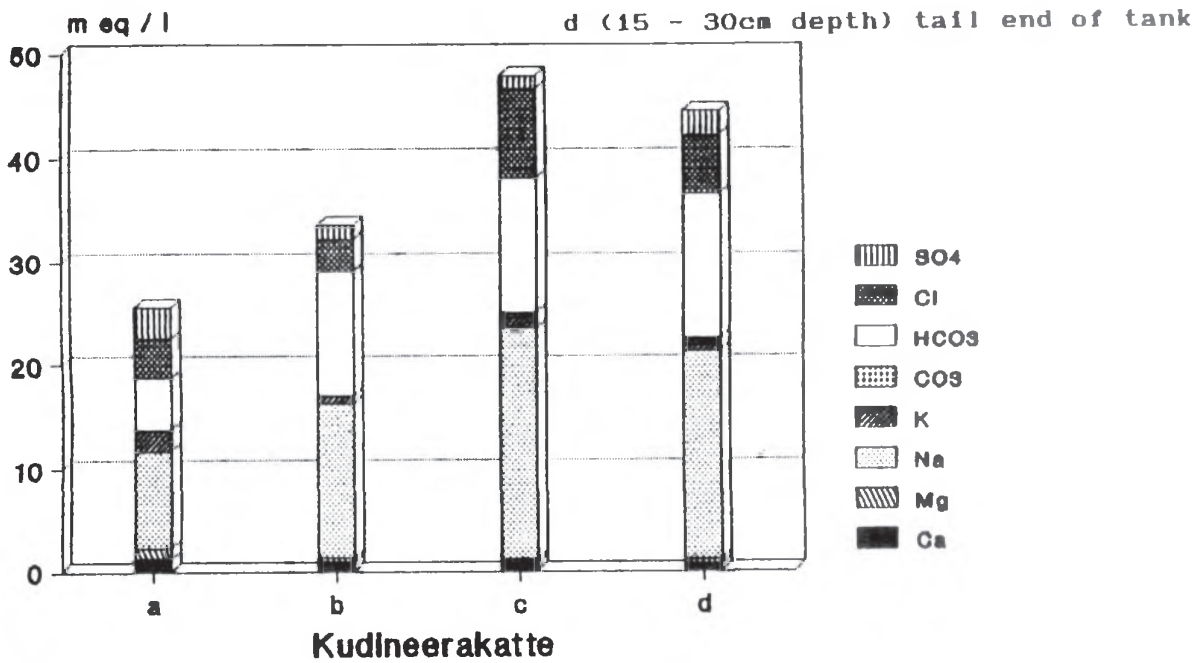
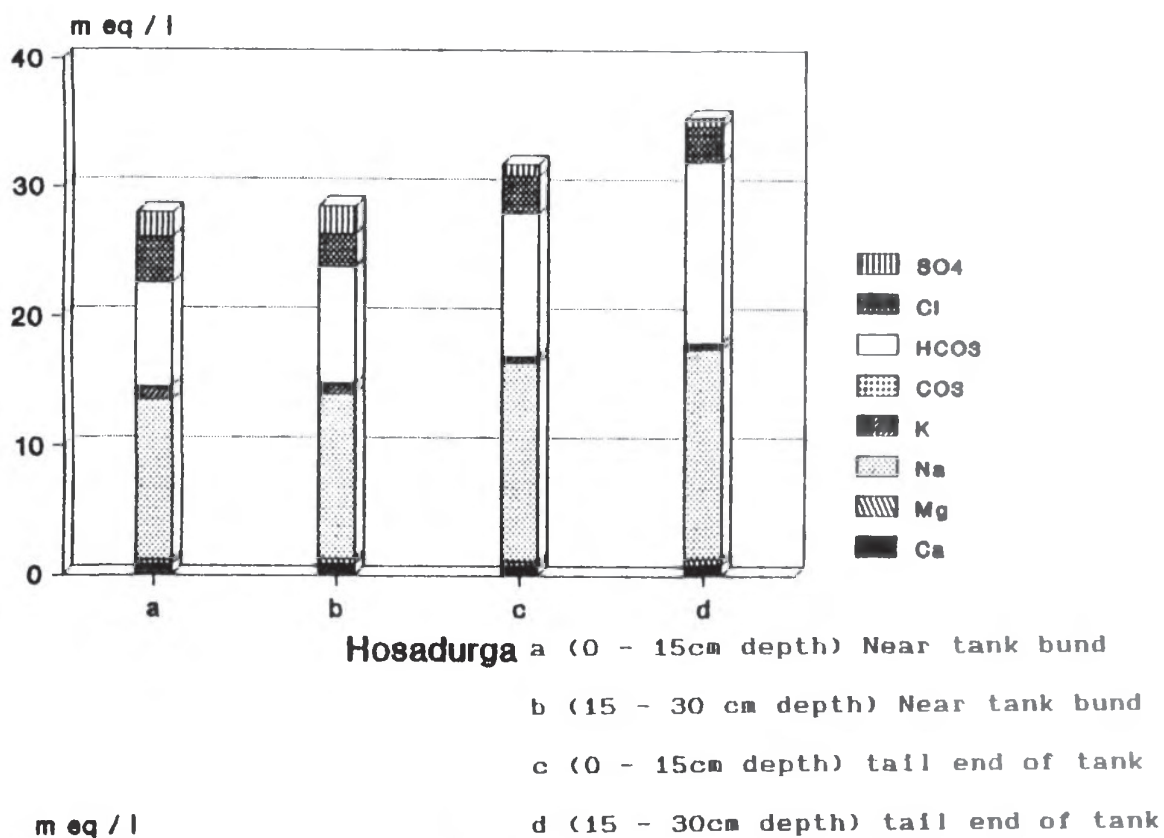


Fig.3e Water soluble ionic concentration in soils of Hosadurga and Kudineerakatte.

#### 4.1.7.2 Water soluble anions

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The water soluble carbonates are absent in all soils studied except in Vertisols at the tail end of Bharamasagara soil and ranged from nil to  $2.0 \text{ me L}^{-1}$ . The water soluble bicarbonate ranged from  $1.0$  to  $14.0 \text{ me L}^{-1}$ . It increased with depth in all Vertisols, while among Alfisols it decreased with depth in Kallambella, Kithagali (nearer the tank bund), Parashurampura and Nonavinakere (at the tail end of tank). Water soluble chloride content varied from  $0.60$  to  $12.96 \text{ me L}^{-1}$ . It decreased with depth in most of the soils, except in Bharamasagara soils and soils near to tank bund in Agrahara and Kallambella soils. Water soluble sulphates varied from  $0.60$  to  $4.79 \text{ me L}^{-1}$ . It decreased with depth in most of the soils except in Agrahara, Hosadurga soils nearer to the tank bund and Parashurampura, Kudineerakatte soils at the tail end of the tank command area.

Concentration of water soluble anion in soils at the tail end of tank is higher compared to soils near the tank bund in most of the soil bodies studied.

#### 4.1.7.3 Sodium adsorption ratio

Sodium adsorption ratio of soils ranged from  $2.79$  to  $38.01$ . The values decreased with depth in all Alfisols and among Vertisols in Daramapura and Hirenallore. While in Bharamasagara and nearer to tank bund in Hosadurga and Kudineerakatte soils it increases with depth. Sodium adsorption ratio of soils near the tank bund was lower than the soils at the tail end of the tank command area except Hirenallore soils.

## **4.2 Physical properties of soil**

### **4.2.1 Particle size distribution**

The results of mechanical composition of soils are presented in Table 6.

#### **4.2.1.1 Coarse sand**

The coarse sand content ranged from 24.10 to 49.90 per cent. The lower value was recorded in lower layer of Hirenallore which is at tail end of the tank command area and highest in surface layer of Parashurampura which is at tail end of the tank. It decreased with depth in most of the soil studied, except in Hosadurga, and soils nearer to the tank bund in case of Agrahara, Parashurampura and Hirenallore where it increased with depth.

#### **4.2.1.2 Fine sand**

The fine sand content ranged from 11.03 to 32.20 per cent, the lowest value was recorded in the subsurface layer of Nonavinakere which is at tail end of the tank and highest in surface layer of Hosadurga which is nearer to the tank bund. It decreased with depth in all Alfisols and Hosadurga, Kudineerakatte soils among Vertisols, while in Bharamasagara, Daramapura and Hirenallore it increased with depth.

#### **4.2.1.3 Silt**

The silt content varied from 10.3 to 30.82 per cent, the lowest value was recorded in the surface layer of Bharamasagara which is at tail end of the tank and highest value in subsurface layer of Kallambella, which is also at tail end of

**Table 6. Particle size analysis of different soil bodies (per cent, moisture free)**

Sl. No.	Soil depth (cm)	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	Textural class
<b>Alfisols</b>						
1	<b>Agrahara</b>					
	a, 0-15	42.83	20.70	20.48	15.48	L
	b, 15-30	45.21	17.50	15.76	20.76	L
	c, 0-15	39.98	19.33	20.28	20.28	L
	d, 15-30	39.25	13.63	20.03	26.03	CL
2	<b>Kallambella</b>					
	a, 0-15	37.15	30.45	20.25	11.25	LS
	b, 15-30	36.96	26.51	21.26	15.26	L
	c, 0-15	38.87	22.87	25.82	15.82	L
	d, 15-30	25.82	22.15	30.82	20.82	SiL
3	<b>Kithagali</b>					
	a, 0-15	48.75	25.41	10.41	15.41	SL
	b, 15-30	43.60	21.90	19.75	15.60	L
	c, 0-15	38.11	20.51	25.06	15.26	SiL
	d, 15-30	37.55	20.25	25.40	15.40	SiL
4	<b>Parashurampura</b>					
	a, 0-15	38.98	30.33	15.33	15.33	L
	b, 15-30	41.52	17.62	25.42	15.42	SiL
	c, 0-15	49.90	24.60	10.25	15.25	L
	d, 15-30	45.05	15.30	15.00	25.00	CL
5	<b>Nonavinakere</b>					
	a, 0-15	39.80	25.50	15.00	20.00	L
	b, 15-30	37.26	16.95	20.26	25.26	CL
	c, 0-15	48.11	15.63	15.63	20.63	L
	d, 15-30	48.08	11.03	16.38	25.08	CL

Table 6. Contd ....

Sl. No.	Soil depth (cm)	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	Textural class
<b>Vertisols</b>						
6	<b>Bharamasagara</b>					
	a, 0-15	36.51	17.96	15.26	30.06	CL
	b, 15-30	34.55	20.00	15.28	30.25	CL
	c, 0-15	30.30	24.10	10.30	35.30	C
	d, 15-30	24.55	24.20	10.65	40.65	C
7	<b>Daramapura</b>					
	a, 0-15	30.92	22.82	15.62	30.62	CL
	b, 15-30	26.75	23.60	14.65	35.00	CL
	c, 0-15	32.60	21.80	15.30	30.30	CL
	d, 15-30	30.55	22.80	12.06	35.00	CL
8	<b>Hirenallore</b>					
	a, 0-15	29.91	23.76	25.66	20.66	SiL
	b, 15-30	31.00	24.00	20.00	25.00	CL
	c, 0-15	31.40	23.90	20.40	25.50	CL
	d, 15-30	24.10	24.81	20.56	30.56	CL
9	<b>Hosadurga</b>					
	a, 0-15	31.60	32.20	15.60	20.60	L
	b, 15-30	34.70	22.60	16.35	26.35	CL
	c, 0-15	30.30	25.50	15.00	30.00	CL
	d, 15-30	30.90	18.35	20.36	30.35	CL
10	<b>Kudineerakatte</b>					
	a, 0-15	33.15	26.05	10.40	30.40	CL
	b, 15-30	30.40	17.90	15.80	35.80	CL
	c, 0-15	29.75	26.80	15.00	30.00	CL
	d, 15-30	28.05	16.75	20.25	35.25	CL

Note : \* a & b : near tank bund

\* c& d : tail end of tank

L - Loam

SL - Sandy loam

LS - Loamy sand

CL - Clay loam

SiL - Silt loam

C - Clay

the tank. It increased with depth in most of the soils studied, except in Agrahara, Daramapura and Hirenallore soils, where it decreased with depth.

#### **4.2.1.4 Clay**

Clay content of these soils ranged from 11.25 to 40.65 per cent. The lowest value was recorded in surface layer of Kallambella which is nearer to tank bund and highest value was recorded in subsurface layer of Bharamasagara which is at tail end of the tank. Illuviation of clay was observed in all soils.

The clay and silt content increased, while coarse and fine sand content decreased at the tail end of the tank.

The textural class of these soils varied from loamy sand to clay.

#### **4.2.2 Rheological properties, sticky point, hydraulic conductivity and mean weight diameter of soils**

The data of Rheological properties (lower plastic limit, upper plastic limit and plasticity index) sticky point moisture, hydraulic conductivity and mean weight diameter are present in Table 7.

##### **4.2.2.1 Lower plastic limit**

The lower plastic limit values ranged from 5.41 to 13.65 per cent in different soils. It increased with depth in most of the soils studied except in Agrahara at tail end of the tank and at Daramapura nearer to the tank bund where it decreased with depth. The values were higher for Vertisols compared to Alfisols.

**Table 7. Rheological properties (% moisture), Hydranlic conductivity and mean weight diameter of different soil bodies**

Sl. No.	Soil depth (cm)	Lower plastic limit	Upper plastic limit	Plasticity index	Sticky point moisture	HC (cm/hr)	MWD (mm)
<b>Alfisols</b>							
1	<b>Agrahara</b>						
	a, 0-15	5.50	9.52	4.01	22.30	30.60	5.91
	b, 15-30	7.30	11.62	4.30	28.40	23.10	5.87
	c, 0-15	8.10	12.14	4.01	22.10	32.60	4.36
	d, 15-30	6.50	12.16	5.64	24.40	30.40	4.22
2	<b>Kallambella</b>						
	a, 0-15	5.70	10.80	5.11	22.81	28.60	1.30
	b, 15-30	5.96	11.50	5.54	23.70	26.30	1.26
	c, 0-15	6.80	15.60	8.80	26.70	27.30	1.76
	d, 15-30	9.46	20.62	11.60	26.10	25.80	1.73
3	<b>Kithagali</b>						
	a, 0-15	5.80	11.80	6.00	23.10	29.20	3.65
	b, 15-30	6.26	14.20	7.94	25.40	25.60	3.45
	c, 0-15	6.13	12.50	6.37	23.50	28.80	3.20
	d, 15-30	6.56	14.76	8.20	26.20	26.20	3.02
4	<b>Parashurampura</b>						
	a, 0-15	5.45	10.57	5.12	21.60	26.30	4.48
	b, 15-30	6.76	12.95	6.19	23.60	24.40	4.32
	c, 0-15	5.86	11.61	5.75	21.40	31.20	5.48
	d, 15-30	6.26	12.48	6.22	22.45	30.60	5.17
5	<b>Nonavinakere</b>						
	a, 0-15	7.36	12.36	5.00	24.32	29.20	2.91
	b, 15-30	8.32	16.53	8.21	31.13	27.20	2.65
	c, 0-15	5.41	10.63	5.22	25.17	26.50	1.47
	d, 15-30	6.65	12.72	6.07	26.42	24.20	1.39

Table 7. Contd ....

Sl. No.	Soil depth (cm)	Lower plastic limit	Upper plastic limit	Plasticity index	Sticky point moisture	HC (cm/hr)	MWD (mm)
<b>Vertisols</b>							
6	Bharamasagara						
	a, 0-15	10.13	23.35	13.20	43.40	0.48	0.89
	b, 15-30	11.30	25.50	14.23	45.50	0.40	0.83
	c, 0-15	9.32	23.48	14.16	47.50	0.36	0.81
	d, 15-30	10.50	26.70	16.20	49.80	0.31	0.81
7	Daramapura						
	a, 0-15	13.65	24.52	10.11	44.20	7.50	1.03
	b, 15-30	10.23	25.39	15.16	46.58	4.20	1.00
	c, 0-15	10.78	28.16	17.38	45.80	6.50	0.75
	d, 15-30	12.76	30.89	18.13	48.70	3.40	0.71
8	Hirenallore						
	a, 0-15	9.37	25.68	16.31	39.70	8.60	0.91
	b, 15-30	11.20	29.90	18.70	42.86	6.30	0.88
	c, 0-15	10.68	28.29	17.61	40.80	7.20	1.06
	d, 15-30	13.12	32.58	19.46	44.60	5.60	0.99
9	Hosadurga						
	a, 0-15	10.20	22.40	12.20	40.60	6.30	1.42
	b, 15-30	10.80	24.30	13.50	42.40	4.70	1.36
	c, 0-15	9.50	21.65	12.15	40.46	5.60	1.15
	d, 15-30	10.46	23.62	13.16	41.12	3.50	1.08
10	Kudineerakatte						
	a, 0-15	9.46	20.76	11.30	42.72	5.50	1.20
	b, 15-30	11.56	23.60	12.06	44.68	4.80	1.15
	c, 0-15	10.18	21.78	11.60	43.60	5.20	1.15
	d, 15-30	12.32	24.43	12.11	46.10	1.10	1.09

Note : \* a & b : near tank bund  
\* c & d : tail end of tank

#### **4.2.2.2 Upper plastic limit**

Upper plastic limit values varied from 9.52 to 32.58 per cent in different soils. The values increased with depth in all the soils studied. The values are higher for Vertisols compared to Alfisols.

#### **4.2.2.3 Plasticity index**

Plasticity index values ranged from 4.01 to 19.46 per cent and it increased with depth in all the soils studied. Vertisols recorded higher plasticity index values compared to Alfisols.

#### **4.2.2.4 Sticky point moisture**

Sticky point moisture ranged from 21.60 to 49.80 per cent and it increased with depth in all soils. Vertisols recorded higher sticky point moisture compared to Alfisols.

Rheological properties such as lower plastic limit, upper plastic limit, plasticity index and sticky point moisture are more in most of the soils at the tail end of tank than near the tank bound soils.

#### **4.2.2.5 Hydraulic conductivity of soil**

The hydraulic conductivity values ranged from 0.31 to 32.60 cm hr<sup>-1</sup> and it decreased with the depth in all the soil bodies studied. Vertisols recorded a very lower values compared to Alfisols. The Hydraulic conductivity is low in soils at the tail end of tank compare to the soils near the tank bund in most of the soils studied.

#### 4.2.2.6 Aggregate analysis (MWD)

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The mean weight diameter values ranged from 0.71 to 5.91 mm and decreased with depth in all the soil bodies studied.

Alfisols have higher mean weight diameter compared to Vertisols.

The mean weight diameter of soils at the tail end of tank is low compare to soils at near the tank bund in most of the soils studied except in Kallambella and Parashurampura soils.

### 4.3 Statistical studies

The data presented in Tables 8a and 8b represents regression equations and correlation coefficients for different characteristics of soils studied.

#### 4.3.1 Relationship between water soluble cations and anions

There was significant positive correlation between water soluble  $\text{Ca}^{++}$  and  $\text{Mg}^{++}$  ( $r = 0.560^{**}$ ). High significance correlation was also noticed between water soluble  $\text{Na}^+$  and  $\text{CO}_3^{=}$  ( $r = 0.548^{**}$ ), watersoluble  $\text{Na}^+$  and  $\text{HCO}_3^-$  ( $r = 0.883^{**}$ ) and water soluble  $\text{Na}^+$  and  $\text{Cl}^-$  ( $r = 0.838$ ). The relationship between SAR and water soluble  $\text{Na}^+$  ( $r = 0.957$ ) also showed high significant correlation.

#### 4.3.2 Relationship between selected soil properties

There was positive correlation noticed between CEC and exchangeable cations with higher significant values of  $r$  for Ca, Mg and Na ( $r = 0.944^{**}$ ,  $r = 0.937^{**}$  and  $r = 0.724^{**}$  respectively).

**Table 8a. Correlatin Matrix for water soible cations and anions**

	pH	EC	W/S Ca	W/S Mg	W/S Na	W/S K	W/S CO <sub>3</sub>	W/S HCO <sub>3</sub>	W/S Cl	W/S SO <sub>4</sub>	SAR
pH	1.000										
EC	0.528**	1.000									
W/S Ca	0.236	0.008	1.000								
W/S Mg	0.042	-0.03	0.560**	1.000							
W/S Na	0.758**	0.654**	0.112	0.013	1.000						
W/S K	0.379*	-0.047	0.274	0.205	0.204	1.000					
W/S CO <sub>3</sub>	0.375*	0.762**	0.154	0.081	0.548**	-0.122	1.000				
W/S HCO <sub>3</sub>	0.697**	0.407**	0.083	0.055	0.883**	0.141	0.221	1.000			
W/S Cl	0.581**	0.713**	0.175	0.069	0.838**	0.198	0.726**	0.518**	1.000		
W/S SO <sub>4</sub>	-0.025	-0.092	0.339	0.099	0.158	0.548**	-0.048	-0.349	-0.015	1.000	
SAR	0.688**	0.6485**	-0.083	0.18	0.957**	0.104	0.509**	0.853**	0.793**	-0.228	1.000

**Table 8b. Correlation for selected soil properties**

Sl. No.	Variables		Correlation Coefficient (r)	Regression equation
	x	y		
1	Ex Ca	CEC	0.944**	$y = -1.4921 + 2.0638 x$
2	Ex Mg	CEC	0.937**	$y = 6.5565 + 2.3331 x$
3	Ex Na	CEC	0.724*	$y = 16.9339 + 21.6487 x$
4	ESP	CEC	0.071	$y = 26.8486 - 0.2583 x$
5	Clay	CEC	0.781	$y = 21.4001 + 0.3701 x$
6	Ex. Mg	Ex. Ca	0.840**	$y = 5.3777 + 0.9561 x$
7	Ex. Na	Ex. Ca	0.735**	$y = 9.1187 + 10.0515 x$
8	Ex. Na	ESP	0.760	$y = 17366 + 0.6289 x$
9	Ex. Ca	ESP	-0.091	$y = 2.7465 - 0.0547 x$
10	Ex. Mg	ESP	-0.124	$y = 2.728 - 0.0848 x$
11	SAR	ESP	0.704**	$y = 0.5128 + 0.1894 x$
12	MWD	HC	0.499**	$y = 7.7288 + 4.1282 x$
13	PH	HC	-0.55	$y = 102.2017 - 10.774 x$
14	EC	HC	-0.372	$y = 22.7886 - 19.5673 x$
15	OC	HC	0.537	$y = -9.7977 + 44.3335 x$
16	CEC	HC	-0.524	$y = 40.5813 - 0.9035 x$
17	ESP	HC	-0.456	$y = 22.5504 - 2.8631 x$
18	W/SNa	HC	-0.774	$y = 34.9602 - 1.6561 x$
19	Coarse sand	HC	0.719**	$y = -33.2356 + 1.392 x$
20	Clay	HC	-0.803	$y = 51.488 - 1.4202 x$
21	MWD	ESP	-0.260	$y = 2.5917 - 0.1971 x$
22	CEC	LPL	0.505**	$y = 4.5189 + 0.1611 x$
23	Clay	LPL	0.786**	$y = 2.4837 + 0.2568 x$
24	CEC	UPL	0.527**	$y = 6.7626 + 1.4686 x$
25	Clay	UPL	0.753**	$y = 2.3412 + 0.6857 x$
26	CEC	PI	0.508**	$y = 2.2231 + 0.3087 x$
27	Clay	PI	0.688**	$y = 0.1173 + 0.4283 x$
28	CEC	SPM	0.472**	$y = 18.0912 + 0.6172 x$
29	Clay	SPM	0.872**	$y = 5.8211 + 1.1669 x$

r value at 5% = 0.3145 = \*

r value at 1% = 0.457 = \*\*

The correlation between CEC and clay was also statistically significant ( $r = 0.781^{**}$ ). The correlation between ESP with SAR ( $r = 0.704^{**}$ ) and exchangeable Na ( $r = 0.760^{**}$ ) were found to be significant.

Hydraulic conductivity showed significant positive correlation with mean weight diameter ( $r = 0.499^{**}$ ). Coarse sand ( $r = 0.719^{**}$ ) and organic carbon ( $r = 0.537^{**}$ ), while with water soluble Na ( $r = -0.774^{**}$ ) and clay ( $r = -0.803^{**}$ ) it showed high negative correlation.

The correlation values between Atterberg's limits such as LPL ( $r = 0.505^{**}$ ), UPL ( $r = 0.527^{**}$ ), PI ( $r = 0.508^{**}$ ) and SPM ( $r = 0.472^{**}$ ) with CEC were highly significant. Also between Atterberg's limits with clay such as LPL ( $r = 0.786^{**}$ ), UPL ( $r = 0.753^{**}$ ), PI ( $r = 0.688^{**}$ ) and SPM ( $r = 0.872^{**}$ ) were highly significant with positive values as presented in Table 8.

#### 4.4 Chemical composition of Irrigation water

Water samples used for irrigation collected from tanks from the respective places were analysed for pH, EC, Soluble cations, anions and boron, RSC and SAR were calculated from the results and irrigation water were classified according to U.S.D.A. hand book 60 (1954). The results are reported in Table 8.

The pH of irrigation water varied from 7.12 to 7.80, the electrical conductivity ranged from 319 to 852 micro mhos  $\text{cm}^{-1}$  at  $25^{\circ}\text{C}$ . The calcium concentration varied from 1.17 to 2.45 me  $\text{L}^{-1}$ , magnesium ranged from 0.49 to 1.37 me  $\text{L}^{-1}$ , while sodium ranged from 0.42 to 1.18 me  $\text{L}^{-1}$  and potassium content was low and varied from 0.09 to 0.40 me  $\text{L}^{-1}$ . Calcium was predominant in most of the irrigation water studied followed by magnesium and sodium.

**Table 9. Chemical composition of Irrigation water (tank)**

Sl. No.	Place	pH	EC μ mhos/Cm	me L-1						Boron ppm	RSC	SAR	Class		
				Ca <sup>++</sup>	Mg <sup>++</sup>	Na <sup>+</sup>	K <sup>+</sup>	CO <sub>3</sub> <sup>--</sup>	HCO <sub>3</sub> <sup>-</sup>					Cl <sup>-</sup>	SO <sub>4</sub> <sup>--</sup>
1	Agrahara	7.35	319.00	1.37	0.88	0.42	0.09	-	0.11	2.10	0.07	Tr	-2.14	0.39	C <sub>2</sub> S <sub>1</sub>
2	Kallambella	7.12	355.00	1.86	0.49	0.56	0.09	-	0.19	2.55	0.09	0.01	-2.16	0.52	C <sub>2</sub> S <sub>1</sub>
3	Kithagali	7.26	568.00	1.56	1.18	0.76	0.34	-	0.07	2.70	0.30	Tr	-2.67	0.65	C <sub>2</sub> S <sub>1</sub>
4	Parashuram pura	7.53	710.00	1.47	1.17	0.73	0.17	-	0.18	2.85	0.14	0.005	-2.46	0.64	C <sub>2</sub> S <sub>1</sub>
5	Nonavinakere	7.31	356.00	1.17	0.79	0.45	0.13	-	0.16	1.95	0.29	0.01	-1.80	0.45	C <sub>2</sub> S <sub>1</sub>
6	Baramasagara	7.80	852.00	2.45	1.37	1.18	0.29	-	0.29	4.20	0.45	0.03	-3.52	0.85	C <sub>3</sub> S <sub>1</sub>
7	Daramapura	7.72	781.00	2.25	1.18	0.98	0.16	-	0.27	3.75	0.44	0.02	-3.15	0.75	C <sub>3</sub> S <sub>1</sub>
8	Hirenallore	7.60	710.00	1.86	1.17	0.81	0.40	-	0.25	3.00	0.18	0.01	-2.78	0.66	C <sub>2</sub> S <sub>1</sub>
9	Hosadurga	7.56	639.00	1.96	1.20	0.90	0.15	-	0.23	3.45	0.33	0.02	-2.93	0.71	C <sub>2</sub> S <sub>1</sub>
10	Kudinerakatte	7.59	568.00	1.76	1.08	0.78	0.14	-	0.26	3.00	0.26	0.01	-2.57	0.65	C <sub>2</sub> S <sub>1</sub>

Among anions carbonate content was absent in all the irrigation water studied, bicarbonate content varied from 0.07 to 0.29 me L<sup>-1</sup>, chloride ranged from 1.95 to 4.20 me L<sup>-1</sup> and sulphate varied from 0.07 to 0.45 me L<sup>-1</sup>. Chloride was predominant in most of irrigation water studied followed by sulphate and bicarbonates. Boron is low varied from traces to 0.03 ppm. The sodium adsorption ratio varied from 0.39 to 0.85, the RSC value ranged from -3.52 to -1.80. The lower SAR values indicates the less possibility of sodium hazard after irrigation. Most of these irrigation waters fall under C<sub>2</sub>S<sub>1</sub> class except Bharamasagara and Daramapura which fall under C<sub>3</sub>S<sub>1</sub> class (U.S.D.A., Staff 1954).

#### **4.5 Effect of anions on exchangeable cations and exchangeable sodium percentage of soils**

The data on the concentration of calcium, sodium, sulphate and chloride in equilibrated soils under chloride and sulphate systems are presented in Table 10.

The data reveals that the concentration of sodium in equilibrated soils increased with an increase in SAR of equilibrating solution in both chloride and sulphate system at both the depths. The sodium values increased from 5.97 to 17.04 me/100g of soil in sulphate system and 5.11 to 15.34 me/100g of soil in chloride system at 0-15 cm depth, 8.52 to 17.90 me/100g of soil in sulphate system and 7.67 to 15.34 me/100g of soil in chloride system at 15-30 cm depth in Kallambella soils. While in Hosadurga soils the sodium content varied from 16.19 to 32.38 me/100g in sulphate system and 14.49 to 28.12 me/100g in chloride system at 0-15 cm depth, 17.80 to 34.09 me/100g in sulphate system and 13.63 to 28.12 me/100g in chloride system at 15-30 cm depth. The concentration of calcium is decreased in both the systems and

**Table 10. Concentration of calcium, sodium, sulphate and chloride in equilibrated soils under chloride and sulphate system (me/100g)**

No.	SAR of equilibrating solution	Kallambella soils				Hosadurga soils				
		0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	
Exchangeable ions me/100g of soil										
Chloride System										
		Ca	Na	Cl	Ca	Na	Cl	Ca	Na	Cl
T <sub>1</sub>	40	0.32	5.11	0.93	0.31	7.67	0.75	0.25	14.49	0.60
T <sub>2</sub>	50	0.31	6.81	1.30	0.28	9.37	0.92	0.24	17.90	1.22
T <sub>3</sub>	60	0.30	11.93	1.81	0.27	12.78	1.84	0.23	20.45	2.09
T <sub>4</sub>	80	0.26	15.34	2.25	0.21	15.34	2.17	0.19	28.12	2.61
Sulphate system										
		Ca	Na	SO <sub>4</sub>	Ca	Na	SO <sub>4</sub>	Ca	Na	SO <sub>4</sub>
T <sub>5</sub>	40	0.23	5.97	1.93	0.15	8.52	1.18	0.35	16.19	1.53
T <sub>6</sub>	50	0.18	9.37	2.10	0.14	11.08	1.16	0.20	18.75	2.06
T <sub>7</sub>	60	0.17	12.78	3.67	0.13	13.63	4.52	0.19	27.26	4.76
T <sub>8</sub>	80	0.13	17.04	4.35	0.12	17.90	4.97	0.14	32.38	5.13
					Ca	Na	SO <sub>4</sub>	Ca	Na	SO <sub>4</sub>
					0.18	17.80	1.25	0.16	20.45	1.60
					0.14	29.83	5.23	0.14	34.09	6.42

at both depths. The calcium content decreased from 0.23 to 0.13 me/100g in sulphate system, 0.32 to 0.26 mg/100g in chloride system at 0-15 cm depth and 0.15 to 0.12 me/100g in sulphate and 0.31 to 0.21 me/100g in chloride system at 15-30 cm depth in Kallambella soils. In case of Hosadurga soils calcium content decreased from 0.35 to 0.14 me/100g in sulphate and 0.25 to 0.19 me/100g in chloride systems at 0-15 cm depth and 0.18 to 0.13 me/100g in sulphate system and 0.26 to 0.20 me/100g in chloride system at 15-30 cm depth. Hosadurga soils adsorbed more amount of sodium than Kallambella soils in both the systems. The amount of Na adsorbed at SAR of 40 was 5.97 and 16.19 me/100g in sulphate systems at 0-15 cm depth, in Kallambella soils and Hosadurga soils respectively. While in chloride system 5.11 and 14.49 me/100g of Na was adsorbed at SAR 40 at 0-15 cm depth in Kallambella soils and Hosadurga soils respectively. Similar trend was observed in other cases. The amount of calcium adsorbed is more in chloride system than in sulphate system in both soils at both depths at the same level of SAR.

#### 4.5.1 Exchangeable sodium ratio

The relationship between SAR of equilibrating solutions and ESR of different soils studied [Table 11], reveals the distinct significant difference between sulphate and chloride systems. In Kallambella soils SAR of 40 recorded ESR values of 0.38 and 0.48 in chloride and sulphate systems respectively at 0-15 cm depth while in Hosadurga soils the values were 0.58 and 0.93 in chloride and sulphate systems 15-30 cm depth. Similar trend was observed in all/cases. For equal values of SAR, more sodium was adsorbed from sulphate system than chloride system. The differences are larger at high values of SAR, that correspond to more concentrated solutions.

Table 11. Effect of SAR on exchangeable sodium ratio in different soils under sulphate and chloride system

Treatments	Place	Kallambella soils				Hosadurga soils			
	System	Chloride system		Sulphate system		Chloride system		Sulphate system	
	Depth (cm)	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
T <sub>1</sub> = SAR 40		0.38	0.65	0.48	0.77	0.71	0.58	0.86	0.93
T <sub>2</sub> = SAR 50		0.59	0.92	1.03	1.31	1.06	0.78	1.17	1.24
T <sub>3</sub> = SAR 60		1.84	1.9	2.27	2.32	1.43	1.49	3.62	4.16
T <sub>4</sub> = SAR 80		6.01	3.69	12.52	11.18	4.21	3.17	13.38	11.71
Mean		2.21	1.79	4.08	3.9	1.85	1.51	4.76	4.51
F.test	A			*				*	
	B			*				*	
	C			*				*	
	AB			*				*	
	AC			*				*	
	BC			*				*	
	ABC			*				*	
SEm±	A			0.018				0.023	
	B			0.013				0.016	
	C			0.013				0.016	
	AB			0.025				0.033	
	AC			0.025				0.033	
	BC			0.018				0.023	
	ABC			0.036				0.040	
CD @ 5 %	A			0.051				0.066	
	B			0.036				0.047	
	C			0.036				0.047	
	AB			0.072				0.094	
	AC			0.072				0.094	
	BC			0.051				0.066	
	ABC			0.102				0.133	

A - SAR  
 B - Chloride / Sulphate system  
 C - Depth  
 \* - Significant @ 5 %

There is a significant variation in exchangeable sodium ratios due to depth, chloride/sulphate system, SAR and their interactions in both Kallambella and Hosadurga soils.

The relationship between SAR of equilibrium solutions and ESP of the different equilibrated soils (Table 12) reveals that, there is distinct significant difference between different SAR levels, sulphate/chloride systems and depth in all the cases. At SAR of 40 ESP values were 27.77 and 32.44 in chloride and sulphate systems at 0-15 cm depth in Kallambella soils where as the values were 41.64 and 46.52 in chloride and sulphate systems at 0-15 cm depth in Hosadurga soils. Similar trend was observed in 15-30 cm depth. The statistical analysis indicates that there is a significant difference between SAR, chloride/sulphate systems and depth as in the case of ESR.

Table 12. Effect of SAR on exchangeable sodium percentage in different soils under sulphate and chloride system

Treatments	Place	Kallambella soils				Hosadurga soils			
	System	Chloride system		Sulphate system		Chloride system		Sulphate system	
	Depth (cm)	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
T <sub>1</sub> = SAR 40		27.77	39.33	32.44	43.69	41.64	36.84	46.52	48.11
T <sub>2</sub> = SAR 50		37.01	48.05	50.92	56.82	51.44	43.77	53.87	55.27
T <sub>3</sub> = SAR 60		64.84	65.54	69.45	69.90	58.76	59.92	78.33	80.62
T <sub>4</sub> = SAR 80		83.37	78.67	92.60	91.74	80.80	76.00	93.05	92.14
Mean		53.25	57.89	61.35	65.54	58.16	54.13	67.94	69.03
F.test	A			*				*	
	B			*				*	
	C			*				*	
	AB			*				*	
	AC			*				*	
	BC			*				*	
	ABC			*				*	
SEm±	A			0.138				0.070	
	B			0.097				0.049	
	C			0.097				0.049	
	AB			0.195				0.099	
	AC			0.195				0.099	
	BC			0.138				0.070	
	ABC			0.276				0.140	
CD @ 5 %	A			0.396				0.201	
	B			0.280				0.142	
	C			0.280				0.142	
	AB			0.561				0.285	
	AC			0.561				0.285	
	BC			0.396				0.201	
	ABC			0.793				0.403	

A - SAR  
 B - Chloride / Sulphate system  
 C - Depth  
 \* - Significant @ 5 %

## **DISCUSSION**

## V DISCUSSION

The intensive irrigated farming causes considerable changes in physical and chemical properties of soils. The periodical assessment of such changes in soil will help in formulating effective remedial measures for improving their productivity.

A study was taken up in selected tank command area soils in zone IV of Karnataka, to study the ionic population in water soluble and exchangeable positions and to find out the effect of tank irrigation on physical properties of soil and derive ion exchange equations that would adequately describe sodicity hazards in soils consequent to tank irrigation.

Keeping this in view a study was taken up to analyse physical and chemical properties of selected tank command area soils in zone IV of Karnataka.

The results of analysis are discussed here.

### 5.1 Chemical properties of soil

#### 5.1.1 Soil reaction (pH)

All Vertisols and most of the Alfisols except Agrahara soils were neutral to alkaline in reaction, Agrahara soils were moderately acidic to neutral. The alkaline nature of most soils may be due to sufficient amount of free calcium carbonate. Similar reports are made by Bhadrapur and Seshagiri Rao (1979) on Thungabhadra project soils and Parvathappa (1981) on irrigated soils of Karnataka.

It was observed that the soils from Kallambella, Bharamasagara and subsurface soils at tail end of tank command areas in case of Daramapura,

It was observed that the soils from Kallambella, Bharamasagara and subsurface soils at tail end of tank command areas in case of Daramapura, Hosadurga and Kudineerakatte have pH 8.2 and above, such high pH may be due to presence of relatively larger proportion of soluble carbonates and bicarbonate of calcium and sodium. Similar findings were reported by Tiwari *et al.* (1983) on salt affected soils of Uttar Pradesh.

An increase in pH is also attributed to higher SAR and ESP values as there will be hydrolysis of sodium which leads to increase in hydroxyl ions. Similar reports were made by Kanwar and Sehgal (1962) and Panjaswamy *et al.* (1973).

The pH increased with depth in Agrahara, Kithagali and most of the Vertisols. The high pH in lower layers may be due to higher concentration of sodium and decreased content of calcium and magnesium. Similar observations were made by Kanwar and Sehgal (1962), Lal and Singh (1974) and Sen *et al.* (1997).

The decreased pH with depth in soils of Kallambella, Parashurampura, Nonavinakere and Bharamasagara, may be due to the surface accumulation of soluble salts of sodium carbonates, bicarbonates and hydroxyl ions. Similar findings were reported by Raychaudhuri and Datt Biswas (1962) and Agarwal and Yadav (1954). The pH increased at the tail end of tank command area soils mainly due to increased clay and soluble salts of sodium carbonates and bicarbonates.

The soil pH was positively and significantly correlated with electrical conductivity ( $r = 0.528^{**}$ ) (Fig 4) and also with water soluble sodium ( $r = 0.758^{**}$ ), bicarbonates ( $0.697^{**}$ ), carbonates ( $r = 0.375^*$ ), chloride ( $r = 0.581^{**}$ ),

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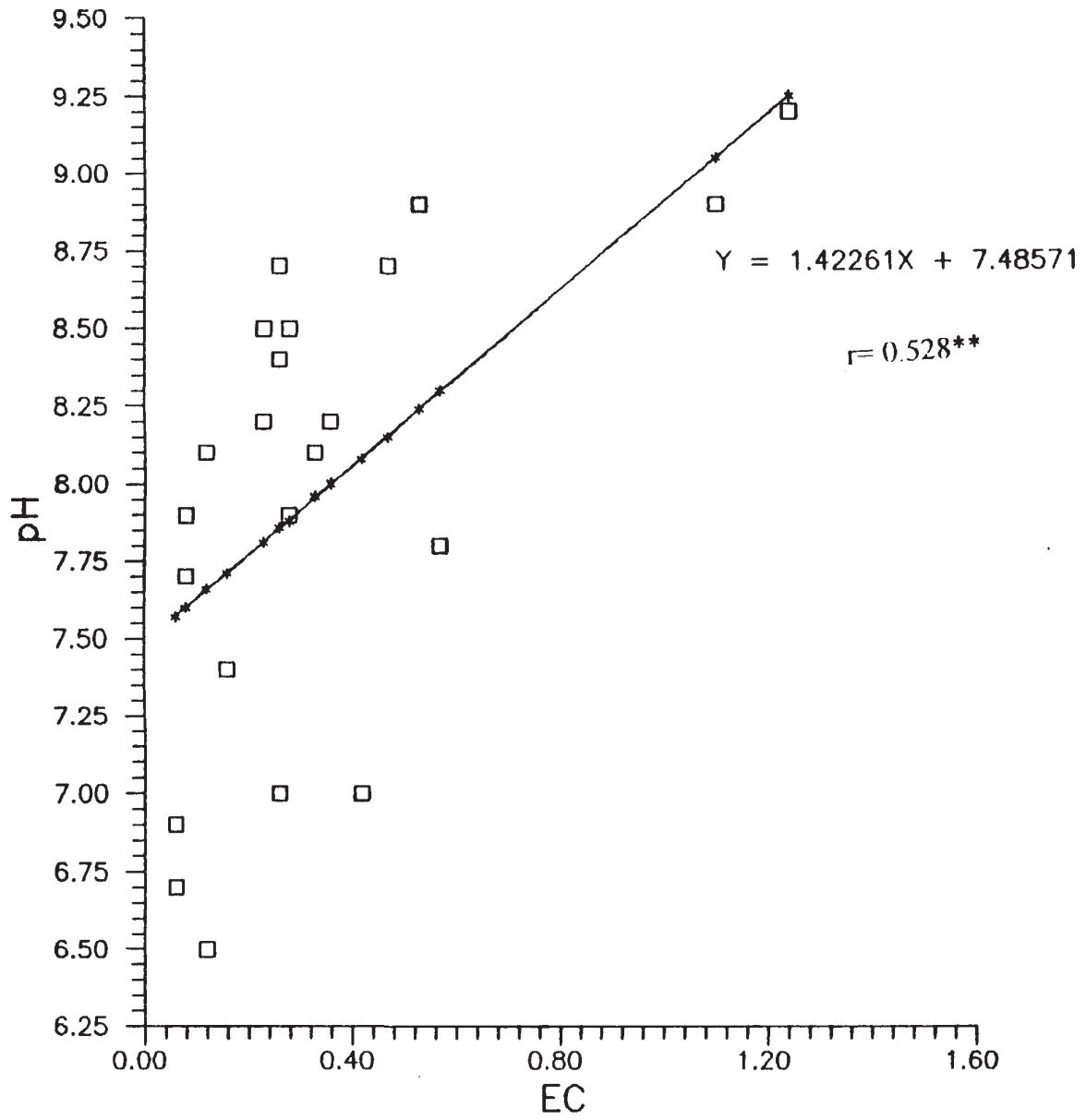


Fig.4. Relationship between pH and EC in soils

and SAR ( $r = 0.688^{**}$ ) indicating the increase in pH, with the increased concentration of these ions.

### 5.1.2 Electrical conductivity

Electrical conductivity values were very low and ranged from 0.06 to 1.24  $d\text{ Sm}^{-1}$ . The values increased with depth in soils of Hosadurga, Kudineerakatte and in soils near the tank bund areas in case of Kallambella and Bharamasagara, while it decreased with depth in the remaining soils. Increase in EC with depth may be due to movement of salts to lower horizons upon irrigation (Bhadrapur and Seshagiri Rao, 1976) and due to the impeded drainage as indicated by Poonia and Bhumbra (1973). The higher concentration of salts in the surface layer may be due to high water table, aridity and also due to upward movement of dissolved salts from the lowest horizon by capillary action upon irrigation. Similar findings were obtained by Medaritta *et al.* (1985), More *et al.* (1988), Bhadrapur and Seshagiri Rao (1976) and Parvathappa *et al.* (1990).

Vertisols recorded higher EC values compared to Alfisols which may be attributed to higher expanding type of clay resulting in lower hydraulic conductivity, in turn reducing downward movement of water and salts. Similar results were obtained by Lal and Singh (1974) and Parvathappa (1981).

EC of soils at tail end of the tank was higher than the soils near the tank bund in most of the soils studied except in Agraphara, Kithagali, Daramapura and Hirenallore soils. The increase in EC at tail end of tank may be due to the topography of the land and increased fineness of texture, increase in water table and more amount of tank irrigation water used during cropping period.

### 5.1.3 Organic Carbon

The organic carbon content decreased with depth in both Alfisols and Vertisols studied. Similar reports were made by Poonia and Bhumbra (1973), More *et al.* (1988) and Sen *et al.* (1997). The higher organic carbon in surface soil indicates, accumulation of organic matter.

The organic carbon content of soils was higher at the tail end of the tank compared to soils near the tank bund in most of the soils studied except in soils of Bharamasagara, Hosadurga and Kudineerakatte. The higher values at tail end of the tank may be due to increased clay content near tail end which resulted in increased crop growth, accumulation of roots and better decomposition of organic matter.

### 5.1.4 Alkaline earth carbonates (Calcium carbonate)

The calcium carbonate content was low in Alfisols compared to Vertisols. It increased with depth, both in Alfisols and Vertisols, which may be due to movement of calcium to lower layers and it precipitated as calcium carbonate upon light irrigation. The higher calcium carbonate content of soils at tail end of the tank compared to soils near the tank bund, may be due to increased carbonate and bicarbonates in soil solution, horizontal movement and precipitation as calcium carbonate. Similar reports are observed by Agarwal and Gupta (1968) Barde and Gowaikar (1965) and Kulkarni *et al.* (1963).

### 5.1.5 Cation exchange capacity

A perusal of the data (Table 4) on cation exchange capacity (CEC) of Alfisols and Vertisols indicates that the CEC was influenced by the amount and type of clay present in these soils. Alfisols had low CEC ranging from 15.0 to 24.0 c mole (P<sup>+</sup>) kg<sup>-1</sup>, while in Vertisols it varied from 26.5 to 39.8 c moles (P<sup>+</sup>) kg<sup>-1</sup>. Vertisols have high CEC because of presence of montmorillonite and vermiculite type of clays, while Alfisols contain predominantly kaolinite and sesquioxide which have low CEC (Raychauderi *et al.*, 1962). CEC increased with depth in most of the soils studied which is attributed to accumulation of finer fractions (clay) brought down by irrigation water (Illuviation). Similar reports were made by Kenchanna Gowda (1977), Bhadrapur and Seshagiri Rao (1977) and Srinath (1979).

In most of the soil bodies studied cation exchange capacity of the soils at the tail, end of tank was higher compared to soils near the tank bund, which is due to fine soil texture. High positive correlation between CEC and clay content ( $r = 0.781^{**}$ ) was observed as depicted in Fig 5. CEC positively and significantly correlated with ex-Ca ( $r = 0.944^{**}$ ), ex-Mg ( $r = 0.937^{**}$ ) and ex-Na ( $r = 0.724^{**}$ ).

### 5.1.6 Exchangeable cations

The dominant cations on the clay complex of these soils were calcium followed by magnesium, potassium and sodium, while sodium ranked third in Bharamasagara and subsurface layer of Daramapura soils. Bhadrapur and Seshagiri Rao (1977) and Bharambe *et al.* (1990) have indicated that exchangeable calcium and magnesium were higher than exchangeable sodium and potassium.

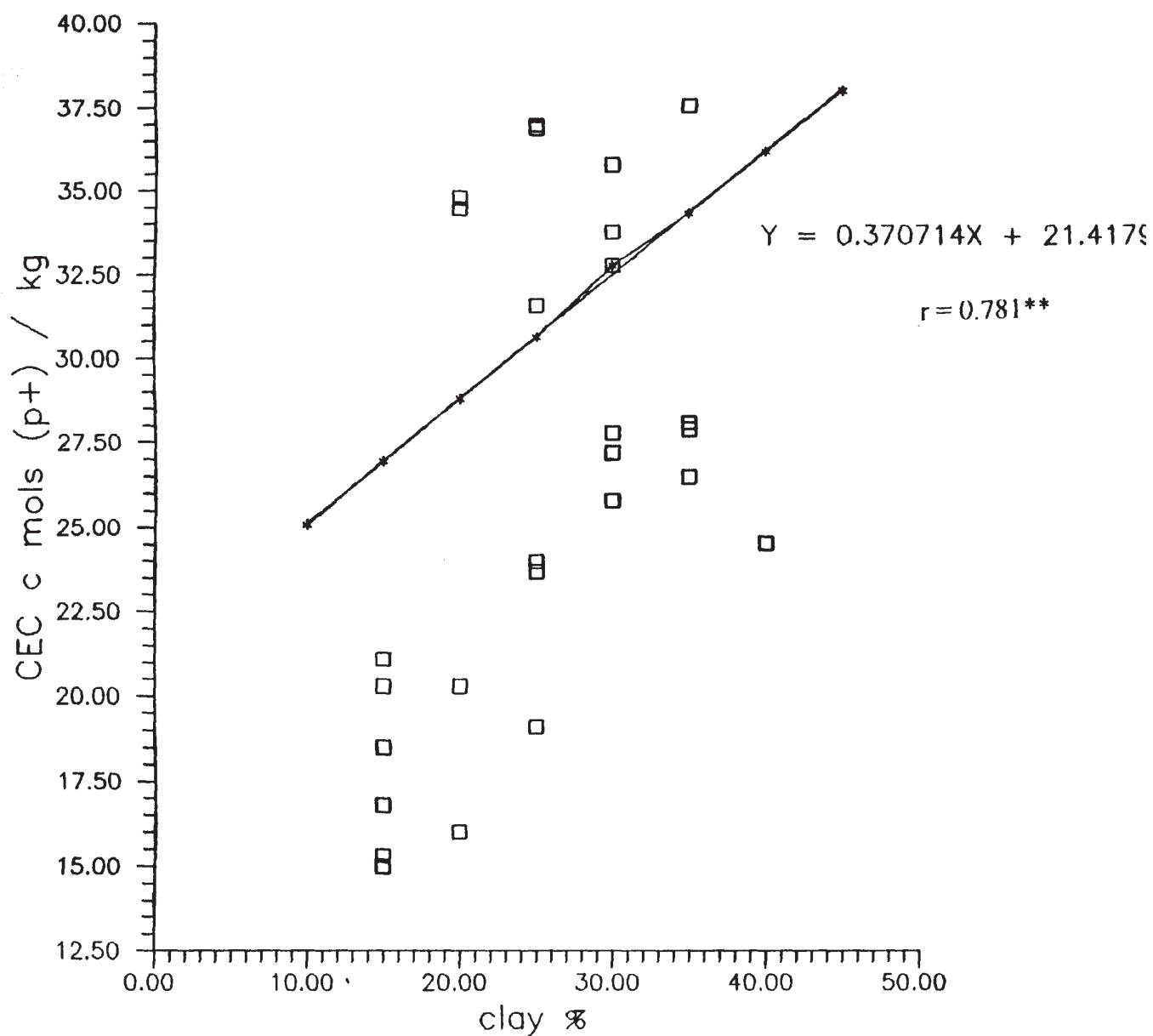


Fig.5. Relationship between CEC and clay % in soils

The exchangeable calcium and magnesium content was found to increase with depth in all the soils. Similar findings were reported by Paliwal and Maliwal (1971) and Parvathappa *et al.* (1990).

The exchangeable sodium content increased with depth in all the soil bodies. Similar findings were reported by Paliwal and Maliwal (1971) and Parvathappa *et al.* (1990). It was higher in Vertisols than in Alfisols which may be due to aridity and impeded drainage.

Exchangeable potassium content decreased with depth in all Alfisols and Vertisols. Similar reports were made by Sarma *et al.* (1997). The variation in K might be associated with the variations in clay and sand content of soil samples.

The exchangeable cations of the soils at tail end of the tank were higher compared to soils near the tank bund in most of the soils studied. It is mainly due to increase in the clay content in the tail end soils.

Correlation studies revealed that exchangeable calcium was highly and significantly correlated with magnesium ( $r = 0.840^{**}$ ) and exchangeable sodium ( $r = 0.735^{**}$ ).

#### **5.1.7 Exchangeable sodium percentage**

The exchangeable sodium percentage (ESP) increased with depth in all the Alfisols and Vertisols. Similar reports were made by Bhadrapur and Seshagiri Rao (1977), Srinath (1979) and Patak and Patel (1980).

Schoonover *et al.* (1957) reported that the ESP values increased with depth up to the zone of accumulation of clay which may be due to increased SAR with depth.

The higher ESP in most of the soils at tail end of the tank than soils nearer to tank bund may be due to increase in the clay content and also increase in the exchangeable sodium content of the soils which is due to rise in water table and accumulation of sodium. Exchangeable sodium percentage is positively correlated with exchangeable sodium ( $r = 0.760^{**}$ ) (Fig 6) and also with sodium adsorption ratio ( $R = 0.704^{**}$ ).

### **5.1.8 Water soluble ions**

#### **5.1.8.1 Water soluble cations**

The data pertaining to water soluble cations (Table 5) indicate sodium as dominant cation followed by calcium in most of the soils studied, while magnesium was least.

The water soluble calcium increased with depth in most of the soils studied except in Parashurampura, Bharamasagara and Kudineerakatte. The water soluble magnesium content increased with depth in most of the soils except in Bharamasagara and soils nearer tank bund in Kallambella, Kithagali and Kudineerakatte. Similar reports were made by Bhadrapur and Seshagiri Rao (1976). Poonia and Talibudden (1977), Srinath (1979) and Parvathappa *et al.* (1990). This may be due to the fact that the surface soils preferred calcium and magnesium more than corresponding subsoils which is mainly attributed to their surface charge density and organic matter content. The increase in calcium and magnesium at lower layers may be due to leaching of these ions with excess

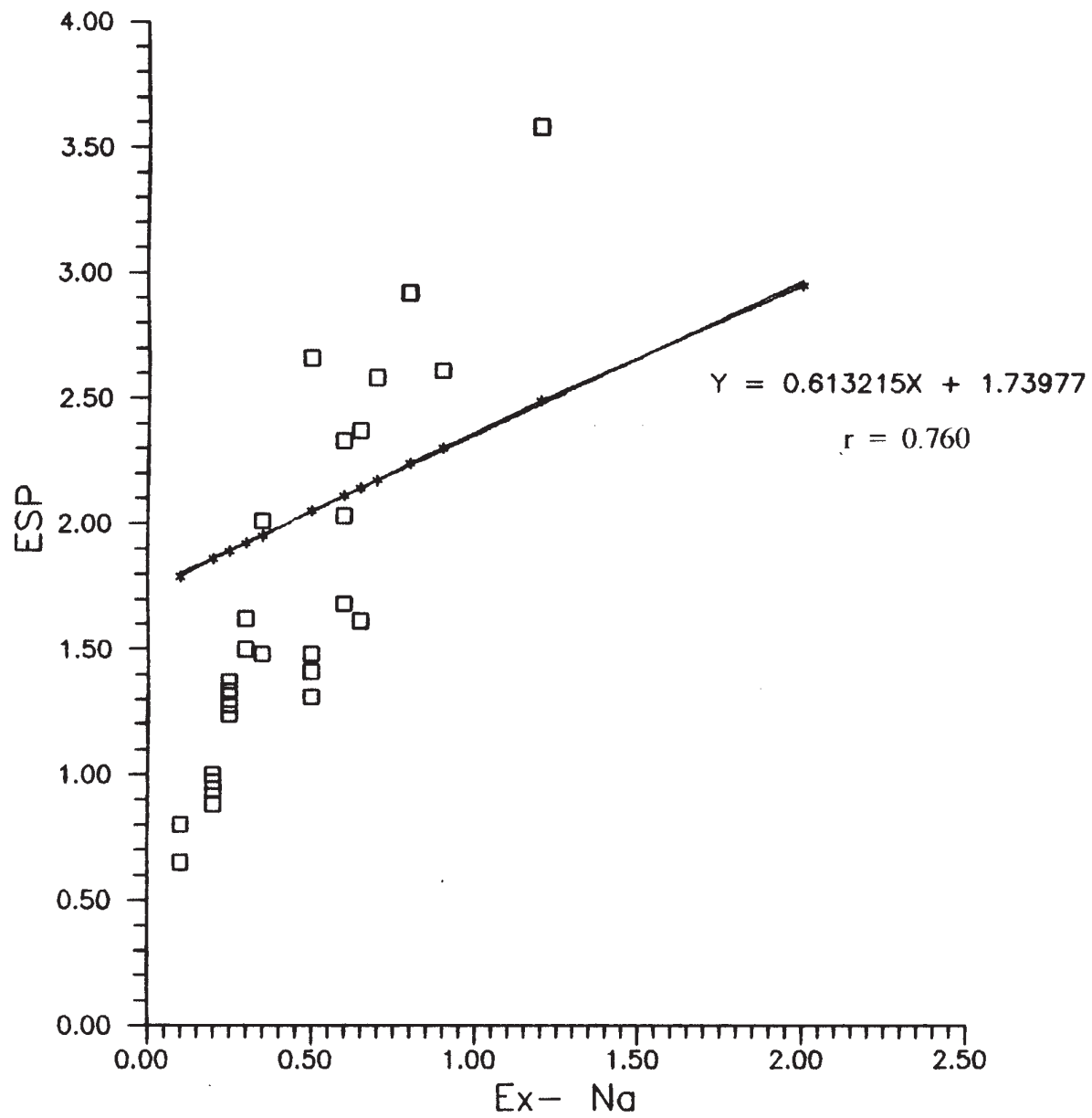


Fig.6. Relationship between ESP and Ex- Na in soils

irrigation water and its subsequent distribution in lower layer upon drying (Bob Cock *et al.*, 1959).

The water soluble sodium content decreased with depth in most of the soils studied except in Bharamasagara, Daramapura, Hosadurga and soils at tail end of tank in Hirenallore and soils nearer to tank bund in Agrahara Kudineerakatte where it increased with depth. The results were in consonance with the work of Patil and Venkata Rao (1965), Bhadrapur and Seshagiri Rao (1976) and Tiwari *et al.* (1983).

Accumulation of sodium in Alfisols is not much pronounced mainly because of the fact that soils have good drainage, low water table and sufficient water to leach excess salts. But Vertisols show higher accumulation of sodium. This may be due to low permeability and impeded drainage as the soils are heavy textured resulting in accumulation of salts in soils (Mruthunjaya, 1991).

The water soluble potassium decreased with depth in most of the soils except Agrahara soils. Similar observations made by Kalbande and Swamynatha (1976).

The water soluble cations content was high in soils at tail end of the tank compared to soils nearer tank bund in most of the soils studied, which may be due to increase in clay content and also excess irrigation water that brought down the cations from higher elevation to lower elevation (low land).

#### **5.1.8.2 Water soluble anions**

The data pertaining to water soluble anions (Table 5) indicate that bicarbonate is dominant in both Vertisols and Alfisols except in Nonavinakere

where sulphates were dominant, order of dominance being  $\text{HCO}_3^- \geq \text{Cl}^- \geq \text{SO}_4^{2-}$ . Water soluble carbonates were very low and were present only in Bharamasagara soils which are at tail end of the tank. Water soluble bicarbonates increased with depth in most of the Alfisols and Vertisols while it decreased with depth in soils of Kallambella and Kithagali and soils at the tail end in Parashurampura and Nonavinakere. Similar findings were reported by Bhadrappura and Seshagiri Rao (1976). Increase in bicarbonate with depth due to light and flood irrigation. However Bandyopadhyaya (1973) and Bhadrappur and Seshagiri Rao (1979) indicated that the distribution of bicarbonate was more or less same in lower layers as well as in surface layers.

The soluble chloride content decreased with depth in most of the soils except in Bharamasagara soils and soils which are near tank bund in Agrahara, Agarwal and Ramamurthy (1964). Talsma *et al.* (1980) reported that the accumulation of chloride on surface was due to evaporation and impervious nature of soil.

The sulphate content was low and decreased with depth in most of the soils studied except in Agrahara, Hosadurga soils near the tank bund and Parashurampura, Kudineerakatte at tail end of tank, Similar observations were reported by Chao *et al.* (1962). Higher concentration of sulphate in surface layers indicates the presence of sodium sulphate, which is easily soluble when compared to calcium and magnesium sulphates. Soil organic matter increased the sulphate adsorption, owing to positive charge on organic matter, and its amphoteric property. In some soils it increased with depth due to its low solubility and slower mobility of calcium and magnesium sulphates. (Kanwar and Sehgal (1962), Bhadrappur and Seshagiri Rao (1977) and Srinath (1979)).

The water soluble anions content was high in soils at tail end of the tank compared to soils near tank bund in most of the soils studied, this may be due to excess irrigation that brought down the anions in soluble form.

Correlation studies indicated that water soluble calcium positively and significantly correlated with water soluble magnesium ( $r = 0.560^{**}$ ).

Water soluble sodium positively correlated with sodium adsorption ratio ( $r = 0.969^{**}$ ), carbonates ( $r = 0.548^{**}$ ) and bicarbonate ( $r = 0.884^{**}$ ).

### **5.1.8.3 Sodium adsorption ratio**

Sodium adsorption ratio values decreased with depth in all Alfisols, Daramapura and Hirenallore among Vertisols, while in remaining soil bodies it increased with depth. The SAR decreased with depth, mainly due to decrease in the water soluble sodium content in lower layers, because of aridity and salts accumulated in surface layers. Where as in some soils it increased with depth due to illuviation and increase in water soluble sodium content in lower layers upon irrigation.

The study of sodium adsorption ratio and exchangeable sodium percentage of soils revealed that with increase in sodium adsorption ratio of soil exchangeable sodium percentage values also increased. These findings are in confirmation with Bhadrapur and Seshagiri Rao (1977), Parvathappa (1981) and Mruthunjaya (1991).

In some soils though sodium adsorption ratio were higher the ESP values were low, because of higher CEC of soils (Paliwal, 1972).

Sodium adsorption ratio of soils at tail end of the soil is higher than soils near tank bund in most of the soils studied, which is mainly due to increase in the water soluble sodium at tail end of tank command area soils.

Correlation studies revealed that significant positive correlation (7) between SAR and ESP ( $r = 0.704^{**}$ ).

## **5.2 Physical properties of soils**

### **5.2.1 Particle size distribution**

The data on particle size (Table 6) revealed that the texture of the soil ranged from loamy sand to clay.

The coarse sand content higher in surface layers as the process of elluviation carries down the finer particles to subsurface leaving behind coarser particles (Mruthunjaya, 1991).

The clay and silt content increased with depth in most of the soils. Similar findings were reported by Tiwari *et al.* (1983) and Dubey *et al.* (1984). Bhargava *et al.* (1973) observed accumulation of clay in lower layers upon irrigation which is attributed to movement of clay from surface to lower horizons along with rain or irrigation water, where as in black soils it may be due to pronounced inversion, cracking, self mulching and pulverising nature of soils.

The fineness of the texture increased at tail end of the tank soils compared to soils near tank bund which is due to transportation of finer particles with irrigation water and its subsequent settling in low land areas.

### **5.2.2 Rheological properties of soil**

#### **5.2.2.1 Lower plastic limit (LPL)**

The data pertaining to lower plastic limit (Table 7) reveals that the values increased with depth in most of the soils except in Agrahara soils at

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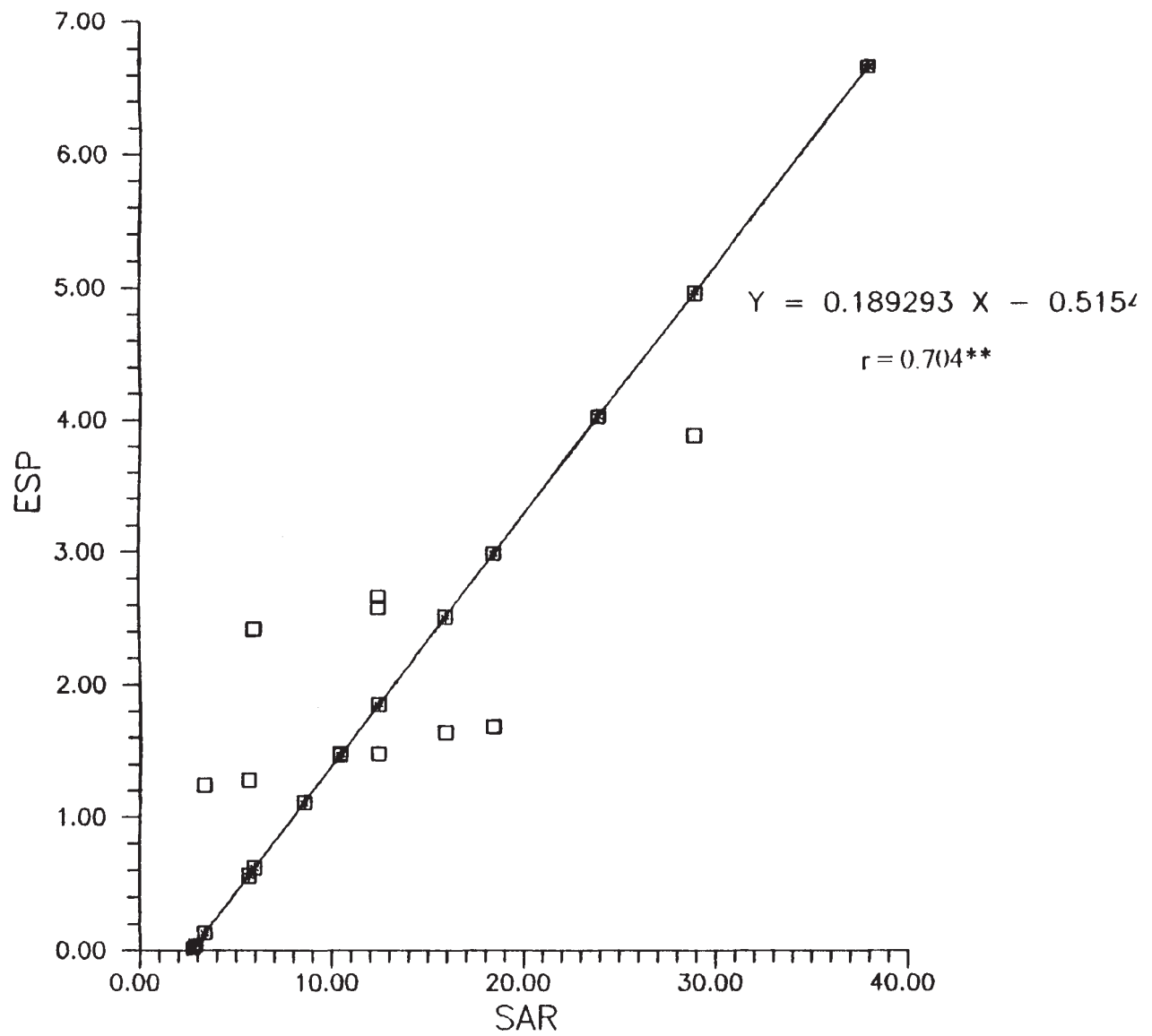


Fig.7.Relationship between ESP and SAR in soils

tail end of the tank and in Daramapura near tank bund where it decreased with depth. The LPL values increased with depth, mainly due to increase in clay content of soil in sub surface soils. The above results are in confirmation with the findings of Raghu Kumar (1977). The LPL showed significant positive correlation with clay ( $r = 0.786^{**}$ ) and CEC of soil ( $r = 0.506^{**}$ ).

#### **5.2.2.2 Upper Plastic Limit (UPL)**

The data pertaining to upper plastic limit (Table 7) shows that the values increased with depth in all the soils studied which is mainly due to increase in the clay content in lower layers. These results are in confirmation with the findings of Raghu Kumar (1977). A significant positive correlation was obtained between UPL and clay content ( $r = 0.753^{**}$ ) and CEC of soil ( $r = 0.527^{**}$ ).

#### **5.2.2.3 Plasticity Index**

The data pertaining to plasticity index (Table 7) reveals that plasticity index increased with depth in most of the soils studied and it is positively and significantly correlated with clay content ( $r = 0.688^{**}$ ) and CEC of soil ( $r = 0.508^{**}$ ) the above results are in confirmation with the findings of Baver (1930) and Raghu Kumar (1977).

All the Atterberg's limits are higher for vertisols compared to Alfisols and also increased with depth may be due to increased exchangeable calcium and magnesium content of soil and fineness of soil texture (Baver, 1930).

#### 5.2.2.4 Sticky point moisture

The sticky point moisture values increased with depth in all soils which is mainly due to increase in clay content. A significant positive correlation was observed between sticky point moisture and clay content ( $r = 0.872^{**}$ ) and sticky point moisture and CEC of soils ( $r = 0.472^{**}$ ). These results are in confirmation with findings of Baver (1930) and Raghu Kumar (1977).

Rheological properties such as LPL, UPL, PI and SPM are higher in soils at tail end of tank than near the tank bund which is due to increase in the clay content of soils.

#### 5.2.3 Hydraulic conductivity

The data pertaining to hydraulic conductivity in Table 7 reveals that, it decreased with depth in all the soils studied. Alfisols recorded higher hydraulic conductivity values compared to Vertisols and these results are in confirmation with the findings of Kovda *et al.* (1973). The lower conductivity in Vertisols may be due to high exchangeable sodium values which resulted in dispersion and clogging of pores by clay particles. The main reason for low hydraulic conductivity and its reduction with depth in Vertisols can be attributed to the sodiumization and increased clay content with depth. Harding *et al.* (1958) reported that hydraulic conductivity decreased with increase in the fineness of texture.

Kovda *et al.* (1973) reported that the increase in ESP values would cause swelling, dispersion and migration of soil colloids in soil profiles with concurrent blocking of pores which lowered hydraulic conductivity.

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The HC increases with increasing soluble salt concentration as divalent cations ( like  $Ca^{++}$ ) in the soil solution bring about flocculation after adsorption consequently increasing HC (Quirk and Schofield, 1955).

Soils near tank bund have higher hydraulic conductivity than soils at tail end of the tank which is due to increase in the clay content at the tail end of the tank compared to near tank bund soils.

Correlation studies revealed that hydraulic conductivity significantly and positively correlated with coarse sand ( $r = 0.719^{**}$ ) and negatively correlated with clay ( $r = -0.803^{**}$ ), ESP ( $r = -0.456^{**}$ ) (Fig 8), pH ( $r = -0.549^{**}$ ) and EC ( $r = -0.372^{**}$ ).

#### **5.2.4 Mean weight diameter**

The mean weight diameter values which is an indication of aggregation, decreased with depth both in Alfisols and Vertisols, Alfisols recorded higher mean weight diameter values compared to Vertisols. These results are in confirmation with the findings of Bharambe *et al.* (1990) on Jaykwadi command area soils which they reported to be due to higher amount of sesquioxides in Alfisols than in Vertisols.

Kovda *et al.* (1973) reported that the irrigated conditions favour the accumulation of organic matter at the surface. The stability of soil aggregates is profoundly influenced by organic matter and exchangeable calcium content and irrigation is also responsible for dispersion of humus and leaching of salts and would tend to dissipate one or both of these soil resources in the profile.

The mean weight diameter of all surface soils are higher compared to lower layers which may be because of presence of organic matter and

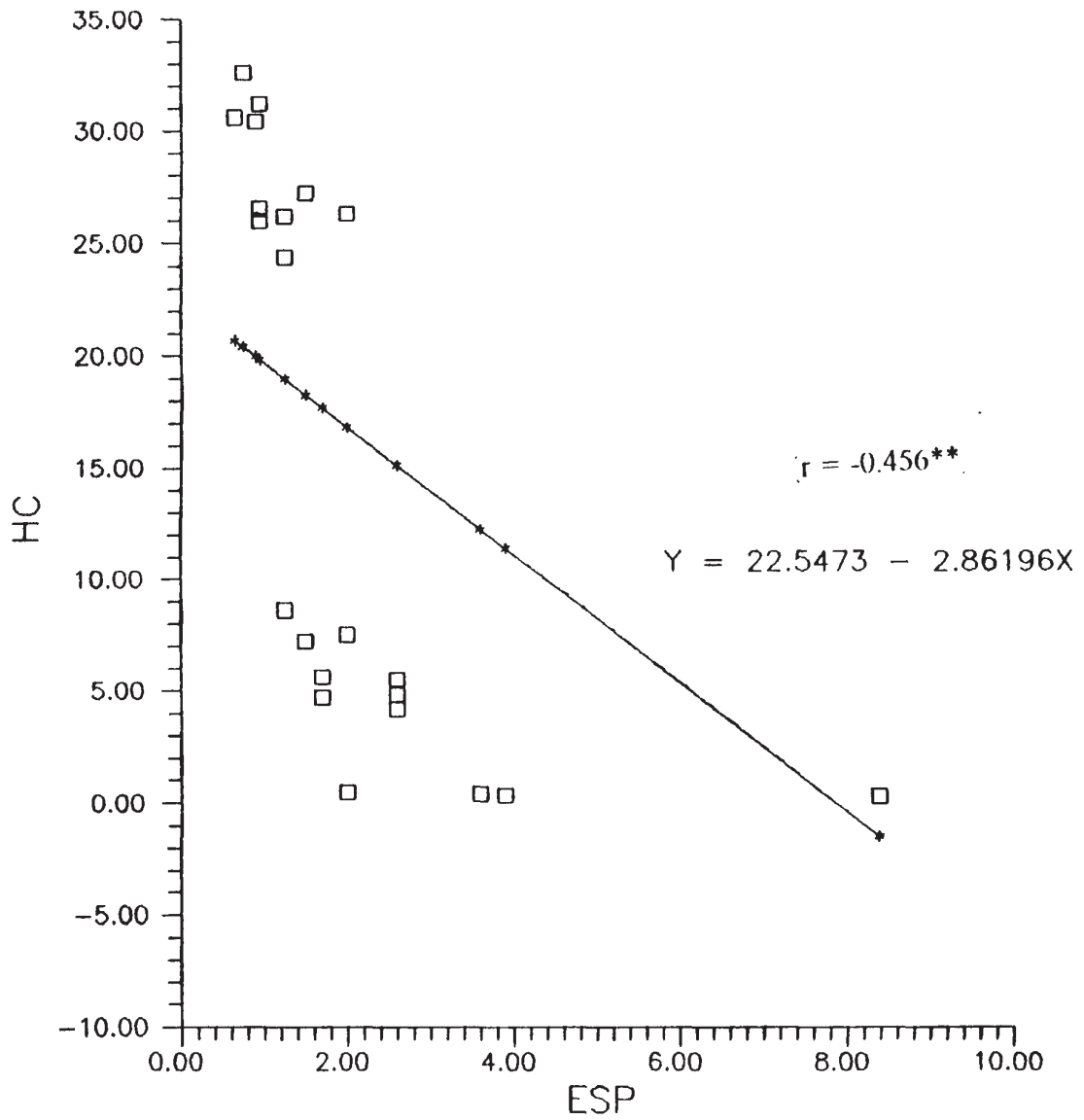


Fig.8.Relationship between HC and ESP in soils

binding roots of crop plants. These results are in confirmation with the findings of Kovda *et al.* (1973) and Kenchanna Gowda (1977). Mean weight diameter of both Alfisols and Vertisols decreased with increase in ESP of soil and SAR of soil solution. Similar reports were made by Gangappa (1989) and Satish Rao (1989).

The mean weight diameter of tail end tank command area soils were lower compared to soils near the tank bund which is mainly due to increase in the sodium content of the soil and raise in water Table.

Correlation studies reveal that, mean weight diameter negatively correlated (Fig. 9) with exchangeable sodium percentage ( $r = -0.259$ ).

### 5.3 Quality of irrigation water

The pH of all the irrigation waters were neutral to slightly alkaline which is mainly due to low ionic concentration. Among cations calcium was the dominant ion followed by magnesium, sodium and potassium, while among anions chloride was dominant followed by sulphate and bicarbonates. The total ionic population is very low in most of the water studied. The examination of cationic and anionic composition of irrigation water (Table 8) indicate that in general these ions are, with in safer limit. The SAR and RSC values are low except in Bharamasagara and Daramapura (Asgar and Dhawan, 1947 ; Agarwal and Mehrotra, 1952). The boron content of the different water samples were below 0.5 ppm (Puttaswamy Gowda *et al.*, 1968) within the critical limit. Hence they can be used for irrigation with little management. Most of the irrigation waters come under  $C_2S_1$  class except Bharamasagara and Daramapura which are in  $C_3S_1$  class as per U.S.S.L. Staff 1954 classification and these water can be used with proper care. These results are in confirmation with the findings of Landey and

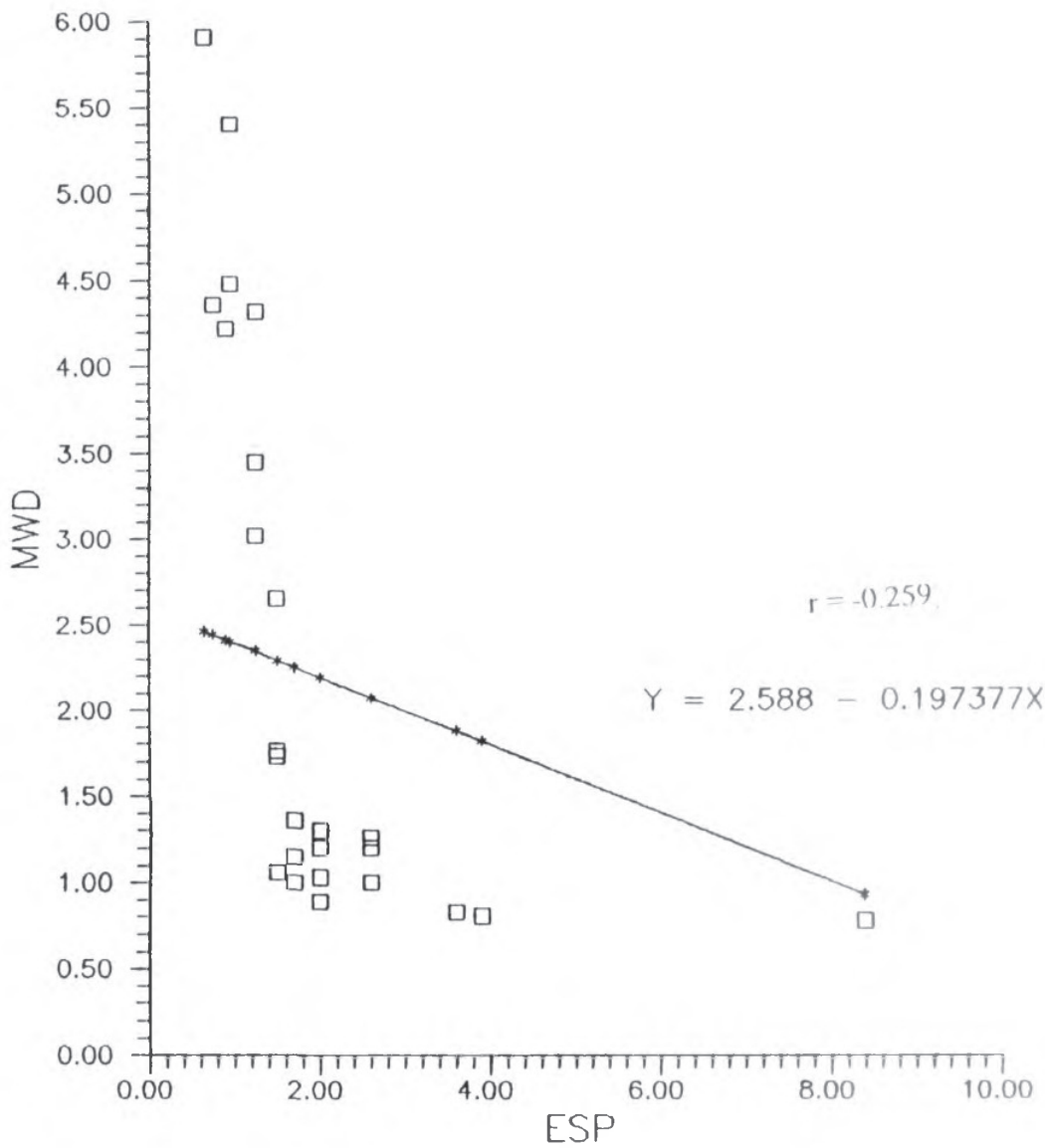


Fig.9. Relationship between MWD and ESP in soils

Murthy (1967), Govinda Rajan *et al.* (1968), Perur (1971) and Parvathappa (1981).

#### **5.4 Effect of anions on exchangeable cations and exchangeable sodium percentage of soils**

The relationship between SAR of equilibrium solutions and ESR of different soils are given in Table 11.

Graphical representation of the relationship between the SAR and ESR were shown in figures (10a, 10b, 10c and 10d).

Distinct differences between sulphate and chloride systems are observed in all cases. More sodium is adsorbed at the same values of SAR in sulphate system than in chloride system in both Kallambella and Hosadurga soils at both depths. The differences are larger at higher values of SAR that correspond to more concentrated solution may be due to there is no possibility of ion-pairing in chloride system and thus there is no need to make any allowance for the same ions while in contrast alkaline earth metals have a strong tendency to form ion-pair with sulphate. The ion-pairs behave as neutral molecules. This is in agreement with similar observations made earlier by Longenecker (1960), Dutt and Doneen (1963), BobCock and Schultz (1963).

Ion pairing between sulphate, calcium and magnesium encourage inactivation of calcium and magnesium, there by increasing activity of sodium in soil solution which in turn encourages adsorption of Na on clay complex resulting in higher ESP/ESR values in sulphate system than in chloride system (Seshagiri Rao 1967).

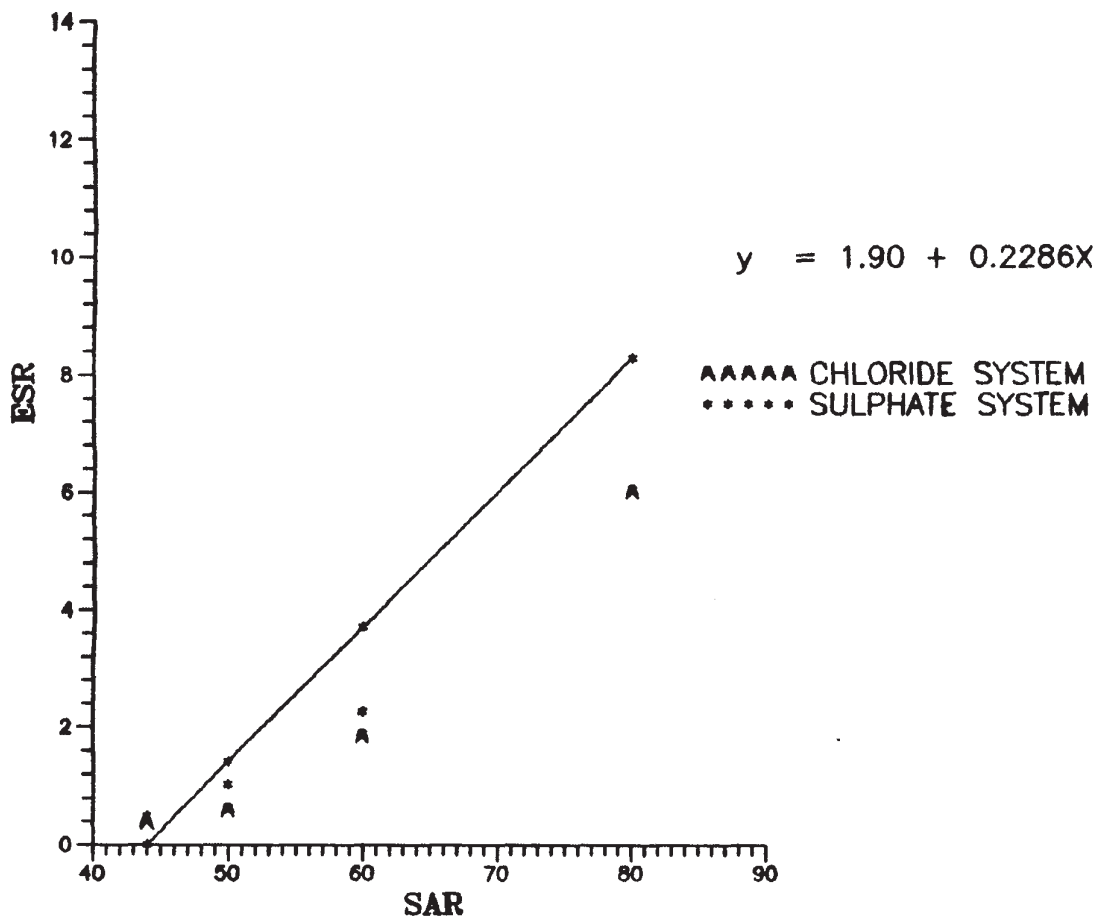


Fig.10a.RELATIONSHIP BETWEEN 'SAR' AND ESR IN KALLAMBELLA SOILS (0 -15cm DEPTH)

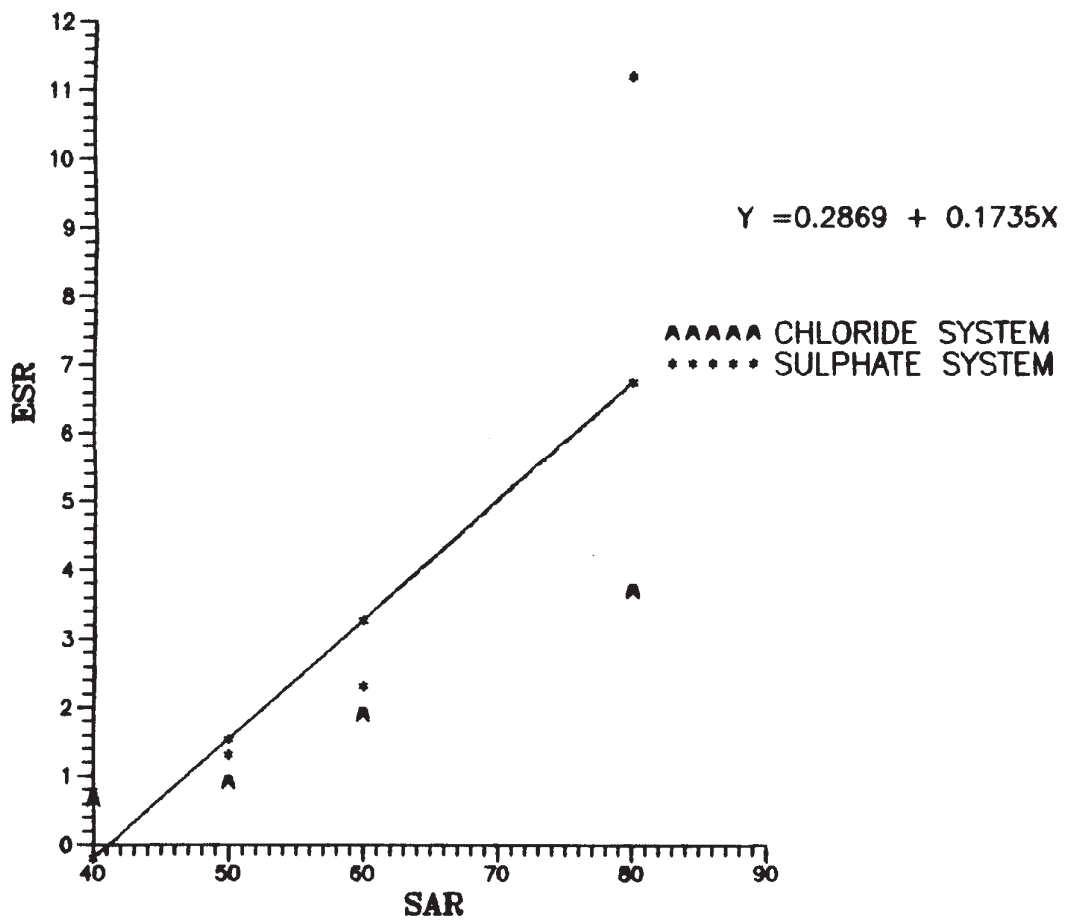


Fig.10b.RELATIONSHIP BETWEEN 'SAR' AND ESR IN KALLAMBELLA SOILS (15 -30cm DEPTH)

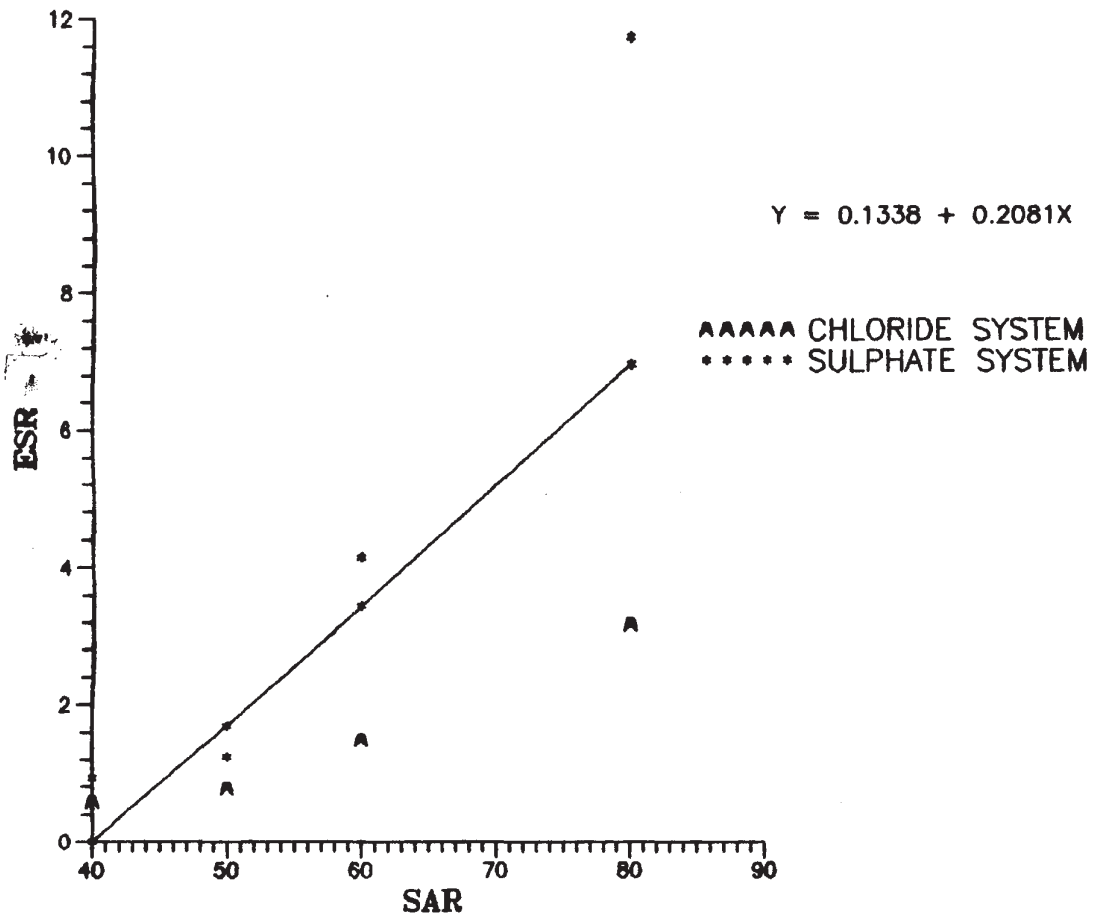


Fig.10c.RELATIONSHIP BETWEEN SAR AND ESR IN HOSADURGA SOILS (0 -15cm DEPTH)

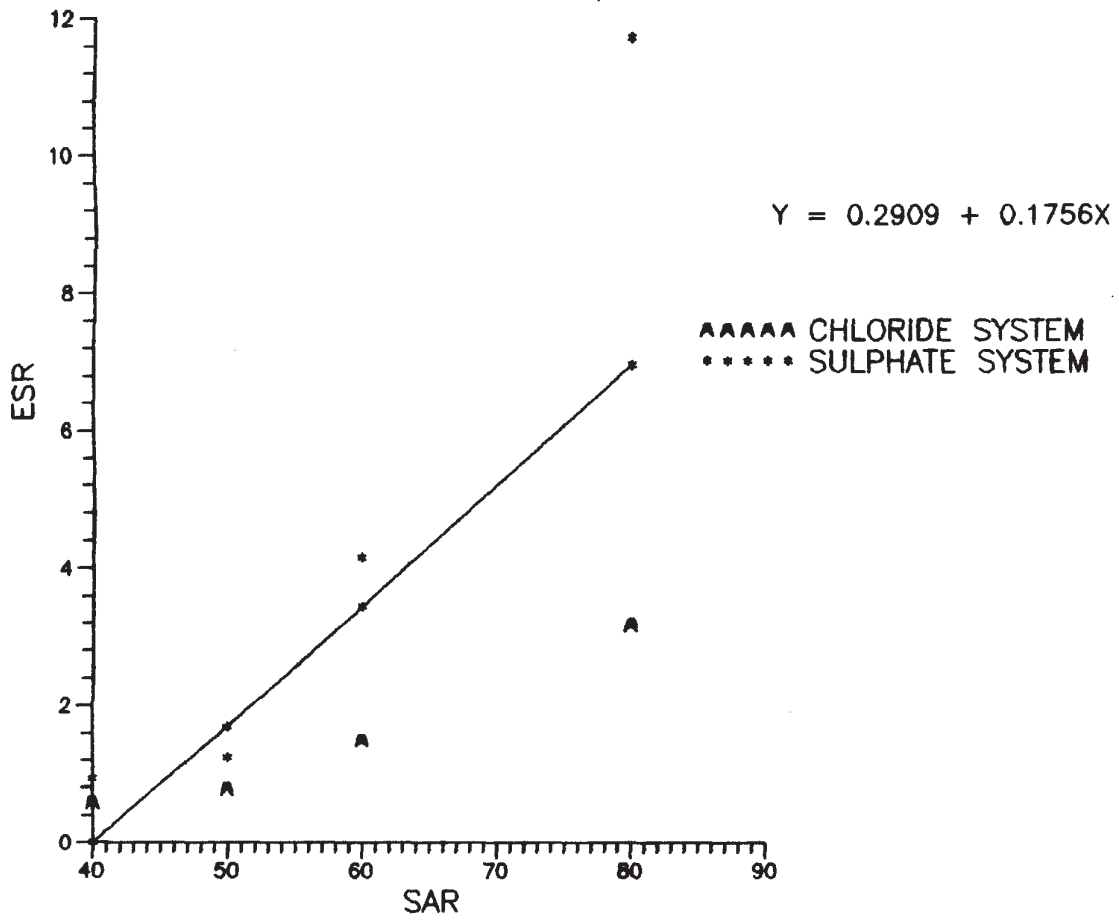


Fig.10d. RELATIONSHIP BETWEEN SAR AND ESR IN HOSADURGA SOILS (15 -30cm DEPTH)

# **SUMMARY**

## VI SUMMARY

In recent times great impetus have been given to irrigation to boost the production of food for the teeming million. In many places the world over, the practice of irrigating agricultural lands has not only enhanced agricultural production but also modified the environment. Most of the soils became saline and sodic in irrigated areas. In an effort to assess the extent of salinity and alkalinity hazard in some tank command area soils in central dry zone of Karnataka. Alfisols and Vertisols were studied for physico-chemical properties. The salient findings of the study are listed below:

Soils of the area are alkaline in reaction except in Agrahara soils where it is acidic and the values increased with depth except in Kallambella, Parashurampura, Nonavinakere and Bharamasagara soils. Vertisols recorded higher pH values compared to Alfisols.

Electrical conductivity values are low in both Alfisols and Vertisols and are within safer limit for crop growth. The variation in EC values in the horizon does not show any specific trend.

Organic carbon was medium to high and decreased with depth in all the soils.

Lime (Calcium carbonate) was found in traces in surface layers and abundantly present in sub surface layers in most of the soils studied.

Alfisols recorded lower CEC compared to Vertisols and the values increased with depth in all soil bodies.

In both Alfisols and Vertisols studied exchangeable calcium was the dominant cation in exchange complex and it increased at lower depth along with magnesium and sodium while potassium decreased at lower depth.

ESP values increased with depth in most of the soils and were less than 15. However it decreased with depth at tail end of tank in Hosadurga soils.

The water soluble cations revealed that, the sodium was dominant cation followed by calcium, potassium and magnesium. Among anions bicarbonate and chloride were dominant followed by chloride and sulphate. Carbonate was absent in most of the soil bodies studied.

Sodium adsorption ratio values were higher and decreased with depth in most of the soils studied except in Bharamasagara soils, where it increased with depth.

The soil pH, electrical conductivity, organic carbon, calcium carbonate, CEC, exchangeable cations, ESP, water soluble cations, and anions and SAR were higher at tail end of the tank command area soils than soils nearer the tank bund.

Texture of Alfisols varied from sandy loam to clay loam, where as that of Vertisols from silt loam to clay. Fineness of the texture increased with depth both in Alfisols and Vertisols.

Atterberg's limits were found to be closely correlated with clay content and CEC of soils. The values were higher for Vertisols compared to Alfisols.

The Alfisols recorded higher hydraulic conductivity compared to Vertisols and the values decreased with depth in most of the soils studied.

In both Alfisols and Vertisols the mean weight diameter values decreased with depth and Alfisols recorded higher mean weight diameter compared to Vertisols.

The fineness of texture and Atterberg's limits were found to be higher in soils at tail end of the tank command area, while hydraulic conductivity and mean weight diameter values were lower in soils near the tank bund.

The irrigation water analysis indicated that most of the irrigation water belong to  $C_2S_1$  class except Bharamasagara and Daramapura which belong to  $C_3S_1$  class. Waters can be used for irrigation with good management practices and drainage system.

The soils irrigated with tank waters for a long time shows higher values of exchangeable sodium percentage (ESP), sodium adsorption ration (SAR) and water soluble sodium content compared to soils irrigated for shorter period both in Alfisols and Vertisols.

The relation of SAR with ESP indicate that at equal values of SAR more sodium was adsorbed in sulphate system than in chloride system. The differences of ESP were larger at higher values than at lower values of SAR.

## **REFERENCES**

## VII REFERENCE

- Abrol, I.P. and Bhumbra, D.R., 1968. Moisture retention and storage Characteristics of some Hissar Soils. Proc. Symp. Water Management, *Indian Soc. Agron.*, New Delhi pp. 9-17.
- Abusharar, T.M., Bingham, F.T. and Rhoades, J.D., 1987, Reduction in Hydraulic Conductivity in Relation to Clay Dispersion and Disaggregation. *Soil Sci. Soc. Amer. J.*, **51** : 342-346.
- Agarwal, R.R. and Mehrotra, C.L., 1952, Soil survey and Soil work in U.P., Supdt. Print and Stat. U.P. Allahabad. Vol. 2. pp. 294.
- Agarwal, R.R. and Yadav, J.S.P. 1954. Saline and Alkali Soils of the Indian Gangetic Alluvium in Uttar Pradesh. *J Soil Sci* **5**, 300.
- Agarwal, R.R. and Yadav, J.S.P., 1956, Diagnostic Techniques for the Saline and Alkali Soils of the Indo-Gangetic Alluvium in Uttar Pradesh. *J Soil Sci.*, **7** (1) : 109-121.
- Agarwal, R.R., 1959, Potential and Economic aspects of utilization of saline Alkali Soils. *Proceedings of Simla seminar on recent advances in Agronomy and Soil Science*. I.C.A.R., New Delhi.
- Agarwal, R.R. and Gupta, R.N., 1968, Saline Alkali Soils in India, I.C.A.R., New Delhi, pp. 221-225.
- Agarwal, R.P. and Ramamoorthy, B., 1970, Morphological and Chemical Characteristics of Alkali and Normal Soils from Black and Red Soils of India. *Geoderma.*, **4** : 403-415.
- Agrawal, G.K. and Tripathi, B.K., 1974, The Applicability of some Soil properties as Measure of Exchangeable Sodium for salt Affected Soils of Uttar Pradesh. *J. Indian Soc. Soil Sci.*, **22** (1) : 43-46.
- Ahmed, A., Swindale, L.D. and El-Swartz, S.A., 1969, Effect of adsorbed Cations on physical properties of tropical Red earths and tropical black earths. *J. Soil Sci.*, **20** : 255-268.
- Ahmed, I.U. and Shafiqur Rahaman, 1986, Note on Soil and Water Characteristics of some saline area of Bangla Desh. *Curr. Agri.*, **10** : 99-101.

- \* Ambadas Rao, 1969, Detailed report of Re-Survey of sugarcane growing area in Visvesvaraya canal tract, Mandaya, Mysore state, Department of agriculture, Mysore state.
- Anonymous, 1990, Status Report. Directorate of Research, *Univ. Agri. Sci.*, Bangalore. Vol. 1-3.
- Asgar, A.G. and Dhawan, C.L., 1948, Quality of irrigation Water. Effect of pH and Exchangeable bases of Soils. *J. Indian Chem. Soc.*, **25** : 179-184.
- Badiger, M.K., Manjunathaiah, H.M. and Venkata Rao, B.V., 1969, High Salt Water as a Reclaimant for Alkali Soils of Mysore state. *Mysore j. agric. Sci.*, **3** ; 449-454.
- Bandyopadhyaya, A.K., 1973, Studies on Depth and Quality of Water on Soil Salination. Behavior of Anions in the Soil profiles with Reference to the Position of Water Table. *J Indian Soc. Soil Sci.*, **21** : 485-489.
- Barde, N.K. and Gowaikar, A.S., 1965, Studies on Soils of semi arid Region of North Gujarath. *J Indian Soc. Soil Sci.*, **13** : 43-52.
- \* Bareley, K.P. and Tisdall, A.L., 1959, Effect of flood irrigation and plant growth on two riverine Soils. *Aust. J. Agric. Res.*, **10** : 510-517.
- Baver, L.D., 1930, The Atterberg's constants. affecting their value and new concept of their significance. *J. Amer. Soc. Agron.*, **22** : 935-948.
- \* Bayko Elisabeth and Bayko Hugo, 1966, The desertgardent of eilent since its foundation. Proc. Inter. Symp. on irrigation with highly saline Water and sea Water with and without desalinization in WAAS series, Vol. IV.
- Bhargava, G.P., Datta Biswas, N.R. and Govinda Rajan, S.V., 1973, Studies on Tungabhadra Catchment Soils II PhysicoChemical Properties and Soil Taxonomy. *J. Indian Soc. Soil Sci.*, **21** : 193-203.
- Bharambe, P.R., Awasarmal, B.C., Ambegaonkar, P.R. and Rodge, R.P., 1990, Characterisation of Soils in Relation to Irrigation in Jayakwadi command Area. *J. Indian Soc. Soil Sci.*, **38** : 488-494.
- Bhadrapur, T.G. and Seshagiri Rao, T., 1976, Salt distribution in Irrigated Black Cotton Soils. *Mysore J. agric. Sci.*, **25** : 11-17.

- Bhadrapur, T.G. and Seshagiri Rao, T., 1977, Salt Affected Soils. Chemical Characteristics and Sodium, Divalent Cation Exchange Relationships. *J Indian Soc. Soil Sci.*, **25** : 11-17.
- Bhadrapur, T.G. and Seshagiri Rao, T., 1979, The Effect of Seepage and Water logging on the Development of Saline and Sodic Soils in Tungabhadra Project Area of Karnataka. *J Indian Soc. Soil Sci.*, **27** : 408-413.
- \* Binder- Barhava, N. and Ravikovitch, S., 1952, Adsorption of Na by Soils from solutions of Na salts. *Soils and Ferti.*, **16** : 2077.
- Black, C.A., 1965a, Methods of Soil analysis, part-I Agronomy monograph, No.9, *Amer. Soc. Agron. Medison. Wisconsin.*, p. 770.
- Black, C.A., 1965b, Methods of Soil analysis part 2. Agronomy monograph, No. 5. *Amer. Soc. Agron., Medison. Wisconsin.*, p. 1572.
- Bob Cock, K.L. and Schultz, R.K., 1963. Effect of Anions on the Sodium-Calcium Exchange in Soils. *Soil Sci. Soc. Amer. Proc.* **27** : 630-632.
- Bob Cock, K.L., Calson, R.M., Schultz, R.K. and Over Street, R., 1959, A study of the effect of the irrigation Water composition on Soil properties. *Hilgardia*, **29** : 155-169.
- Boltania, N.I., 1959, The effect of irrigation on the nutrient regime of calcaussian chernozems, *pochvovedeniye*, **1** : 40-50.
- Chandrasekharan, H., Yadav, B.R., Tomar, S.P.S. and Sarma, P.B.S., 1994, Studies on Salinity and Water Content of Soils-Geoelectrical Approach. *J. Indian Soc. Soil Sci.*, **42** : 430-436.
- Chao, T.T., Haward, M.E. and Fang, S.C., 1962, Movement of S<sup>35</sup> Tagged Sulfate Through Soil Columns. *Soil Sci. Soc. Am. Proc.*, **26** : 27-32.
- Chesters, G., Attoe, O.J. and Allen, O.N., 1957, Soil Aggregation in relation to Various Soil Constituents. *Soil Sci. Amer. Proc.*, **21** : 272-277.
- Dixit, V.K. and Lal, R.N., 1972, Effect of Exchangeable Sodium on Hydraulic Conductivity of Soils. *J Indian Soc. Soil Sci.*, **20** : 1-5.

- Dixit, V.K. and Mir, S.U., 1985, Note on effect of Exchangeable Cations on hydraulic conductivity of some Soils of Uttar Pradesh, *Curr. Agri.*, **9** : 91-94.
- Dubey, D.D., Sharma, O.P. and Shila, P.K., 1984, Formation and Taxonomy of salt Affected Aridisols. *J Indian Soc. Soil Sci.*, **32** : 146-149.
- Dubey, D.D. and Sharma, O.P., 1987, Characteristics and Classification of Coastal Salt Affected Soils. *J Indian Soc. Soil Sci.*, **34** : 712-717.
- Dutt, G.R. and Doneen, L.D. 1963. Predicting the Solute Composition of the Saturation Extract from Soils Undergoing Salination. *Soil Sci. Soc. Amer. Proc.* **27** : 627-630.
- Eaton, F.M., 1950, Significance of Carbonates in Irrigation Waters. *Soil Sci.*, **69** : 123-133.
- Edward, A.P. and Bermner, J.M., 1967, Micro-aggregates in Soil. *J. Indian Soc. Soil Sci.*, **18** : 64-73.
- El-Swaify, S.A. and Swindale, L.D., 1970 Effects of Saline Water on the Chemical Properties of Some Tropical Soils. *Soil Sci. Sci. Amer. Proc.*, **34** : 207-211.
- El-Seewi, Ahmed, A., El-Attar, H.A and Danod, A.M., 1977, Relationship Between Soluble and Exchangeable Sodium in Some Soils of the Nile Delta : An Examination of SAR Concept. *Soil Sci.*, **124** : 249-252.
- \* Emmerson, W.W. and Bakker, A.C., 1973, The Comparative effect of Exchangeable calcium, magnesium and sodium on some physical properties of red-brown earth subSoils. The Spontaneous Dispersion of Aggregates in Water. *Aust. J. Soil Res.*, **11** ; 151-157.
- Gangappa, P.V., 1989, Nature of salt affliction in salt Affected Soils of Challakere Taluka, Chitradurga district. *M.Sc. (Agri.) Thesis*, Univ. Agril. Sci., Bangalore.
- Girdhar, I.K. 1996. Effect of Leaching with Waters of Varying Residual Sodium Carbonate, SAR and Electrolyte Concentration on Properties of a Haplustalf. *J Indian Soc. Soil Sci.* **44** : 495-499.

- Govinda Rajan, S.V., Murthy, R.S. and Venugopal, K.R., 1968, *Radical transformation in the profile morphology and chemistry of a granite gneiss derived Soil by irrigation and management* proceedings, Sir M. Visvesvaraya memorial Tech. Seminar on Soil and Water management, 23-25 Dec., 1968, pp 19-25, Institution of Engineers (India), Bangalore.
- Gupta, I.C. and Abhichandani, C.T., 1970, Seasonal Variation in Salt Composition of Some Saline Water-Irrigation Soils of Westren Rajasthan. *J. Indian Soc. Soil Sci.*, **18** : 429-435.
- Gupta, R.K., Bhumbla, D.K. and Abrol, I.P., 1985, Release of Exchangeable Sodium from Alkali Soil upon Amendment Application. Role of variable Charge and Exchangeable Cation hydrolysis. *Soil Sci.*, **139** : 312-318.
- Gupta, R.K., Singh, C.P. and Abrol, I.P., 1985, Determining CEC and Exchangeable Sodium in Alkali Soils. *Soils Sci.*, **139** : 326-332.
- Hamid, K.S. and Mustafa, M.A., 1975, Dispersion as an Index of Relative Hhydraulic Conductivity in Salt Affected Soils of Sudan. *Geoderma*, **14** : 107-114.
- Harding, R.B., Pratt, P.F. and Jones, W.W., 1958, Changes in salinity nitrogen and Soil reaction in a differentially fertilized irrigated Soil, *Soil Sci.*, **85** : 177-184.
- \* Helfferich, F. 1962 Ion Exchange. Mc Graw Hill series in Advanced Chemistry New York. 624p.
- Jackson, M.L., 1973, *Soil Chemical analysis*, Asia Publishing House, New Delhi, P. 448.
- Jain, B.L. and Saxena, S.N., 1970, Distribution of Soluble Salts and Boron in Soils in Relation to Irrigation Water. *J. Indian Soc. Soil Sci.*, **18** (2) : 175-182.
- Kalbande, A.R. and Swamynatha, R., 1976, Charactrisation of Potassium in Black Soils Developed on Different Parent Materials in Tungabhadra Catchment. *J Indian Soc. Soil Sci.* **24** : 290-296.
- Kanwar, J.S. and Singh, S.S., 1961, Boron in normal and Saline-Alkaline Soils of the irrigated Soils of the Punjab. *Soil Sci.*, **92** : 207-209.

- Kanwar, J.S. and Sehgal, J.L., 1962, Classification of Saline Sodic and Normal Soils of Karnal District. *J Indian Soc. Soil Sci.*, **10** : 19-25.
- Kanwar, J.S., Sehgal, J.L. and Bhumbra, D.R., 1963, Relationship Between Some Indices of Saline Sodic Soils. *J Indian Soc. Soil Sci.*, **11** : 39-44.
- Kanwar, J.S. and Kanwar, B.S., 1968, Quality of irrigation Water. *Trans. 5<sup>th</sup> Int. Congr. Soil Sci.*, **1** : 391-403.
- Kenchanna Gowda, S.K., 1977, Effect of Continuous irrigation on physical, Chemical and mineralogical properties of the Soils of Tungabhadra project command Area. *Ph.D. Thesis*, Univ. Agri. Sci., Bangalore.
- Keren, R. and Singh, M.J., 1988, Effect of Low Electrolyte Concentration on Hydraulic Conductivity of Sodium/Calcium Montmorillonite Sand System. *Soil Sci. Soc. Am. J.*, **52** : 368-373.
- Kotur, S.C. and Seshagiri Rao, T., 1988, Relationship between Exchangeable Sodium Percentage and Sodium Adsorption ratio in Some Salt Affected Soils. *J. Indian Soc. Soil Sci.*, **36** : 407-413.
- \* Kovda, V.A., Penman, F., Minashina, N.G. Kononova, M.M., Kalinkin, N.P. and Hamdi, H., 1973, some effects of irrigation and drainage on Soils. In irrigation drainage and salinity. An. Int. Source Book FAD/UNESCO Hutchinsm and col. Ltd., London, pp. 509.
- \* Kulkarni, R.V., Kulkarni, K.V. and Perur, N.G., 1963, sulphur as a Chemical amendment for reclamation of Karl Soils of Karnataka Agricultural college Magazine, pp. 1-6.
- Lal, P. and Singh, K.S., 1974, A comparative Study of the Effect of Qualities of Irrigation Water on Different Soils. *J. Indian Soc. Soil Sci.* **22**(1) : 19-25.
- Landey, R.J. and Murthy, R.S., 1967, Investigation on the Quality of Irrigation Water in the Tungabhadra Water shed, Hadagalli Taluk, Bellary District, Mysore state. *Indian J. Agron.*, **12** : 262-266.
- Landey, R. and Feighonbaum, S., 1977, Effect of dilution on soluble and Exchangeable sodium in Soils differing in mineralogy. *Geoderma*, **18** : 193-205.
-

- Longenecker, D.E. 1960. Influence of Soluble Anions on Some Physical and Physicochemical Properties of Soils. *Soil Sci* **90** : 185-191.
- Mahajan, V.P. and Kanwar, J.S., 1974, Distribution of forms of Nitrogen in Saline Alkali Soils of Punjab and Haryana. *J. Indian Soc. Soil Sci.*, **22** : 47-51.
- Mathan, K.K. and Mahendran, P.P., 1993. Hydraulic Conductivity of Vertic Haplustalfs in Relation to Soil Properties *J. Indian Soc. Soil Sci.*, **41** : 759-761.
- Mathur, C.M., Shankaranarayana, H.S. and Mogh, V.B., 1968, Studies on Saline. Sodic Problem in Desert Soils of Western Rajasthan and their Classification for Effective Reclamation. *J. Indian Soc. Soil Sci.*, **16(4)** : 355-364.
- McNeal, B.L. and Coleman, N.T., 1966, Effect of Solution Composition on Soil Hydraulic Conductivity. *Soil Sci. Soc. Amer. Proc.*, **30** : 308-312.
- McNeal, B.L., Norvell, V.A. and Coleman, N.T., 1966, Effect of Solution Composition on the Swelling of Extracted Soil Clays. *Soil Sci. Soc. Amer. Proc.*, **30** : 313-317.
- Mediratta, J.C., Bansal, K.N. and Gupta, G.P., 1985, Characterisation of Some Salt Affected Soils of Harsi Command Area of Madhya Pradesh. *J. Indian Soc. Soil Sci.*, **33** : 214-217.
- Misra, S.G. and Sharma, D.P., 1968, Studies on Some Saline Alkali Soils of Allahabad. *J. Indian Soc. Soil Sci.*, **16** : 271-275.
- More, S.D., Shinde, J.S. and Malewar, G.U., 1988, Characterisation of Some Salt Affected Soils of Purna Command Area of Maharashtra. *J. Indian Soc. Soil Sci.* **36** : 146-150.
- Mruthunjaya, S., 1991, Characterization of some salt Affected Soils of Cauvery and Vanivilas sagar command area, Karnataka, *M.Sc. Agri. Thesis*. Univ. Agric. Sci., Bangalore.
- Nadakarani, R.M., 1975, A study of the ion-Exchange properties of some of the important Soil series in Malaprabha project area, *M.Sc. (Agri.) Thesis*, University of Agril. Sci., Bangalore.

- Narayana, M.R., Mehta, V.C. and Datar, D.S., 1966, Effect of sea Water and its dilution on some Soil Characteristics. *In solinity and acidity*, Editor H. Bayko, 314-322. Junc, N.V. Publisher, The Hague.
- Odell, R.T., Thombum, T.H. and McKenzie, L.T., 1960, Relationship of Atterberg Limits to Some Other Properties of Illinois Soils. *Soil Sci. Soc. Amer. Proc.*, **24** : 297-300.
- Olsen, S.R., Watanabe, F.R. and Cole C.V., 1960, Soil properties affecting the solubility of calcium phosphates. *Soil Sci.*, **90** : 44-50.
- Oster, J.D. and Sposito, G., 1980, The Gapon Co-efficient and the Exchangeable Sodium Percentage-Sodium Adsorption Ration Relationships. *Soil Sci. Soc. Amer. J.*, **44** : 258-260.
- Paliwal, K.V. and Maliwal, G.L., 1971, Some Relationships between Constituents of Irrigation Water and Properties of Irrigated Soils of Western Rajasthan. *J. Indian Soc. Soil Sci.*, **19** : 299-303.
- Paliwal, K.V. and Gandhi, A.P., 1976, Effect of Salinity, SAR, Ca, Mg Ratio in Irrigation Water and Soil Texture on the Predictability of Exchangeable Sodium Percentage. *Soil Sci.*, **122** : 85-90.
- Pandey, R.N., Narain, R. and Pathak, A.N., 1974, Effect of Electrolyte Concentration on the Hydraulic Conductivity of Bundelkhand Soils. *J. Indian Soc. Soil Sci.*, **22** (2) : 190-193.
- Panjaswamy, N., Dhanapalan. and Mosi, A., 1973, Studies on Saline Irrigation Water Influence on Soil Properties. *Madras Agril. J.*, **60** : 804-809.
- Panse, V.G. and Sukhatme, P.V., 1961, *Statistical Methods for Agricultural Workers*. Indian Council of Agricultural Research., New Delhi, p. 347.
- Parvathappa, H.C., 1981, Exchangeable and Water soluble Cations equilibria in some irrigated Soils of Karnataka state. *Ph.D. Thesis*, Univ Agril. Sci., Dharwar.
- Parvathappa, H.C., Kenchanna Gowda, S.K. and Rao, T.S., 1990, Impact of irrigation Water quality on Soil properties in semi-arid tropics. In proceedings of 14<sup>th</sup> International Congress on Irrigation and Drainage. No-1-4, 83-90.

- Parvathappa, H.C., Rao, B.S. and Prathap Reddy, B. 1992. Effect of Salt Water on Aggregation Stability and Volume Expansion of Soil. *Mysore J agric Sci* **26** : 159-164.
- Patak, S.R. and Patel, N.K., 1980, Study of Some Physico-Chemical Characteristics of Salt Affected Soils of Kaira District Gujarat State. *J. Indian Soc. Soil Sci.*, **28** : 31-37.
- Patil, S.V. and Venkata Rao, B.V., 1965, Effects of irrigation in black Soils in the Thungabhadra Project area in Mysore state. *Univ. Agril. Sci., Bangalore Msc. Ser.*, **1** : p. 54.
- Perur, N.G., 1971, Review of research work done on irrigation and Water use and further lines of work suggested. In *Soil and Water Research in India in retrospect and prospect (A review)*, I.C.A.R. Tech. Bull. (Agric.) No.22. 238-242. New Delhi.
- Piper, C.S., 1966, *Soil and Plant Analysis*, Hans Publishers, Bombay, p. 368.
- Poonia, S.R. and Bhumbra, D.R., 1973, Some Physico-Chemical Characteristics of Salt Affected and Adjacent Normal Soils of Rothak District. *J. Indian Soc. Soil Sci.*, **21** (3) : 335-341.
- Poonia, S.R. and Talibudeen, O., 1977, Sodium Calcium. Exchange Equilibria in Salt Affected and Normal Soils. *J. Soil Sci.*, **28** : 276-288.
- Prabhu, N.V., Talashilkar, S.C. and Chavan, A.S., 1987, Interrelationships between Dispersion Ratio and Water Transmission Characteristics of Salt Affected Soils of Maharashtra, *J Indian Soc. Soil Sci.*, **35** : 497-502.
- Puttaswamy Gowda, B.S., Perur, N.G. and Suseela Devi, L., 1968, An appraisal of the quality of Waters in Bangalore district for irrigation. Proceedings Sir. M. Vesvesvaraya memorial Tech. Seminar, on Soil and Water management 23-25 Dec., 1968, p 66A Institution of engineers (India), Bangalore.
- Quirk, J. P. and Schofield , R. K., 1955, The effect of electrolyte concentration on soil permeability. *J soil sci.*, **6** : 163- 173.
- Raghu Kumar, T.R., 1977, studies on physical and Chemical properties of some saline sodic Soils of Karnataka, *M.Sc. (Agri.) Thesis*, Univ. Agri. Sci., Bangalore.

- Raj Pal, Kapoor, A.K. and Poonia, S.R., 1985, Simulation of Salinisation of a Fallow Soils Irrigated with Saline Sodic Water. *J. Indian. Soc. Soil Sci.*, **33** : 20-24.
- \* Ramaiah, P.V., 1937, *Report on the Soil survey of the Tungabhadra Project.* Department of Agriculture, Govt. Madras, p. 106.
- Rao, B.S. and Parvathappa, H.C., 1993 Effect of Dissolved Salts on Hydraulic Conductivity of Soils. *J. Indian Soc Soil Sci.*, **41** : 418-421.
- Raychaudari, S.P., Murthy, R.S. and Sharma, V.D., 1962, Studies on Saline Alkaline Soils of India V. Morphology Genesis and Classification of Saline Alkali Soils of South India. *Indian J. Agri Sci.*, **32** : 278-287.
- Sarma, P.K. Bordoloi, P.K. Baruah, T.C. Das, K.N. and Borah, N., 1997, Shysical Characterisation of Soils in Two Command Areas of Assam. *J Indian Soc. Soil Sci.* **45** : 709-7112.
- Satish Rao, B., 1989, Effect of quality of irrigation Water on soul properties in selected Soils of Karnataka, *M.Sc. Agri. Thesis*, Univ. Agri. Sci., G.K.V.K. Bangalore.
- Schoonover, W.R., Elgabaly and Nagvit, H., 1957, A study of some Egyptian saline and Alkali Soils. *Hilgardia*, **26** : 566-596.
- Sehgal, J.L., Bhumbla, D.R. and Dhingra, D.R., 1968, Soils of the Sutlej Flood Basin Areas in the Punjab. *J. Indian Soc. Soil Sci.*, **6(3)** : 241-247.
- Sen, T.K., Dubey, P.N. and Chamuah, G.S., 1997, Characteristics and Classification of Some Soils of Barak Valley in Assam. *J Indian Soc. Soil Sci* **45** : 206-208.
- Seshagiri Rao, 1967, The influence of ionic strength and Ion-Pair formation on Na-Ca and Na-Mg ion Exchange equilibria. *Ph.D. Thesis, Univ. California, River Side.*
- Shankaranarayan, H.S. and Mehta, B.V., 1967, Soil Structural Studies in Chambal Command Area of Rajasthan. *J. Indian Soc. Soil Sci.*, **15** : 77-87.
- Sharma, H.C. and Bajwa, M.S., 1989, Different Forms of Boron in Salt Affected Soils. *J. Indian Soc. Soil Sci.*, **37** : 470-474.

- Sharma, B.M. and Jha, S.N., 1989, Comparative Studies on Some Salt Affected Soils. *J. India Soc. Soil Sci.*, **37** : 524-531.
- Sharma, D.L., Moghe, V.B. and Mathur, C.M., 1968, Salinity and Alkalinity Problems and Fertility Status of Soils of Pali District, Rajasthan. *J. Indian Soc. Soil Sci.*, **16** (3) : 263-269.
- Singh, R.A., 1980, *Soil Physical Analysis*, Kalyani Publishers, New Delhi, Ludhiana.
- Smith, R.M., Browing, D.R. and Pohlman, G.G., 1944, Laboratory percolation Through Undisturbed Soil Samples in Relation to Pore size Distribution. *Soil Sci.*, **57** : 197-213.
- \* Sobornikova, I.G., 1959, The effect of irrigation on the Kerrace Cis-Caucasian Chernozems of the Rostor region. *Pochvovedeniya*, **2** : 67-74.
- Srinath, K., 1979, A study of physico-Chemical Characteristics of some salt Affected Soils in Tungabhadra river valley project left bank canal area. *M.Sc. (Agri.) Thesis, Univ. Agril. Sci., Banagalore.*
- Srivastava, A.K. and Srivastava, O.P., 1993, Cation Exchange capacity in Relation to Soil Sodidity in Amended Saline Sodic Soil. *J Indian Soc. Soil Sci.*, **39** : 155-157.
- \* Sudina, Ye, S., Prichodko, V. Ye, Ivanov, I.V. and Beilin, V.V., 1989, Effect of irrigation in the Trasvolga syrt plain on southern Chernozems properties. *Pochvovedeniye*, **5** : 128-135.
- \* Suchkov, S.P., 1962, Productivity of uzbekistan Soils that have been irrigated for a different number of years. *Pochvovedniye*, **10** : 1-9.
- Talsma, T., Mansell, R.S., and Hallam, P.M., 1980 Potassium and Chloride Movement in a Forest Soil under Simulated Rainfall. *Aust. J. Soil Res.*, **18**; 333 - 342.
- Tiwari, K.N., Anil Kumar and Pathak, A.N., 1983, Characterisation of Salt Affected Soils in Central Alluvial Region of Uttar Pradesh. *J. Indian Cos. Soil Sci.*, **31** : 272-280.

- Tripathi, B.R., Singh, R.M. and Dixit, S.P., 1969, Quality of Irrigation Water and its effect on Soil Characteristics in the Semi arid tracts of Uttar Pradesh I. Water quality, *Indian J. Agron.*, **14** : 180-186.
- United states saniility Laboratory staff, 1954, Diagnosis and Improvement of saline and Alkali Soils. Agril. hand Book No.60, U.S.D.A., Washington, U.S.A.
- Ved Prakash, K. Sharma, N.L. and Room Singh., 1995, Characterisation of Salt Affected Soils of Sultanpur District of Uttar Pradesh. *J. Indian Soc. Soil Sci.*, **43** : 143-144.
- Walia, C.S. and Rao, Y.S., 1997, Characteristics and ClassifiCation of Some Soils of Trans-Yamuna Plain. *J Indian Soc. Soil Sci.*, **45** : 156-162.
- William, R.G., Carl, A. and Reaves, 1957, Relationship of Atterberg's limits and CEC to some physical properties of Soils. *Soil Sci. Soc. Amer. Proc.*, **21** : 491-497.
- Yousaf, M., Ali, O.M. and Rhoades, J.D., 1987, Clay Dispersion and Hydraulic Conductivity of Some Salt Affected Arid Land Soils. *Soil Sci. Soc. Am. J.*, **51** : 905-907.

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ಗಾ.ಕೃ.ವಿ.ಲೆ., ಬೆಂಗಳೂರು-05

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