Chapter VIII

SOIL REGIME

SOIL REGIME

INTRODUCTION

Soil is considered to be the most important land resource. It constitutes the natural medium, a chemically, physically and biologically complex dynamic system, which supports the growth of plants.

Soils may be greatly influenced by various human activities particularly in irrigation command, when in the degradation of the soil is attributed to the waterlogging problems, causing soil salinisation and soil acidification.

The study of soil regime has been carried out in the Chalthan Branch Canal Command Area to assess the impact of canal irrigation on soils and quantifying the magnitude of change in physical and chemical parameters of soils.

FIELD INVESTIGATIONS

For the purpose of precise evaluation of various soil parameters, the author has divided the entire study area into equal area grids of 10 sq. km. and the soil samples were collected at each node (Fig. 7.4). As the seasonal changes and the irrigation practices greatly influence the soil parameters, the sampling were done for two different seasons i.e. pre and post monsoon 1999. For collection of samples the author has adopted standard guidelines and methodology, as prescribed in Soil Survey Manual USDA (1975). Field related inventory and other relevant informations were recorded in standard performa. A copy of adopted performa is given as APPENDIX - V.

SOIL SAMPLING

The collection of soil samples solely depends upon the types of the properties to be studied. As the objective of the present study was to evaluate the physical and chemical characteristics of the soils; there by giving nomenclature of the various soil types and identifying the different secondary, induced characteristics (viz. permeability, salinity and alkalinity). The soil sampling was done with the help of soil auger (Plate 4). In addition to this some existing open excavated pits have also been examined to study soils' pedomorphological characteristics.

SITE SELECTION CRITERIA

The following criteria and precautions (USDA, 1975) were adopted while carrying out soil sampling:

1. The site should be in continuous use of irrigation and away from any permanent structure viz. buildings, road cuts, railways etc.
2. While collecting samples, avoid small areas where the soil conditions are obviously different from those in the rest of the field—for example, wet spots, old manure sites and urine spots, places where wood piles have been burned, severely eroded areas, old building sites, fence rows, spoil banks, and burrow areas.
3. Avoid the fertilizer bands in fields where row crops have been grown. Because samples taken from each location would not be typical of the soil as in the rest of the field, and may provide misleading results.
4. The site should not be excavated and refilled or layered with the soil from other locations.
5. Sampling point within the farm should not be nearby the field channels, cattle walk, and/or under or near large tree.
6. As sampling is to be carried out seasonally, care should be taken to collect sample from the same sites for subsequent seasons.

3. Auger and remove the soil till the next sampling depth i.e. 10-50 cm is achieved.
4. Once the depth is achieved, broaden the hole by using 4-inch diameter posthole auger till the depth is achieved and collect the soil in the same plate or bucket. The broadening of the hole is essential for smooth penetration of 1.5-inch diameter auger and to avoid mixing of above lying soil while rotating the auger.
5. Once the desired depth is achieved, extract the auger and collect the sample in the plate or bucket. Mix up the collected sample and reduce the soil to 1 kg by adopting coning and quartering procedure.
6. Pack the soil sample in a cloth bag and give indexing to the packed samples.
7. Repeat the above steps till the final depth is achieved as per requisite depth intervals.
8. Soil samples for the nutrient analysis should be collected separately.

Similarly the soil falling within the limits of fluctuating water table conditions, the soil samples were collected for both pre and post monsoon periods. Also, in waterlogged area wet samples were collected.

SOILS OF CHALTHAN BRANCH CANAL COMMAND AREA

SOIL PROFILES

A soil profile comprises different layers, which are known as horizon (Brady, 1990). Each horizon is different from other horizon due to change in its composition, colouration and textural characters (Miller and Donahue, 1997). A schematic diagram of an ideal soil profile (Fig. 8.1) depicting various sub-soil horizons amply highlights the soil horizon characteristics.

The extensive field studies have revealed that in the Chalthan Branch Canal Command Area there is a prevalence of the mineral soil profile. It has also been observed that there exists, different kind of matured soil profiles with the distinct development of "A" and "B" horizons comprising number of smaller units. As it has already been eluded in the previous chapter that the KLBC area is characterized by number of soil types. The Chalthan Branch Canal Command Area also exhibits varied soil types (Fig. 8.2). The State run Soil Survey Department has carried out a detailed inventory of the various soils of the Kakrapar Command Area and has classified the soils using standard classification (Table 8.1); the author has utilized this available information and further substantiated with his own studies.

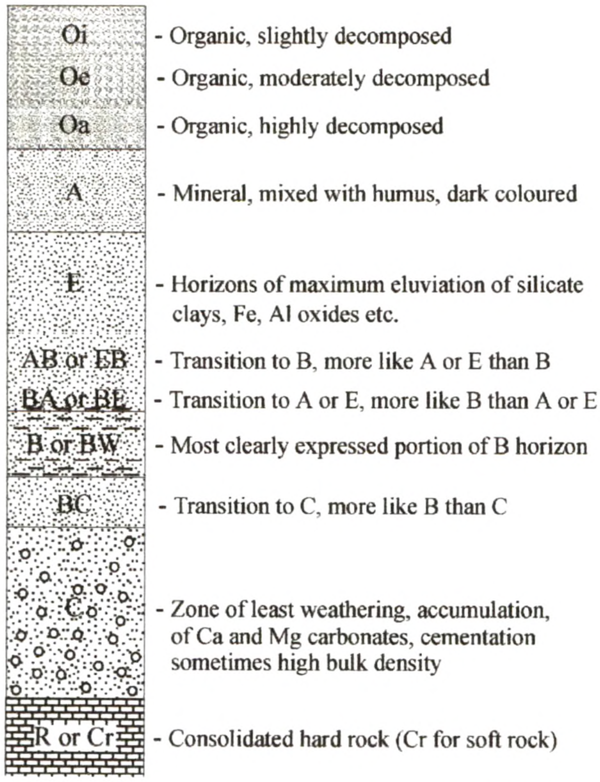

Fig. 8.1 Schematic Diagram of an Ideal Soil Profile.

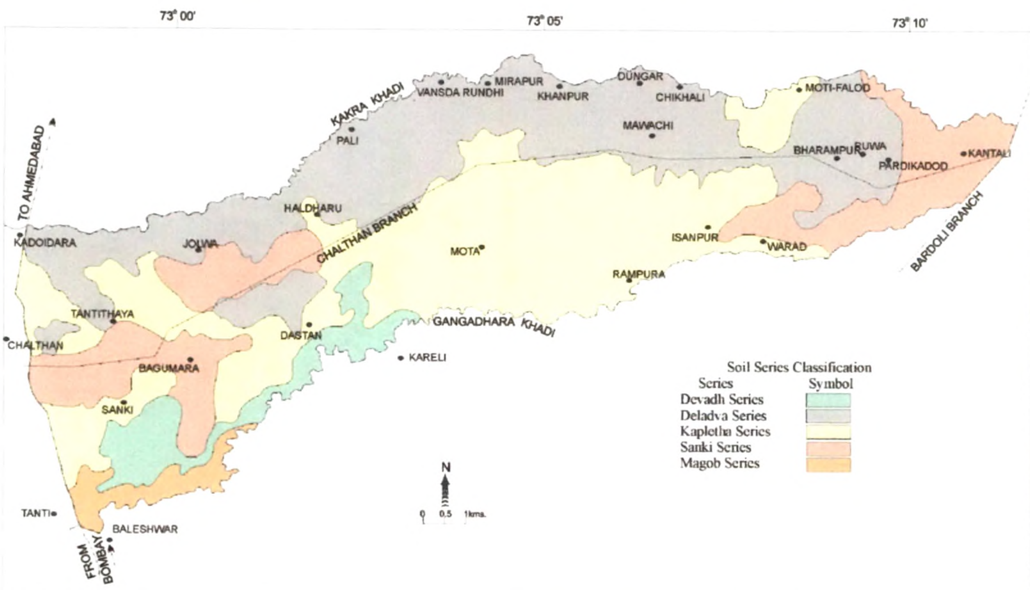

Fig. 8.2 Soil Series Classification in Chalthan Branch Canal Command Area.
(Modified from Soil Survey Dept, Govt. of Gujarat)

Table 8.1 Soil Series and Taxonomic Classification of Soils in Chalthan Branch Canal Command Area.

Sr. No.	Soil Series	Broad Characteristics	Taxonomic Name	Locality of Occurrence
1	Kapletha	Very deep, dark brown, hard, sticky, plastic, calcareous, fine to moderate texture,	Typic chromusterts (calcareous)	Mota
2	Sanki	Very deep, brown, hard, moderately sticky and plastic, non calcareous, moderate texture	Typic chromuderts	Kantali
3	Deladwa	Very deep, dark brown to brown, hard, sticky and plastic, non calcareous, fine texture	Typic chromusterts	Khoj-Pardi
4	Devadh	Very deep grayish brown to dark brown, moist, friable, less sticky, calcareous, fine to moderately texture,	Fluventic ustochrepts	South of Bagumara
5	Magob	Very deep, moderate texture, moist friable, slightly sticky and having very low plasticity	Typic ustifluvents	South of Sanki

(After Soil Survey Dept, Govt. of Gujarat)

A detailed description of the location specific typifying pedon for each soil types along with morphological description of the various profiles of study area is as follows:

1. **Mota**

The exposed soil profile at Mota village belongs to *Kapletha series* with solumn depth of more than 170 cm (v. deep). Soil profile is dominated by the development of two main horizons A and B (Fig. 8.3). "A" horizon is from 0 to 13 cm, dark brown (10 YR 4/3), fine (clayey) texture; and medium sub angular blocky structure. "A" horizon is characterized by humus, availability of roots and well developed cracks. The "B" horizon is thick (13 - 170 cm) comprising five different sub horizons, with dark brown (10 YR 4/3, 3/3) to dark yellowish brown (10 YR 4/3, 4/6) colour. These sub-horizons have medium to fine texture and having mixture of clay and silt size particles. The structure is predominantly sub angular blocky, occasionally comprising small calcareous nodules and few roots.

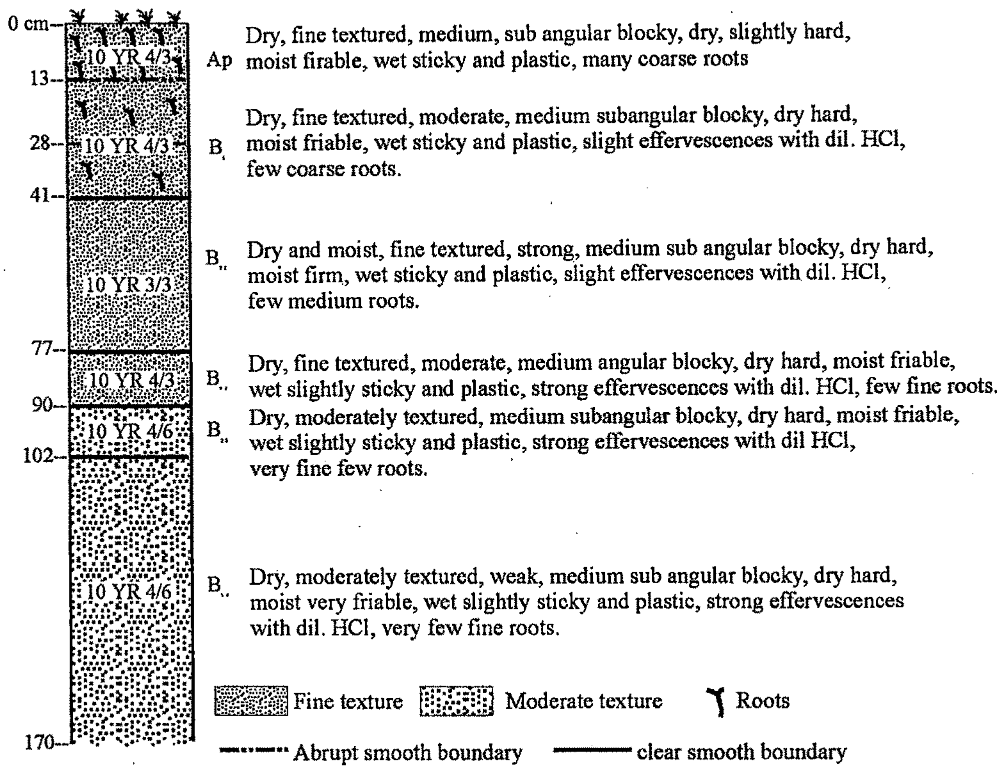

Fig. 8.3 Pedomorphological Characteristics of Soil Profile at Mota Village.

2. **Sanki**

Soils of village Sanki having depth of more than 135 cm and belongs to *Typic ustifluvents* sub group, locally *Magob series*. This profile is characterised by well developed "A" horizon and is divided into six different sub horizon (Fig. 8.4), showing colours ranging from grayish brown (10 YR 3/2) to yellowish brown (10 YR 4/3). The texture is dominantly moderate (loamy), structure is medium sub angular blocky. Soil sub-horizons are moist, friable, slightly sticky and having very low plasticity. Very few roots are found in these sub-horizons.

3. **Khoj-Pardi**

The depth of the solumn exposed at Khoj-Pardi is more than 160 cm (Fig. 8.5) and belongs to *Deladwa series*, i.e. *Typic chromusterts* sub group (Table 8.1). Its "A" horizon, which is of about 16 cm thick, is of very dark brown (10 YR 3/2) in colour. The texture is dominantly fine (clayey), with weak, medium sub angular blocky structure. Medium roots are ubiquitously found in this horizon. The boundary between "A" and "B" horizons is very clear and smooth. "B" horizon has a thickness ranging from 16 to 160 cm and depicts development of five different sub horizons viz. B_{21}, B_{22}, B_{23}, B_{24} and B_3 with a colour ranging between very dark brown (10 YR 3/2) and dark brown (10 YR 4/3). Texturally soils are very fine (clayey) and exhibiting medium, moderate angular blocky to weak, moderate angular blocky structures. Soils of these sub-horizons are wet, sticky and plastic. Very few roots are found in these sub-horizons

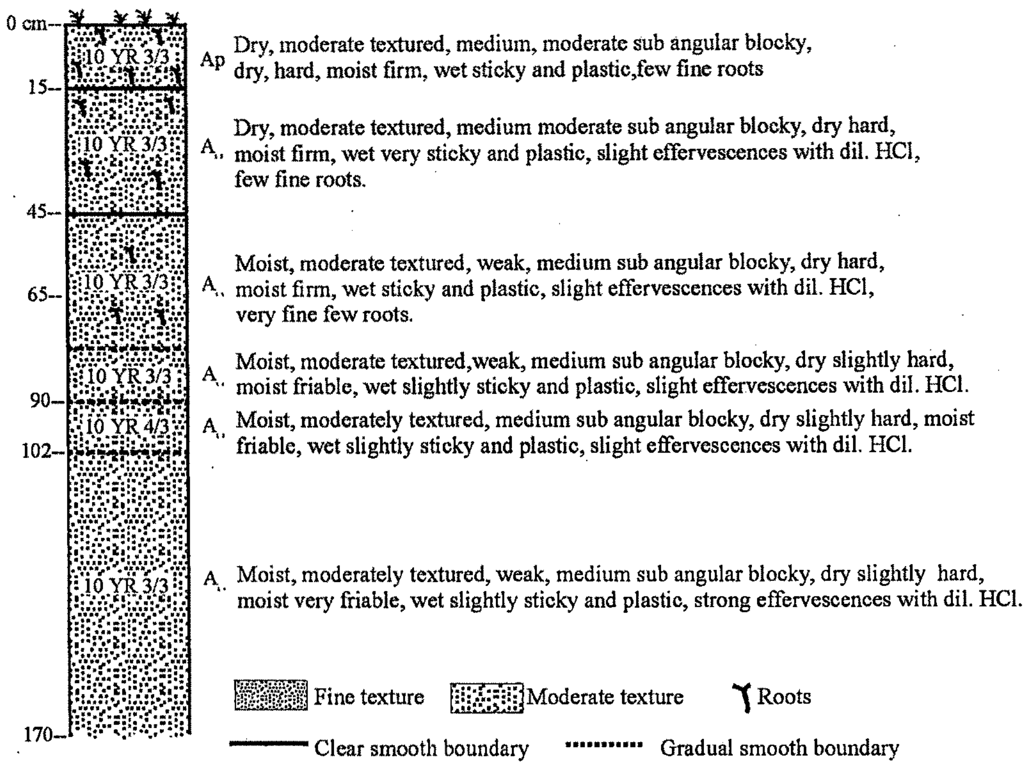

Fig. 8.4 Pedomorphological Characteristics of Soil Profile at Sanki Village.

4. Bagumara

Soil profile at Bagumara is considered to be very deep with an average depth upto 105 cm (Fig. 8.6). The soil characteristics are typical of *Fluventic ustochrepts*, locally known as *Devadh series*. The studied soil profile is characterized by 25 cm thick "A" horizon with a distinctly developed A_p and A_{12} sub-horizons. Soil of "A" horizon is very dark grayish brown (10 YR 3/3) in colour. The structure is weak, medium sub angular blocky with fine to moderate texture. The boundary separating "A" and "B" horizons is of gradual and wavy in nature. The below lying "B" horizon which is of 25 to 105 cm thick depicts development of four different sub horizons viz. B_1, B_2, B_3 and B_4, with colours from dark grayish brown (10 YR 3/3) to very dark brown (10 YR 4/3). These sub-horizons have medium to fine texture with varied clay and silt content. The structure is ranging from medium, moderate angular blocky to sub angular blocky. Soils of these horizons are moist friable, wet very sticky and plastic and has a significant concentration of calcium content.

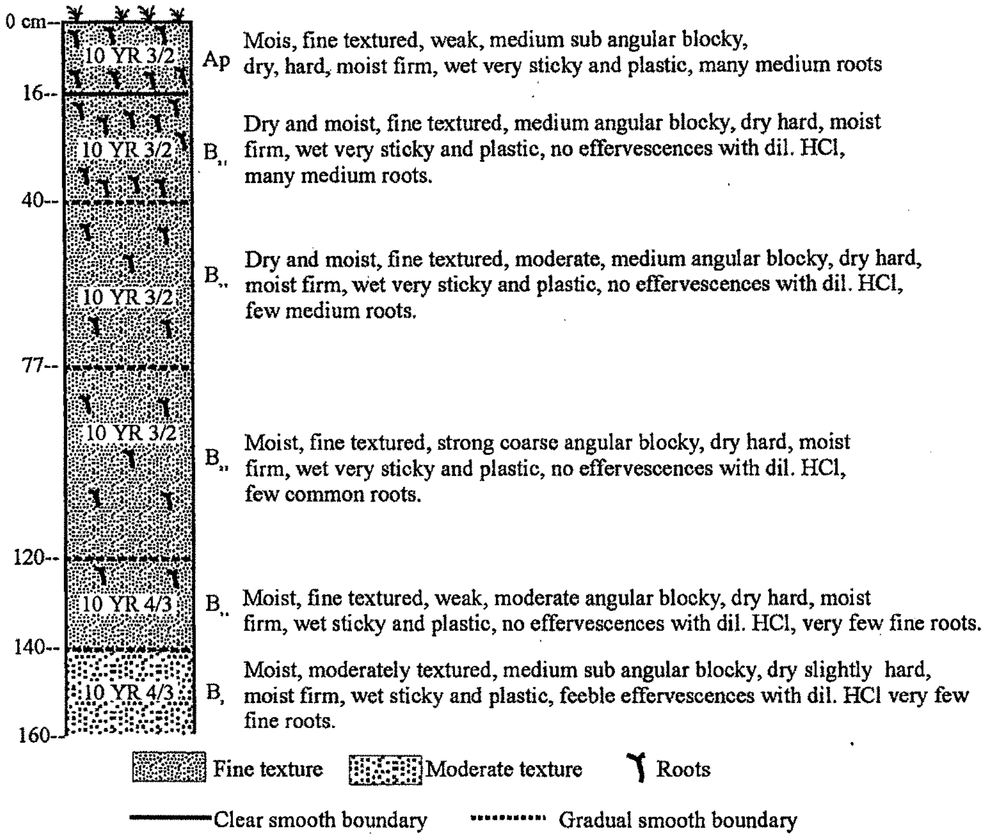

Fig. 8.5 Pedomorphological Characteristics of Soil Profile at Khoj-Pardi Village.

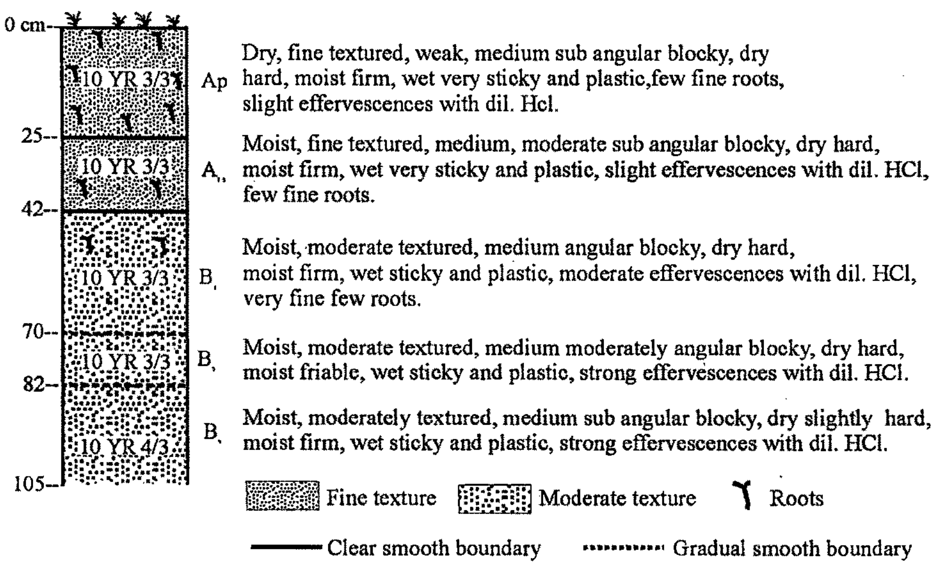

Fig. 8.6 Pedomorphological Characteristics of Soil Profile at Bagumara Village.

5. **Kantali**

At Kantali village solumn has depth up to 140 cm and the soil profile is matured in nature (Fig. 8.7). Here the soil profile is characterised by well developed "A" and "B" horizons. The top "A" horizon is of 50 cm thick with a distinctly developed two sub horizons i.e. A_p and A_{12}, colour is of dark brown (10 YR 4/3) on Munsell Colour Index. The soil texture through out the solumn is dominantly fine (clayey). The structural formation ranges from weak and moderate sub angular blocky to coarse sub angular blocky. "A" horizon is characterized by availability of roots and having clear smooth boundary with "B" horizon. The "B" horizon is from 50 to 160 cm with development of two different sub horizons viz. B_{21} and B_{22}, characterized by dark brown (10 YR 3/3). The structure is ranging from moderate, medium angular blocky to sub angular blocky. Soils of these horizons are wet, moderately sticky and plastic. The profile shows typical soil characteristics of *Typic chromuderts, which* is locally assigned as *Sanki series.*

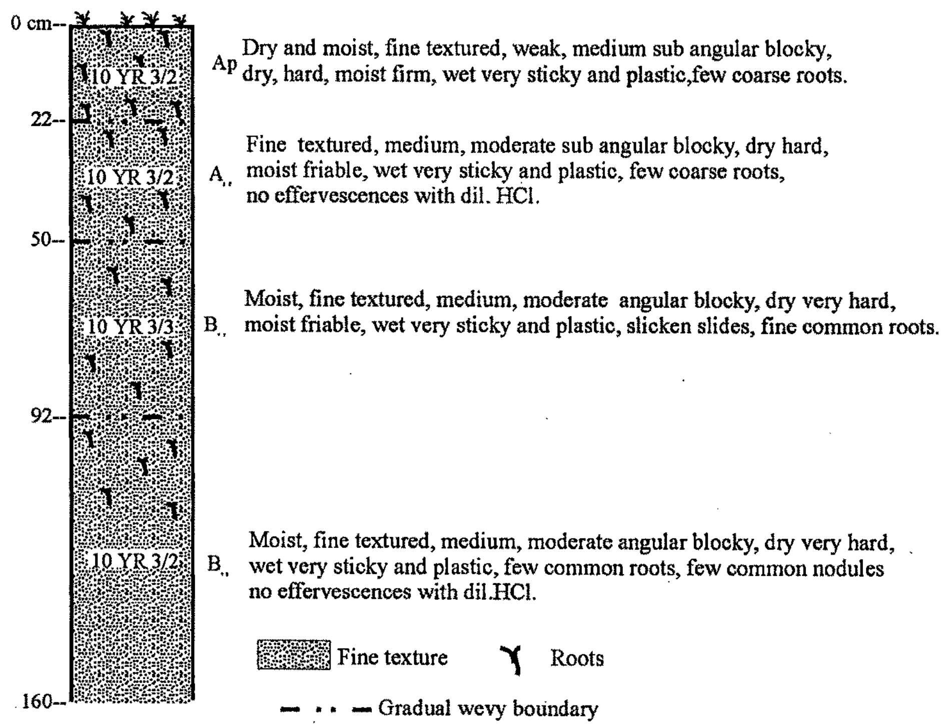

Fig. 8.7 Pedomorphological Characteristics of Soil Profile at Kantali Village.

LABORATORY INVESTIGATIONS

Sample Preparation for Laboratory Analysis

Extreme care is warranted while preparing soil samples for laboratory analysis. The collected soil samples were processed in accordance with the standard methodology and procedures prescribed by (Hesse, 1994). Later on these samples were run for various testing, for determining the various physical, hydraulic and chemical characteristics (Table 8.2). The quantitative as well as qualitative aspects of the various soil characteristics are discussed as under:

Table 8.2 Inventories of Soils Data for Studying Irrigation Impacts (Compiled after FAO, 1979).

	Soil Characteristics	Significance
A.		**Physical**
1.	Effective soil depth	Root room, water and nutrient retention; land leveling; drainage; aligning and design of irrigation and drainage channels.
2.	Grain size distribution (texture)	For establishing homogeneity of soil and for deriving many characteristics.
3.	Soil structure and Porosity	Root environment, nutrient, water and soil management, drainage and permeability especially of sodic soils, leaching of salts, tilth and workability for seedbed and land preparation.
4.	Infiltration rate	Rainfall and irrigation intake or run-off, selection of irrigation method, erodibility.
5.	Hydraulic conductivity or permeability	Soil drainage, removal of excess water and salts.
6.	Water holding capacity and Available water capacity	Soil water balance, residual water between and following irrigations, choice of irrigation methods.
7.	Plasticity and Liquid limits	Indicative of mineralogy and physical behaviour.
B.		**Chemical**
1.	Soil reaction (pH)	To identify alkaline, sodic and acid i.e. nature of soils; nutrient deficiencies and toxicities.
2.	Electrical conductivity	Salinity hazards.
3.	Soluble ions (Na, Ca, K, Mg, Cl, SO_4, CO_3, HCO_3)	Interpretation of salinity hazards
4.	Cation Exchange Capacity (CEC)	Nutrient retention and chemical fertility status.
5.	Exchangeable Sodium Percentage (ESP)	Sodicity or alkalinity problems.
6.	Exchangeable cations (Na, K, Ca, Mg)	Base saturation, ESP, potassium status.
7.	Bio-nutrients as N, P, K	Macro and micronutrient content, toxic elements.
8.	Organic carbon	Organic matter, nutrient retention, fertility.

Contd.........

C	Mineralogical	
1.	Sand and Silt fraction	Indicate parent material and degree of weathering.
2.	Clay fraction	To identify stickyness, swelling and shrinkage characteristics of clay minerals having tetra and octahedral structures.
3.	Calcium carbonate	Hardpans restricting rooting depths, large amount decrease nutrient retention and fertility.

PHYSICAL PROPERTIES

The physical properties of soil affect its use and behaviour of plant growth. The study of the various physical properties of soils such as texture, structure, density, consistency, porosity, colour, soil depth and their arrangement gives rise to morphological characteristics of soils (Rai, 1995). A detailed quantitative data on the various physical properties of soils in study area are given in APPENDIX VI.

Texture

Soil texture refers to the relative proportion of various particle sizes in a soil (IARI, 1970). A diverse range of parent materials, impacted by various degrees of physical and chemical weathering, produce a wide variety in size of particles, ranging from large stones to microscopic clay colloids. The sizes of mineral particles influences both soil structure and the physical, chemical and biological properties of the soil (Rai, 1995, Miller and Donahue, 1997). Important soil textural categories based on nature and relative abundance of sand - silt - clay have been ideally explained by USDA Soil Survey Manual (USDA, 1975). A comprehensive account and the textural classification is given as under:

Group	Soil Textural Class
Fine textured	clay, silty clay, sandy clay
Moderately fine textured	silty clay loam, clay loam, sandy clay loam
Medium textured	loam, silty loam, silt
Coarse textured	sandy loam, loamy sand
Very coarse textured	Sand

A detailed quantitative data based on granulometric analysis of soil samples collected from the various locations and for various depths is given in APPENDIX VI. These granulometric data have been plotted on standard textural triangular diagram (Fig. 8.8) to determine the textural characteristics of the various soils and to decipher any vertical changes in soil textures.

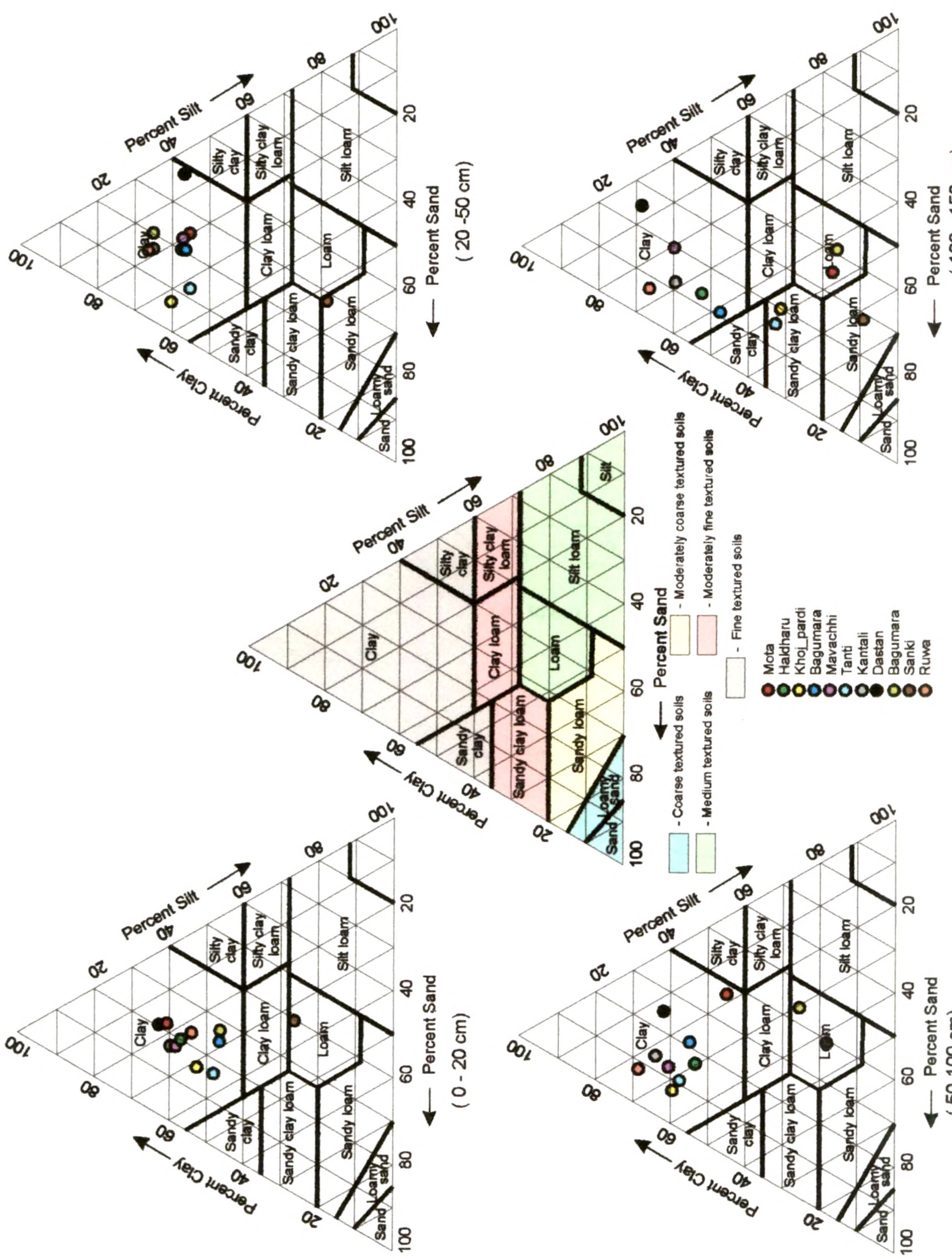

Fig. 8.8 Textural Characteristics of Soils in Chalthan Branch Canal Command Area.

In order to view any lateral changes in soil texture characteristics, the author has plotted the spatial texture profiles along A-A' transact of the study area (Fig. 8.9). The spatial profile depicts variation in the clay, silt and sand percentage along the section line as well as with depth. In general, clay proportion is above 50 % with in a depth of 0 to 100 cm. while at a depth of 100 - 150 cm it decreases between Isanpur and Ruwa villages thereby indicating change in soil texture with depth.

So far effect of soil texture on plant growth and soil irrigability are concern, the clayey soil holds plant nutrients well and has a high moisture retention capacity. But, if the percentage of clay particles is very high (apex. > 70%) than soil turn out to be impermeable to air, water and plant roots (Rai, 1995). In the study area as the clay percentage is < 60 % therefore, soils are suitable for the irrigation as well as agricultural purposes.

Soil Structure

The arrangement of the individual soil particles and their aggregates in a particular manner is called soil structure (Rai, 1995). Maintaining good soil structure is essential to sustain long-term agricultural productivity (Topp et al, 1995). On the basis of field studies, the soil structure of study area falls within the categories of angular to sub angular blocky structures. The soil profile at Mota village shows medium sub angular blocky structure while the soil profiles at Sanki, Bagumara, Khoj-Pardi and Kantali villages, soil structure varies from medium angular blocky to medium sub angular blocky. Therefore taking the basis of soil structure, the soils in the study area are moderate to highly suitable for irrigation purpose (USDA, 1975).

Moisture Holding Capacity (MHC)

The amount of water that can be stored varies widely among soils depending upon the number and size of pore spaces they contain. The number and size of pore spaces in a soil depend on its texture, organic matter content and structure (Miller and Donahue, 1997). The observation on moisture holding capacity of all the soil samples of study area was tested with the help of Keen's Box method (I.S. 2720, Part XVII - 1992). Based on the obtained results the MHC of various soil sub group may be arranged in decreasing order as, Kantali (*Typic chromuderts*) > Mota (*Typic chromusterts*, calcareous) > Khoj-Pardi (*Typic chromusterts*) > Bagumara (*Fluventic ustochrepts*) > Sanki (*Typic ustifluvents*). Author has also prepared Iso-MHC maps

(Fig. 8.10 - 8.13) for all the measured depths from which the soil samples were collected viz. 0-50, 50-100, 100-150 and 150-200 cm. Since MHC is governed by the textural characteristics of the soil; and the soil texture in the study area is predominantly clayey; therefore the MHC values does not show much changes upto 100 cm depth (Fig. 8.10 - 8.11). At this depth almost 93 % of the study area is characterised by MHC more than 50% (Table 8.2).

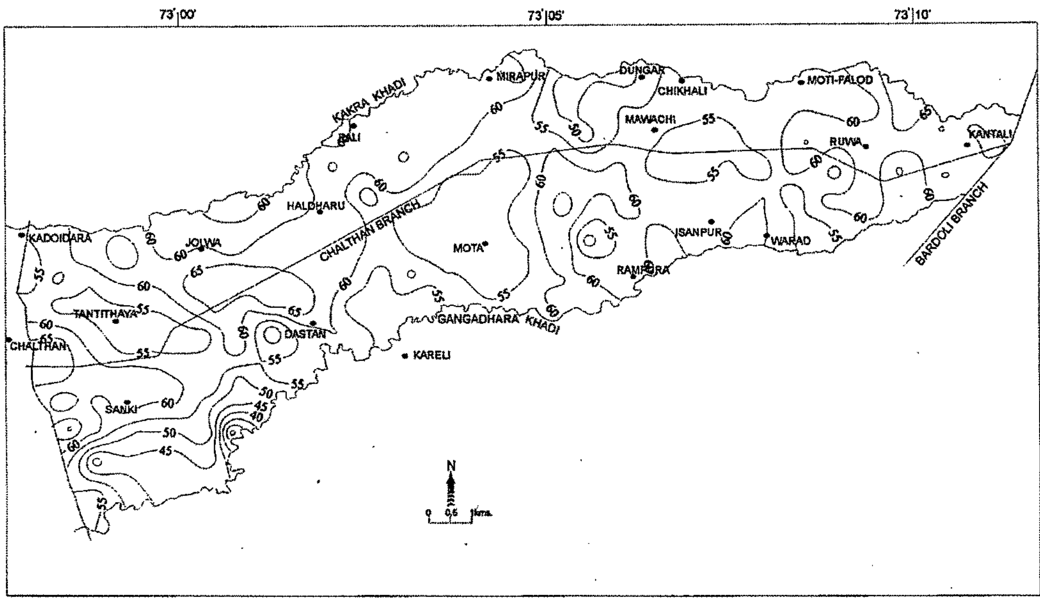

Fig. 8.10 Soil Iso-MHC (%) Contour Map, Chalthan Branch Canal Command Area (0 - 50 cm).

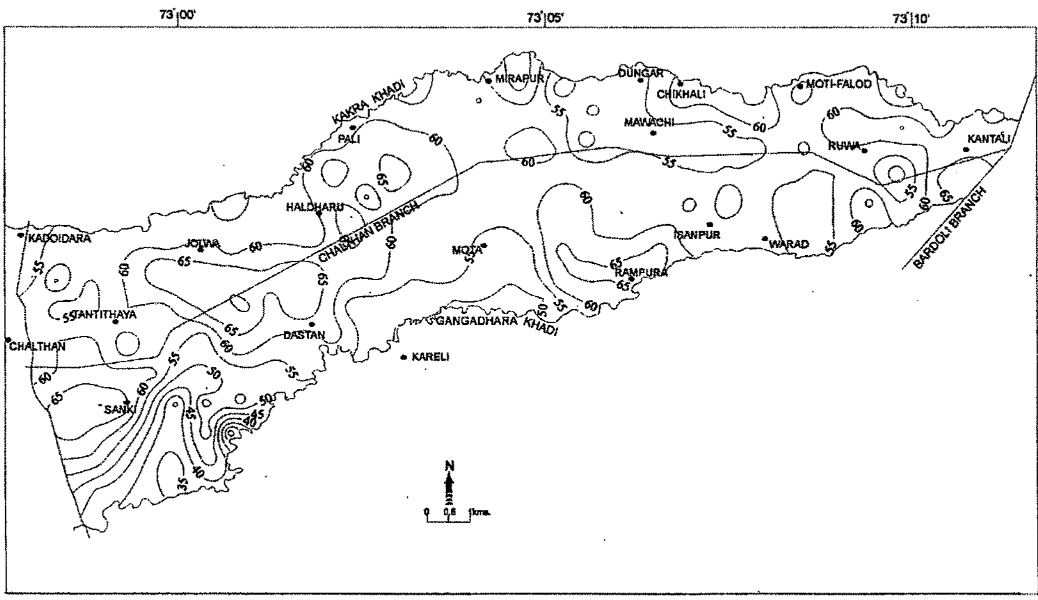

Fig. 8.11 Soil Iso-MHC (%) Contour Map, Chalthan Branch Canal Command Area (50 - 100 cm).

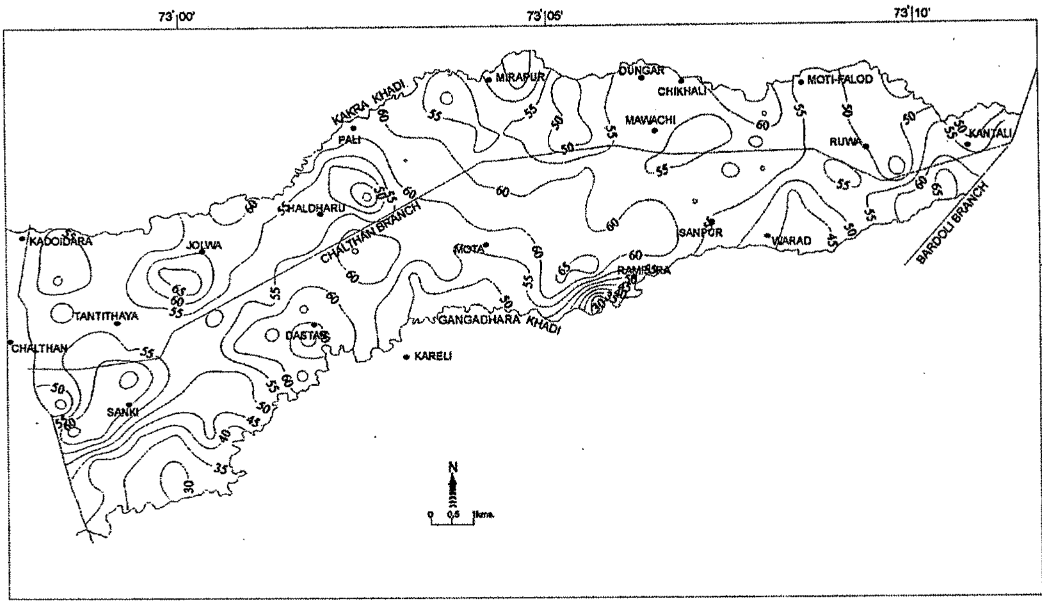

Fig. 8.12 Soil Iso-MHC (%) Contour Map, Chalthan Branch Canal Command Area (100 - 150 cm).

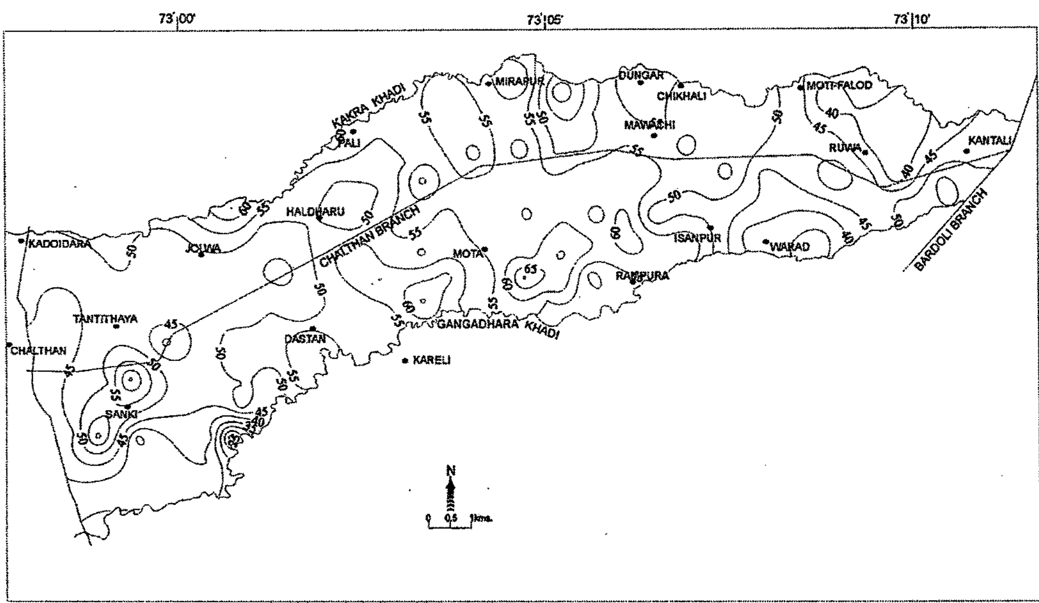

Fig. 8.13 Soil Iso-MHC (%) Contour Map, Chalthan Branch Canal Command Area (150 - 200 cm).

Further deep owing to change in soil texture i.e. from fine to moderately coarse texture, particularly between 150 - 200 cm depth, MHC shows sharp decrease and almost 46% of the command area has MHC ranging between 40% and 50% (Fig. 8.13). Detailed quantitative estimates, based on various MHC ranges and their respective aerial coverage for various soil depths are given in Table 8.3.

Table 8.3 Aerial Distribution Pattern of Moisture Holding Capacity at Various Depth Range, Chalthan Branch Canal Command Area.

Depth (in cm)	Range of Moisture Holding Capacity					
	< 25 %		25 - 50 %		> 50 %	
	Area in ha.	(%)	Area in ha.	(%)	Area in ha.	(%)
0 - 50	0.87	0.01	696.54	6.36	10247.10	93.63
50 - 100	1.26	0.01	793.16	7.25	10150.09	92.74
100 - 150	0.00	0.00	1957.62	17.89	8986.89	82.11
150 - 200	9.20	0.08	5057.66	46.21	5877.64	53.70

Available Water Holding Capacity (AWHC)

Soil's water storage characteristics are very important for irrigation management. Since the size and number of pores in soil are directly related to soil texture (particle sizes), soil texture is the prime indicator for the amount of water any soil can hold (Klocke and Hegert, 1990).

The soil moisture between the field water capacity and the moisture of permanent wilting is the total available water for plant use. The depth of this available water per unit of soil depth is referred as; the available water holding capacity of soil. Soil depth, texture, structure, type of clay minerals and thickness of soil are the factors, which greatly influence the available water holding capacity of the soil (Miller and Donahue, 1997).

For the evaluation of available moisture holding capacity of Chalthan Branch Canal Command Area author has relied on the data collected by the State Soil Survey Department. The data on AWHC of soils of the study area is ranging between 9 and 15.3 cm (Table 8.4). The lower portion of command area i.e. between Sanki village and Gangadhara Khadi is characterised by the lower available water holding capacity, which is very well correlated with the soils texture.

Table 8.4 Distribution of Available Water Holding Capacity in Chalthan Branch Canal Command Area.

Village	AWHC (cm)	Village	AWHC (cm)
Mota	14.5	Jolwa	13.6
Bagumara	14.4	Kadodara	14.4
Haldharu	14.4	Pali	14.4
Sanki	9.0	Chikhli	14.4
Kantali	14.4	Dungar	15.3
Ruwa	14.4	Isanpur	14.4
Khoj-Pardi	14.4	Tantithaiya	14.7
Khanpur	15.3	Mavachhi	14.4

Source: Soil Survey Division, Surat

Infiltration

Rate of infiltration of water through the soil surface is extremely important in determining the total water storage in a soil profile (Garg and Gupta, 1997). The infiltration capacity is greatly influenced by soil structural stability, especially in its upper horizon. In addition the factors like; organic matter content, soil texture, the kind and amount of swelling clays, soil depth, tendency to form crust and the presence of impervious soil layers, have influence on the infiltration capacity (Brady, 1990).

It is an established fact that continuous and in excess application of water on soil surface drastically reduces the infiltration. Also the infiltration rate varies greatly with the soil texture; very low infiltration rate (< 0.25 cm/hr) is associated with the soils having very high content of clay percentage while high infiltration rate (> 2.5 cm/hr) is associated with the sandy soils (USDA, 1975).

The observation on infiltration rate, made by the State Soil Survey Department using standard Percolation test procedure for the soil of the study area shows considerable variations (Table 8.5). The infiltration rate varies in between 0.12 and 0.44 cm/hr and the highest infiltration rate was observed around Mirapur village (0.44 cm/hr) while lowest rate at Chikhli (0.12 cm/hr), this variation in rate of infiltration may be attributed to the change in percentage of clay content.

Table 8.5 Soil Infiltration Rate at Various Locations in Chalthan Branch Canal Command Area.

Village	Infiltration (cm/hr)
Mirapur	0.44
Pali	0.32
Chikhli	0.12
Pardi	0.43
Haldharu	0.36
Ruwa	0.31
Jolwa	0.32
Tantithaiya	0.31
Sanki	0.33
Min.	0.12
Max.	0.44
Avg.	0.33

(Source: Soil Survey Division, Surat)

Hydraulic Conductivity

The flow of water under saturated condition is determined by hydraulic conductivity or permeability (Brady, 1990). Any factor affecting the size and configuration of soil pores will influence hydraulic conductivity. Soils' texture and structure are the properties to which hydraulic conductivity is most directly related. Sandy soils with poor water holding capacity is characterized by higher (> 25.4 cm/hr) hydraulic conductivity, while clayey with nearly impervious soils have extremely low (<0.0025 cm/hr) hydraulic conductivity (Smith and Browing, 1946).

For evaluation of soil hydraulic conductivity in the study area the author has relied on the State Soil Survey Department data (APPENDIX VI) and has developed Iso-hydraulic conductivity contour maps for various depths (Fig. 8.14 - 8.17). The Iso-hydraulic conductivity map for the soil depths 0-50 and 50-100 cm (Fig. 8.14 and 8.15) by and large denotes uniform hydraulic conductivity i.e. 0.2 cm/hr, except lower extremity of the command area viz. south east of Sanki village, where the iso-hydraulic contours are as high as 1.4 cm/hr. This observed higher range may be attributed to the presence of moderate to coarse textured soils. While the Iso-hydraulic conductivity maps (Fig. 8.16 and 8.17) for the soil depths of 100-150 and 150-200 cm shows an overall increase in hydraulic conductivity ranging between 0.6 and 0.2 cm/hr. This can be very well correlated with the soil texture as with in the study area soil becomes coarser with increase in depth.

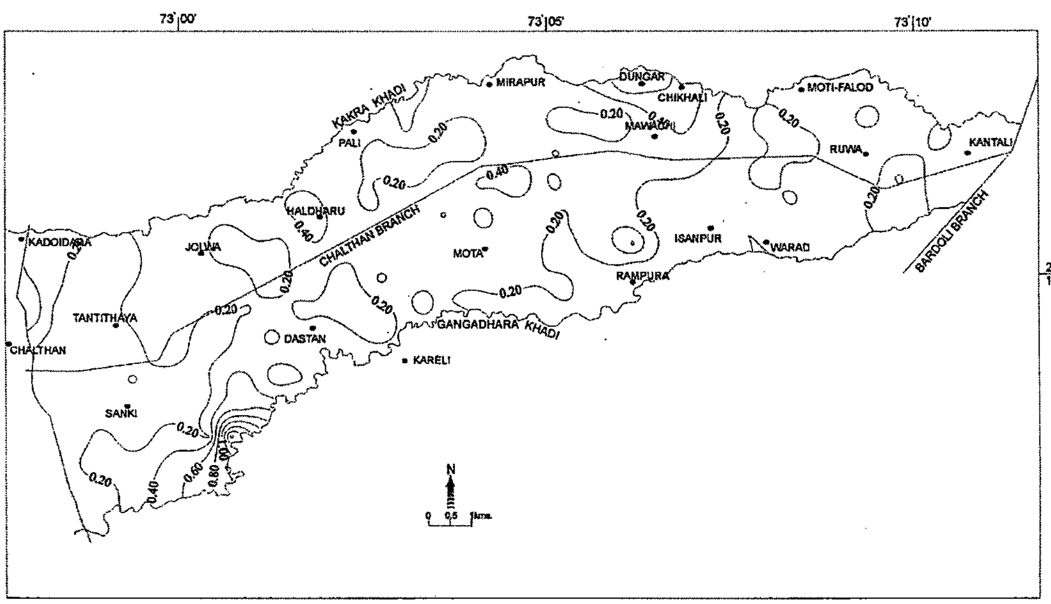

Fig. 8.14 Soil Iso-Hydraulic Conductivity Contour Map, Chalthan Branch Canal Command Area (0 - 50 cm).

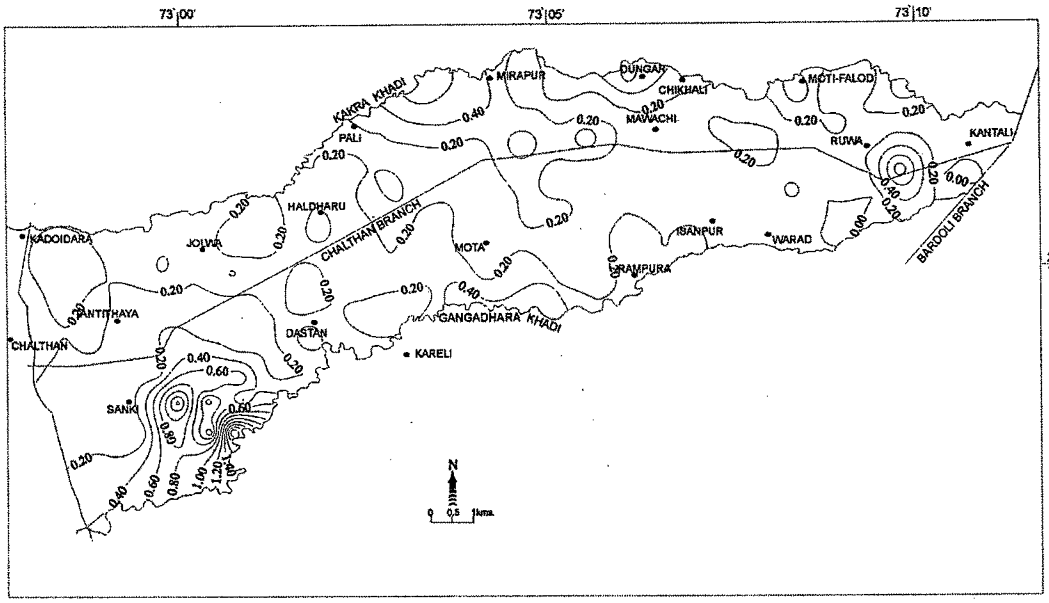

Fig. 8.15 Soil Iso-Hydraulic Conductivity Contour Map, Chalthan Branch Canal Command Area (50 - 100 cm).

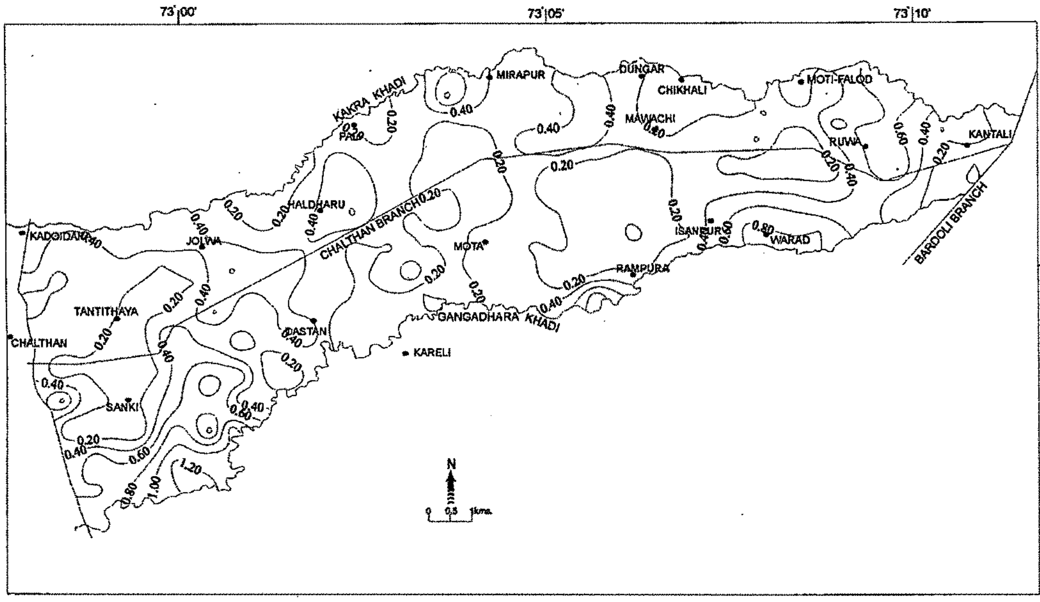

Fig. 8.16 Soil Iso-Hydraulic Conductivity Contour Map, Chalthan Branch Canal Command Area (100 - 150 cm).

The spatial distribution pattern of the various range of hydraulic conductivity at various depths of soil in the study area (Table 8.6) shows that more than 90% of the study area is having hydraulic conductivity less than 0.5 cm/hr upto 100 cm soil depth. Whereas the hydraulic conductivity tend to increase, wherein almost 50% of the study area shows hydraulic conductivity in the range of 0.5 - 1.0 cm/hr between 150 and 200 cm soil depths.

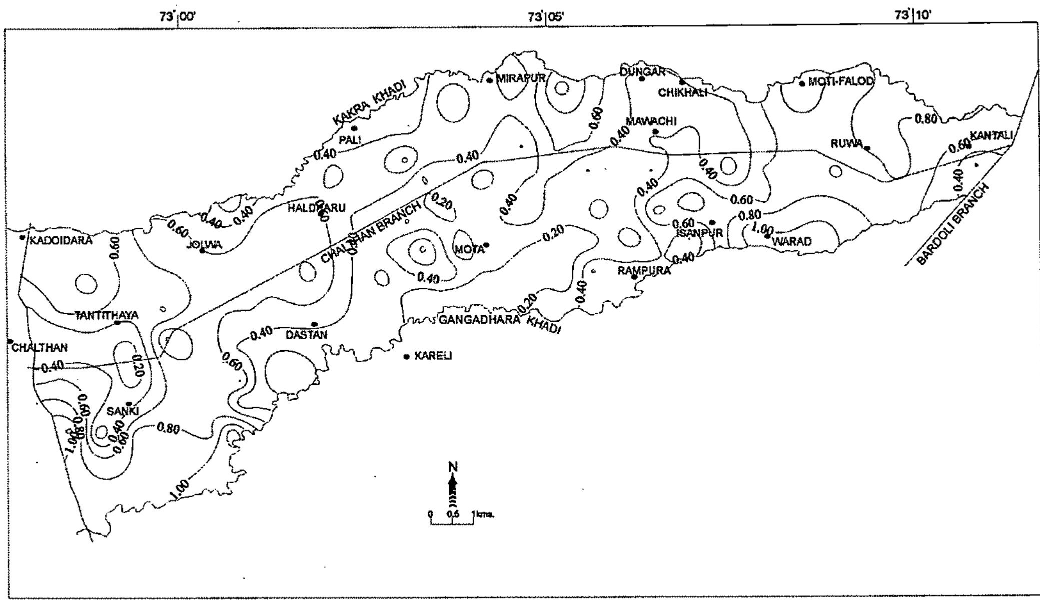

Fig. 8.17 Soil Iso-Hydraulic Conductivity Contour Map, Chalthan Branch Canal Command Area (150 - 200 cm).

Table 8.6 Aerial Distributions of Hydraulic Conductivity at Various Depth Range in Chalthan Branch Canal Command Area.

Soil Depth (cm)	Range in Hydraulic Conductivity (cm/hr)					
	< 0.5		0.5 - 1.0		> 1.0	
	Area in ha.	(%)	Area in ha.	(%)	Area in ha.	(%)
0 - 50	10547.88	96.38	358.33	3.27	38.29	0.35
50 - 100	10089.02	92.18	723.97	6.61	131.52	1.21
100 - 150	9070.00	82.87	1707.63	15.60	166.88	1.52
150 - 200	5170.28	47.24	5510.15	50.35	264.08	2.41

SOIL CHEMISTRY

Quality of water, decides the use of water for various purposes such as domestic, industrial and irrigation, like wise the soil chemistry decides the agricultural and irrigation utility of soil with its suitability to particular crops. Various chemical constituents of soils can affect the plant growth, depending upon their concentration in a soil profile. The study of chemistry of soil holds vital significance in understanding the various physicochemical processes influencing the physical, hydraulic and fertility characteristics of the soils.

In this presented study the author has attempted to chemically examine the soils of Chalthan Branch Canal Command Area to assess the impact of irrigation on the soil regime, by evaluating the various parameters viz. pH, Electrical Conductance, Soluble Cations (Ca^{++}, Mg^{++}, Na^{+}, and K^{+}) and Anions (Cl^{-}, CO_3^{--}, HCO_3^{-}, and SO_4^{--}), Exchangeable Cation (Na & K), Cation Exchange Capacity (CEC), Exchangeable Sodium Percentage (ESP), Organic Carbon (OC), P_2O_5, K_2O_5, Organic Matter (OM), and nutrients (N, P, and K). To determine these parameters author has used standard analytical methods and equations suggested by Jackson (1973), Hesse (1994) and FAO (1960). Detailed quantitative data on various parameters for the study area soils are given in APPENDIX VII & VIII for pre and post monsoon (1999) seasons respectively.

Soil Reaction (pH)

One of the most important physiological characteristics of the soil solution is its reaction. When an acid is dissolved in water, it releases hydrogen ions (H+) which makes solution acidic. When an alkali dissolved in water, it releases hydroxyl ion (OH^-), which makes the solution alkaline. Equivalent quantities of all acids or alkalies contains the same number of total hydrogen and hydroxyl ions respectively, but when they are dissolved in water they do not ionize to the same extent. This is because of greater number of hydrogen ions or hydroxyl ions in a strong acidic or alkalic forms respectively (Rai, 1995).

There are many factors which causes major fluctuations in soil pH viz. carbon dioxide, removal of bases, effects of fertilizers, rainfall etc as well as drying of soil above the field temperature can also cause minor fluctuation in pH of soil (Rai, 1995).

Author has made an attempt to evaluate soil pH for its seasonal behaviour by utilizing the Command Authority's available data (pre monsoon 1991) and the authors own measured data for the pre monsoon 1999 and post monsoon 1999 at various soil profile depths i.e. 0-50, 50-100, 100-150 and 150-200 cm.

Taking in to account the typic soils (Table 8.7), the pH of clayey textured dominated soils at Mota, Khoj-Pardi and Kantali villages is ranging between 7.5 and 8.0. While pH of Bagumara and Sanki soils is slightly higher and ranging between 7.9 and 8.1, here soils are characterised by loam to sandy loam texture. These observations on pH variation categorically indicate to this fact that the percentage of soil fractions does affect the pH of soils.

Soil pH data for the pre monsoon 1991 (Fig. 8.18) shows, pH is ranging between 7.6 and 8.6 within a depth of 0-50 cm. The central part of the study area i.e. south of Mirapur is marked by a maxima having pH > 8.6, similarly the extreme western part around Chalthan also has pH > 8.6. Rest of the area soil pH is between 7.6 and 8.0. Contrary to this pre monsoon 1999 data shows slight change in pH of soil.

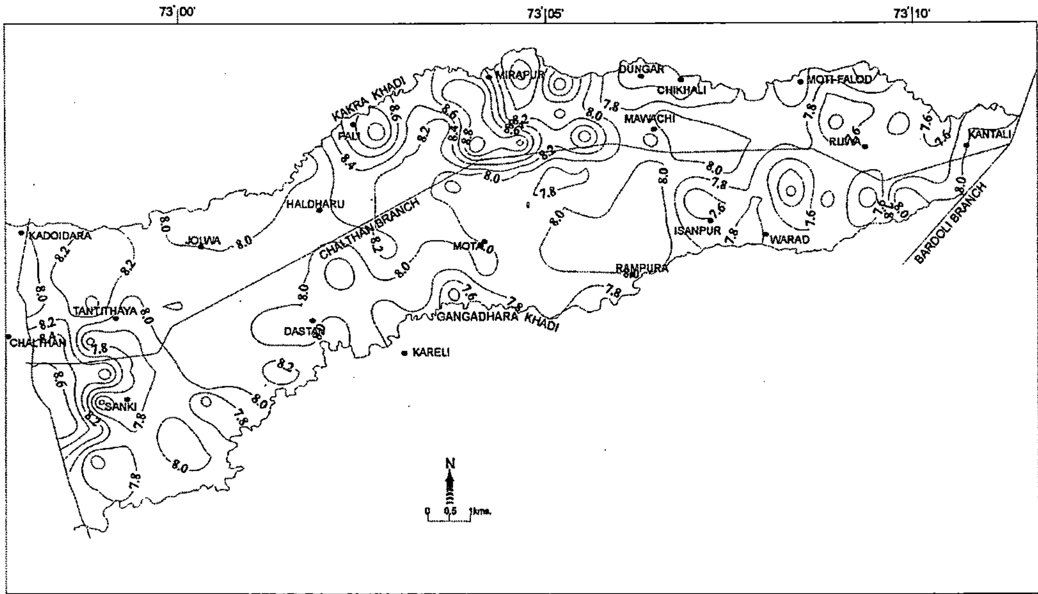

Fig. 8.18 Aerial Distribution of Soil pH During Pre monsoon 1991 in Chalthan Branch Canal Command Area (0-50 cm).

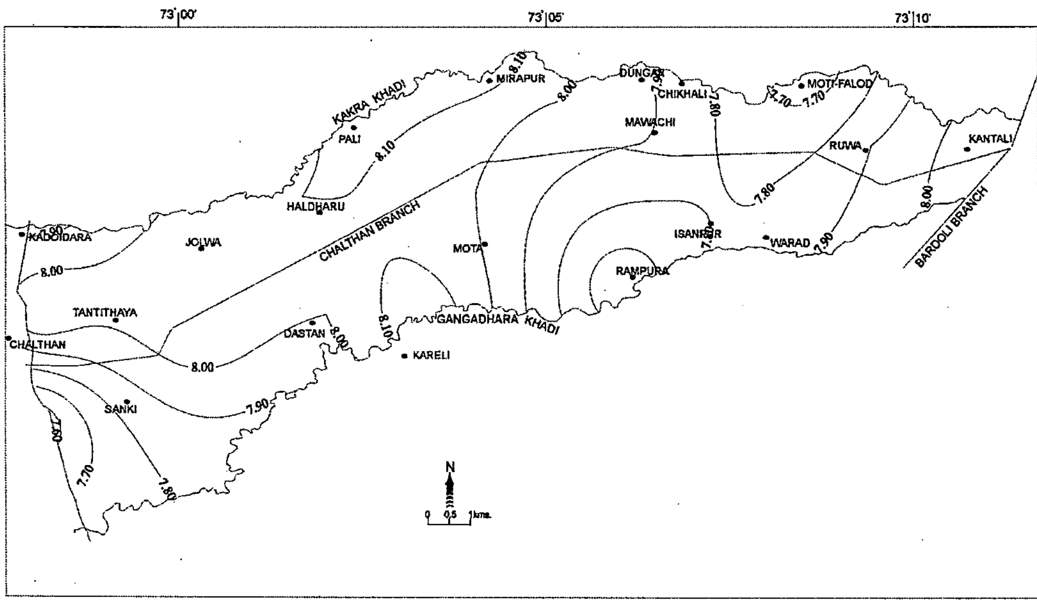

Fig. 8.19 Aerial Distribution of Soil pH During Pre monsoon 1999 in Chalthan Branch Canal Command Area (0-50 cm).

Pre monsoon, 1999 the pH is ranging between 7.6 and 8.1 during in depth zone of 0-50 cm (Fig. 8.19). The upper command area show marked increase in pH while the central and lower command has recorded decrease in pH. Other depth zones show more or less same behaviour pattern in soil pH during pre monsoon 1991 period (Fig. 8.20 - 8.21) as the surface soil pH. However on comparing pH data of 1991 and 1999 periods there is an overall reduction in soil pH from 1991 to 1999, this change in pH may be attributed to the increase in carbon dioxide due to an overall rise in water table (Rai, 1995).

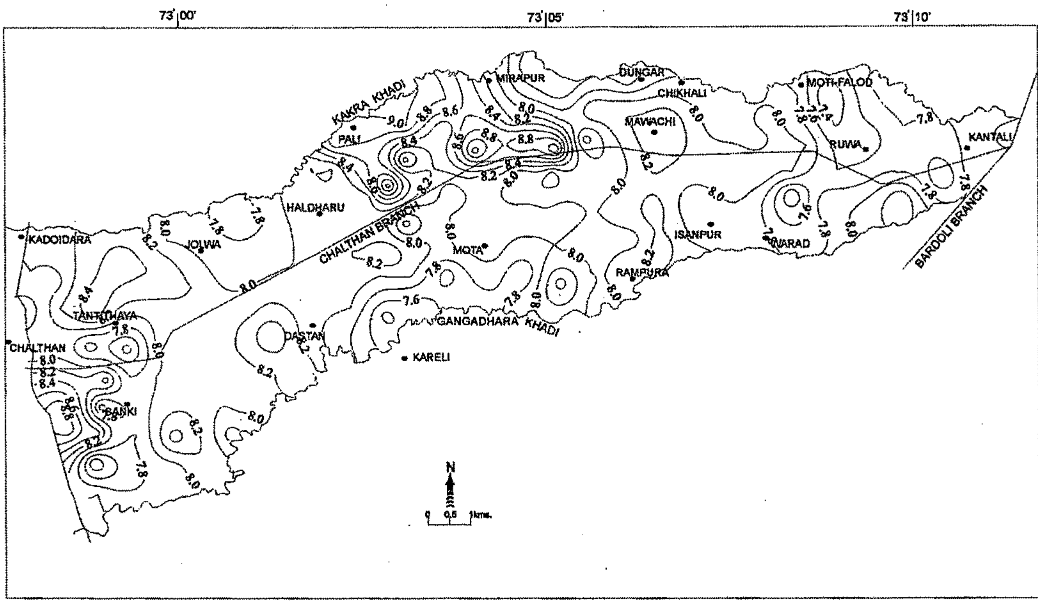

Fig. 8.20 Aerial Distribution of Soil pH During Pre monsoon 1991 in Chalthan Branch Canal Command Area (100-150 cm).

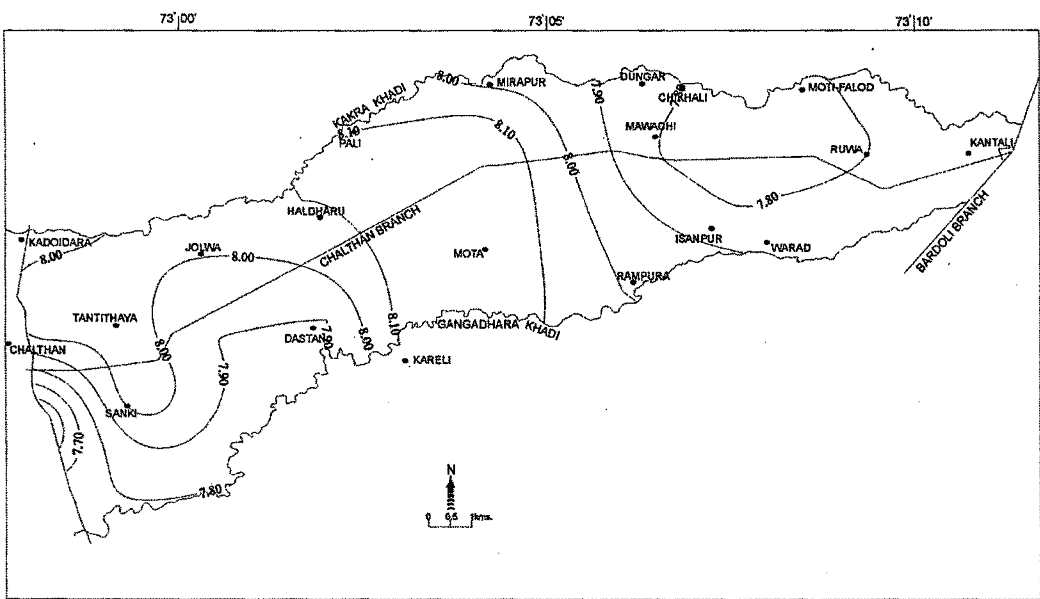

Fig. 8.21 Aerial Distribution of Soil pH During Pre monsoon 1999 in Chalthan Branch Canal Command Area (100-150 cm).

In order to evaluate the lateral trend in pH across the study area, author has constructed a spatial profile along A - A' transact for various depths (Fig. 8.22). The pH profiles clearly shows that with in a depth of 0-50 cm pH of soil is considerably high during pre monsoon 1991 than the pre monsoon 1999 except the area around Ruwa village. While pH levels within a depth of 50-200 cm, remained more or less same for pre monsoon 1991 and 1999, except the command area between Mota and Ruwa villages, displaying slight increase. The seasonal fluctuations in pH from pre monsoon to post monsoon (1999) the surface soils (0-50 cm) exhibits rise in pH while there is marginal decrease in pH with in a soil depth from 50 to 200 cm. This may be attributed to the change in field temperature, as during summer more carbon dioxide is evolved due to greater microbial activity; and roots of plants gives away acid exudates; thus increase in acidity. The reverse is true in spring or winter seasons (Rai, 1995). A summary on observed pH for different soil series of command area for various depths is given in Table 8.7.

Table 8.7 Secular and Seasonal Variations in Soil pH in Chalthan Branch Canal Command Area.

Soil Series *Soil Type* (Village)	Depth (cm.)	pH of soil		
		Pre monsoon 1991*	Pre monsoon 1999	Post monsoon 1999
Kapletha *Clayey soil* (Mota)	0-50	7.6	8.0	7.8
	50-100	7.8	7.9	7.6
	100-150	7.9	8.2	7.8
	150-200	NA	7.8	7.6
Sanki *Clayey soil* (Kantali)	0-50	7.6	8.1	7.4
	50-100	7.6	7.7	7.8
	100-150	7.7	7.9	7.6
	150-200	NA	8.0	7.7
Deladwa *Clayey soil* (Khoj-Pardi)	0-50	7.5	7.9	7.6
	50-100	7.9	8.0	7.8
	100-150	7.7	7.8	7.9
	150-200	NA	7.7	8.0
Devadh *Loamy soil* (Bagumara)	0-50	7.9	8.1	7.8
	50-100	8.1	8.0	7.8
	100-150	8.0	7.9	7.8
	150-200	NA	8.2	7.6
Magob *Clayey loam to Sandy loam* (Sanki)	0-50	8.0	7.9	7.6
	50-100	8.1	8.2	7.9
	100-150	7.9	8.1	7.7
	150-200	NA	8.2	7.6

* - Data source: State Soil Survey Dept., NA - Not Available

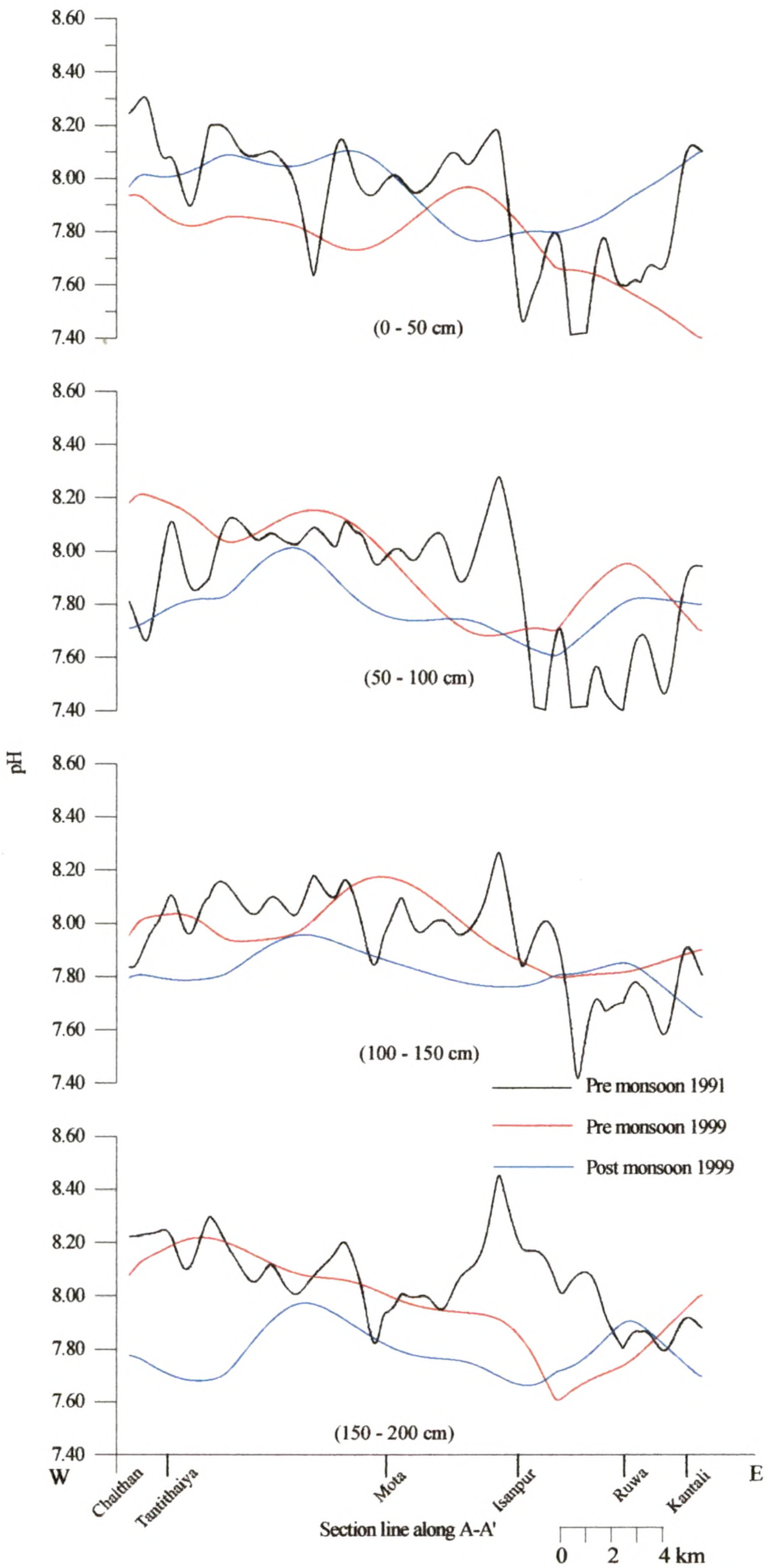

Fig. 8.22 Depth Wise Spatial and Temporal Behavioral Pattern of Soil pH in Chalthan Branch Canal Command Area (along A-A' transact).

Electrical Conductivity (EC)

Soluble salts in soil or water cannot be seen. Salts are solids when dry and sometimes can be seen on the surface of soils during drying conditions. The electrical conductivity is a measure to determine soluble salts. Presence of salts directly affects plant growth by osmotic phenomena. High salt concentration increases the forces that hold water in the soil and requires plant roots to expand more energy to extract the water. During drying period, salt in soil solution may become concentrated enough to kill plant by "pulling" water from them (Miller and Donahue, 1997). Soluble salts also affects the plant uptake of phosphorus; sodium, potassium and especially calcium depress the solubility of phosphate in soil, and chloride and nitrate have a similar effect; sulphate however, particularly in high concentration, increases phosphate solubility (Hesse, 1994).

At a given EC the adverse effects to plant growth is more in fine textured soils than coarse textured soils because coarse textured soils have low moisture retention and high permeability, whereas fine textured soils have high moisture retention and generally low permeability (Garg and Gupta, 1997).

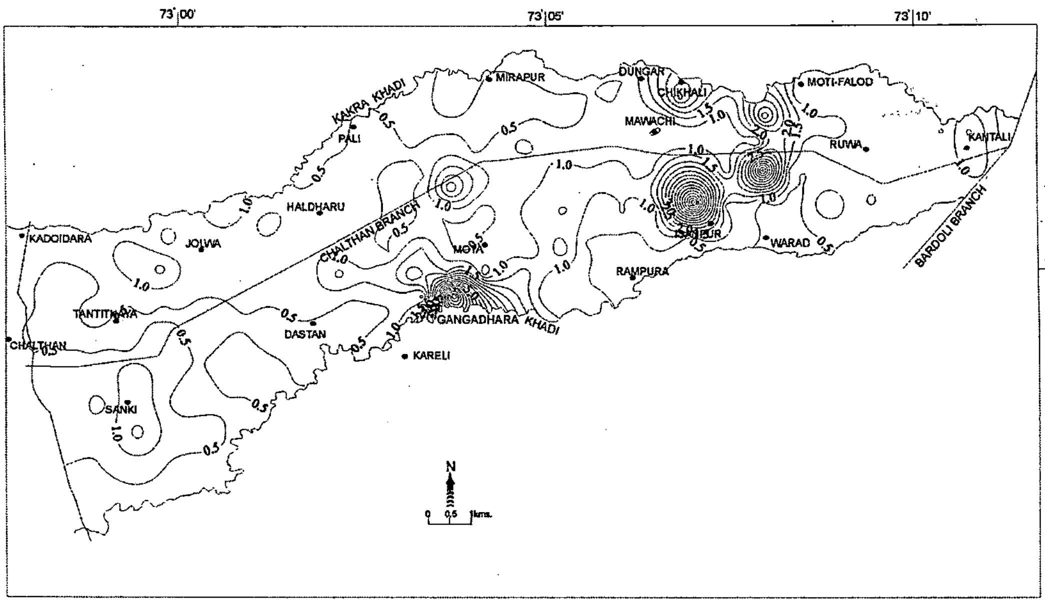

Fig. 8.23 Aerial Distribution of Soil EC (mmhos/cm) During Pre monsoon 1991 in Chalthan Branch Canal Command Area (0-50 cm).

Author has studied the spatial and temporal behaviour on electrical conductivity with in the study area by comparing the EC levels for the periods, pre monsoon 1991 and pre & post monsoon 1999. Fig. 8.23 shows aerial distribution of EC during pre monsoon 1991 for the soil depth 0-50 cm, this map shows that an overall EC is ranging between 0.5 and 1.0 mmhos/cm except the area south of Mota, north of Isanpur and around Chikhli villages. These obtained EC maximas are attributed to higher concentration of salts within the soils. Observations on EC for the surface soils (0-50 cm) pre monsoon 1999 shows 0.4 - 1.8 mmhos/cm EC range (Fig. 8.24), which tend to decrease during post monsoon period due to rainfall recharge causing dilution in salt content.

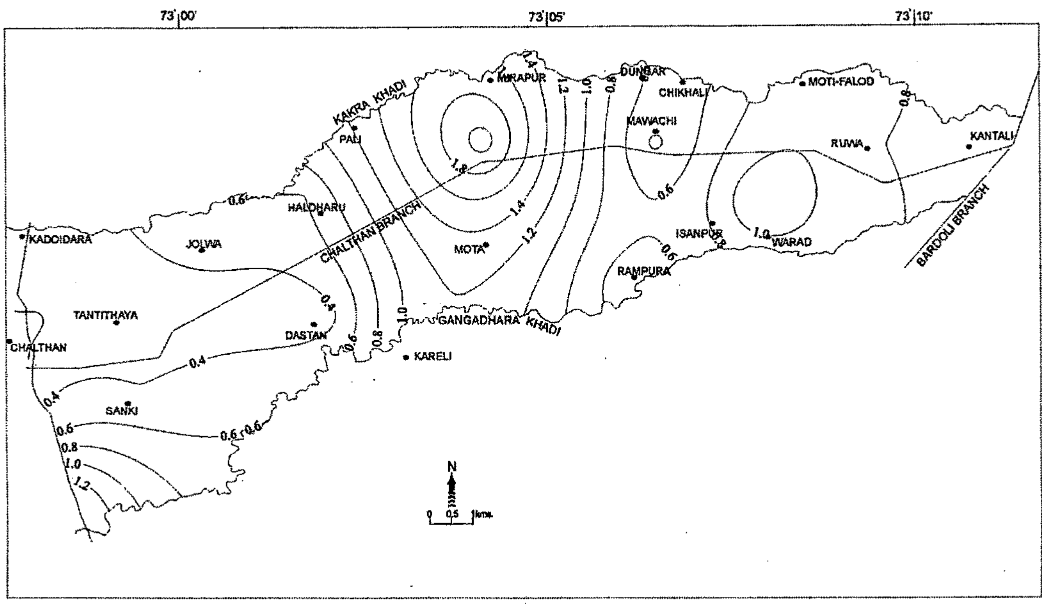

Fig. 8.24 Aerial Distribution of Soil EC (mmhos/cm) During Pre monsoon 1999 in Chalthan Branch Canal Command Area (0-50 cm).

In order to evaluate spatial and seasonal behaviour of EC the author has prepared a longitudinal cross sectional profile along A-A' transact for various soil depths (Fig. 8.25). It can be seen from the EC profiles that during 1991 (pre monsoon) the average EC values across the study area was < 2 mmhos/cm, except the two deceptive peaks at Mota and Ruwa villages. The subsequent overall decrease in EC values during pre and post monsoon seasons (1999), may be attributed to the leaching of salts through various measures, adopted by the command area authority, to nullify the effects of soluble salts on plant growth in the past 9 years. The available peaks of higher EC values near Mota and Ruwa villages are on account of excessive salt built up due to waterlogging problems. So far as seasonal changes in EC levels are concern, the profile does not reveal much changes in EC except at a depth of 150-200 cm, where it shows considerable reduction in EC between Tantithaiya and Mota villages. This seasonal change in EC may be attributed to the flushing action of salts through rainfall and applied irrigation water (Pariente, 2001).

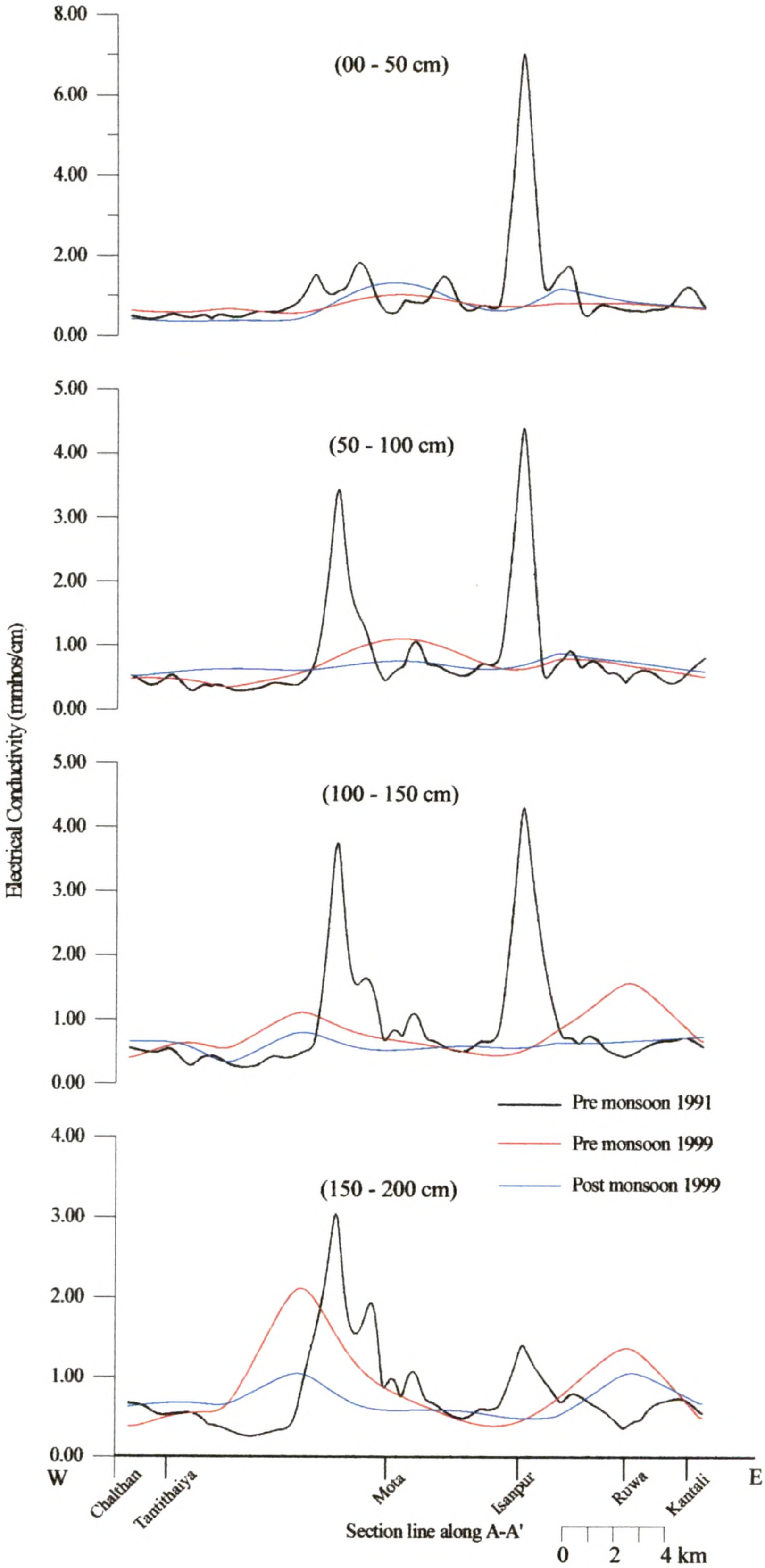

Fig. 8.25 Depth Wise Spatial and Temporal Behavioral Pattern of Soil EC in Chalthan Branch Canal Command Area (along A-A' transact).

A summary on observed electrical conductivity for different soil series of command area at various depths is given in Table 8.8.

Table 8.8 Secular and Seasonal Variations in Soil EC in Chalthan Branch Canal Command Area.

Soil Series *Soil Type* (Village)	Depth (cm.)	Electrical Conductivity (mmhos/cm)		
		Pre monsoon 1991*	Pre monsoon 1999	Post monsoon 1999
Kapletha *Clayey soil* (Mota)	0-50	0.60	2.10	1.46
	50-100	0.75	1.50	0.97
	100-150	0.28	0.85	0.60
	150-200	NA	1.00	0.80
Sanki *Clayey soil* (Kantali)	0-50	0.47	0.68	0.65
	50-100	0.41	0.52	0.60
	100-150	0.41	0.68	0.75
	150-200	NA	0.50	0.68
Deladwa *Clayey soil* (Khoj-Pardi)	0-50	0.65	0.81	0.80
	50-100	0.60	0.72	0.75
	100-150	1.20	1.80	0.70
	150-200	NA	1.60	1.20
Devadh *Loamy soil* (Bagumara)	0-50	0.30	0.37	0.70
	50-100	0.32	0.32	0.65
	100-150	0.31	0.49	0.25
	150-200	NA	0.51	0.60
Magob *Clayey loam to Sandy loam* (Sanki)	0-50	0.33	0.41	0.45
	50-100	0.27	0.72	0.70
	100-150	0.26	1.10	0.98
	150-200	NA	0.91	0.80

* - Data source: State Soil Survey Dept., NA - Not Available

IONIC CONCENTRATION

The soluble ions found in soil consist of sodium, calcium, magnesium and potassium among cations and chloride, bicarbonate, carbonate, sulphate and nitrate among anions (Rai, 1995). The primary source of soluble ions within the soil is of weathering phenomena and secondary source, through surface water or groundwater. As excessive accumulation of a particular ion or a group of ions in the form of soil solution produces harmful effects in the soil (Rai, 1995), therefore it becomes imperative to evaluate the ionic available content and its probable effects in soil. Detailed analytical data on ionic content of soil samples are given in APPENDIX VII & VIII.

Soluble Cations

Of the cations sodium, calcium and magnesium are usually the most important and potassium is usually occurring in small amounts (Hesse, 1994). Scrutiny of quantitative data on various cations is indicative of the order of concentration of the soluble cations in soils of the study area as Na > Mg > Ca > K. Brief characterization of each cations is given as under:

Sodium: Sodium is by far in higher proportion is found in soils of the study area, which is the most dominating ion among all the cations. The minerals belonging to feldspar and feldspathoid groups are the major source of sodium in groundwater as well as the soil. In the study area sodium is ranging between 1.30 and 8.58 meq/l during pre monsoon 1999, while during post monsoon it is ranging between 1.24 and 16.2 meq/l. The higher concentration of sodium is observed at the localities viz. Khoj-Pardi, Dastan, Mota and Tanti, which may be attributed to the development of salts, in accordance with high groundwater table and also due to Base Exchange reactions where by sodium replaces other cations in clay minerals. The concentration of sodium shows an overall decrease from pre to post monsoon 1999, except the locality around Dastan. This reduction in concentration of sodium from pre to post monsoon may be attributed to the leaching of salts through precipitation and applied irrigation water (Rai, 1995).

Calcium: Calcium occurs widely and abundantly in soils as the carbonate, phosphate, silicate, fluoride and sulphate, among which carbonate is the most dominant source of calcium (Hem, 1959). Calcium is typically deficient in very acidic soils, but can be deficient also in sodium rich alkali soils; where it may be precipitated as the carbonate and can also become involved in a complementary ion effect. In plants calcium is essential for the growth of meristems and root tips and tends to accumulate in leaves as calcium pectate (Hesse, 1994). Albrecht and Smith (1952) considered that calcium deficiency is a prominent feature of the adverse effect of soil acidity upon plant growth. In the study area calcium is ranging between 0.17 and 3.5 meq/l (pre monsoon) while during post monsoon it is between 0.13 and 2.41 meq/l; this observed reduction in calcium from pre to post monsoon season may be attributed to the dissolution effect due to precipitation and excessive irrigation. The command area around Mota and Tanti villages exhibits high calcium content.

Magnesium: Magnesium is absorbed by plants in the form of divalent Mg^{2+} ions (Rai, 1995). In soils, magnesium is principally associated with the clay minerals, it sometimes also occur as carbonates. Minerals like olivine, amphiboles and pyroxenes are important source of magnesium (Hem, 1959). Magnesium is an essential constituent of chlorophyll and also involved in enzyme reactions. A deficiency of magnesium in plants typically causes chlorosis (Reith, 1963). Soils of the command area posses' rich concentration of magnesium after sodium and its concentration ranges between 0.19 and 7.10 meq/l during pre monsoon and between 0.16 and 3.04 meq/l during post monsoon. This comparative reduction in magnesium content during post monsoon season may be because of leaching action through rainfall and irrigation (Hesse, 1994).

Potassium: The potassium content of soil depends primarily upon the parent material i.e. source rock containing potash bearing feldspar, feldspathoids & mica minerals and degree of weathering. In plants potassium is an essential element associated with metabolism (Hesse, 1994). High concentration of potassium in a soil solution affects the osmotic pressure of that solution and makes the water less available to plants (Wallace, 1958). The concentration of potassium is comparatively very less among the soluble cation in the study area, and is ranging between 0.03 and 1.24 meq/l (pre monsoon) while 0.06 and 1.26 meq/l (post monsoon), these measured value for both the season does not show much fluctuation in potassium. This extremely low observed concentration of potassium is possibly on account of its non-reactant nature than the sodium ions and could also be due to conversion of montmorillonite to illite thereby removal of potassium from natural water (Mason, 1952).

Soluble Anions

Of the anions chloride and sulphate are considerable to be the most dominant anions in soil/water solution. Scrutiny of quantitative data on various anions has indicated $Cl > HCO_3 > SO_4$ order of concentration of the soluble anions in soils of the study area. Carbonate concentration has been found to be very low. Brief characterization of each anion is given as under:

Chloride: Chlorine exists in soils almost entirely as chloride ion, which is highly soluble and mobile. And also has little tendency to react with anything in soil. Its role in plants is believed to be osmotic and in balancing cell cationic charges. Chloride may accumulate in toxic amounts. Soluble salts, which hinder plant growth, usually have chloride as the most numerous anion (Miller and Donahue, 1997). The chloride is the most dominant among the anions in study area. The chloride concentration in the soil during pre monsoon 1999 is found to be ranging between 1.24 and 16.8 meq/l while during post monsoon it is between 1.48 and 7.49 meq/l. In the study area higher concentration of chloride is observed around the localities viz. Mota, Sevni and Dastan. These higher concentrations may be attributed to the higher values in EC (Hesse, 1994).

Carbonate and Bicarbonate: Soluble carbonate is unlikely to occur if the soil pH is less than 9.5 (Hesse, 1994); as there is not such area having alkali environment, the carbonate concentration in the study area is negligible. The bicarbonate concentration is the second most among the anions and is ranging between 0.67 and 9.6 meq/l during pre monsoon while during post monsoon it is ranging between 0.61 and 5.85 meq/l. Exceptionally higher levels of bicarbonate is observed around Mota and Dastan villages. Further the bicarbonate concentration also varies with the soil depth.

EXCHANGEABLE CATIONS

As the clay colloids are negatively charged, they attract positively charged ions- cations, or bases, which are also replaceable, therefore denoted as exchangeable bases or exchangeable cations and the phenomenon is known as cation exchange (Rai, 1995). Cation exchange is an important reaction in soil fertility, in causing and correcting soil acidity and basicity, in altering soil physical properties, and as a mechanism in purifying or altering percolating waters (Miller and Donahue, 1997).

Generally a soil leached with a salt solution has a capacity to adsorb the cations of the percolating solution and also to liberate an equivalent amount of other cations. Different cations have different power of replacement, depending upon their dominance (Kelley, 1964). The predominant cations involved in exchange are hydrogen, calcium, magnesium, potassium, sodium and ammonium. Among these exchangeable cations, the author has evaluated exchangeable sodium and potassium which is described as under:

Exchangeable Sodium (ES)

The exchangeable sodium markedly influences the physical and chemical properties of the nonsaline-alkali soils (Rai, 1995). In order to identify the level of exchangeable sodium under seasonal changes; author has analyzed the soil samples for both the pre and post monsoon seasons and has found that the data does not show much variation in the exchangeable sodium content (APPENDIX VII & VIII). To study the secular changes in ES, author has accounted both pre monsoon 1991 and 1999 data and has developed Iso-ES contour diagrams (Fig. 8.26 and 8.27).

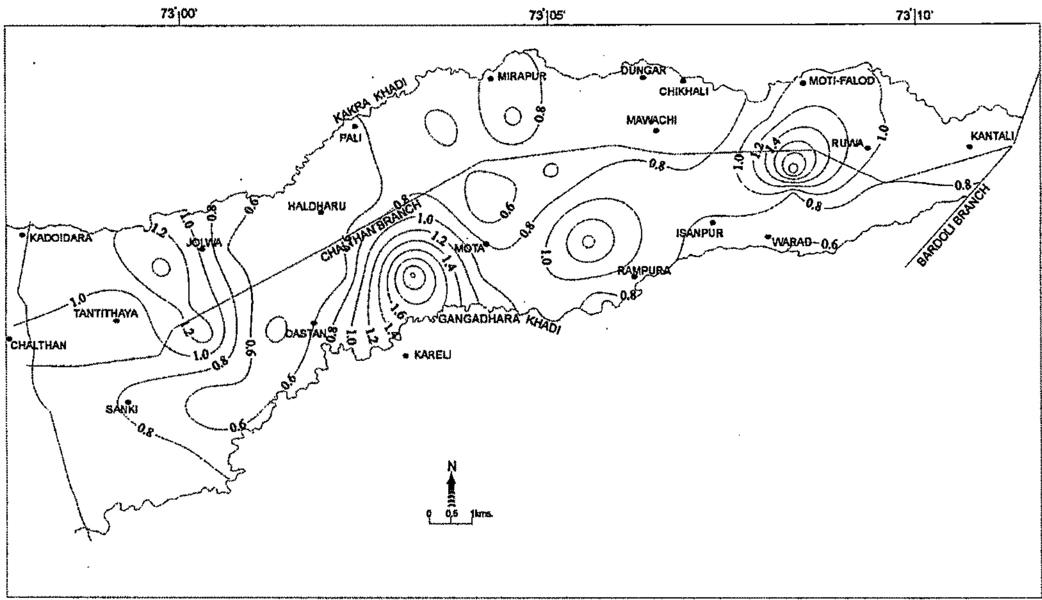

Fig. 8.26 Aerial Distribution of Soil Exchangeable Sodium (meq/100 gm) During Pre monsoon 1991, Chalthan Branch Canal Command Area (0-50 cm).

The exchangeable sodium during 1991 (Fig. 8.26) was ranging between 0.6 and 0.8 meq/100 gm. Exceptionally higher values in the form of well developed maxima can be seen near Mota (2.2 meq/100 gm) and Ruwa (2.0 meq/100 gm) villages. Further the level of exchangeable sodium tends to increase in the sub-soil horizons, between 50-100 cm (i.e. 4.6 meq/100 gm) near Mota. Also there is an overall increase in ES in the western parts of the command area. These higher levels of exchangeable sodium may be attributed to the saline nature of soils (Rai, 1995). While during pre monsoon 1999 scenario (Fig. 8.27) exchangeable sodium is found to be ranging between 0.80 and 1.2 meq/100 gm. The study of ES data of 1991 and 1999 suggests, slight increase in exchangeable sodium throughout the study area from 1991 to 1999. Wherein the upper command area is marked with higher exchangeable sodium as compared to lower command area having development of maxima around Isanpur and Warad villages i.e. 2.0 meq/100 gm. This observed higher levels in exchangeable sodium in upper command area may be attributed to the presence of fine clayey soils, having poor drainability.

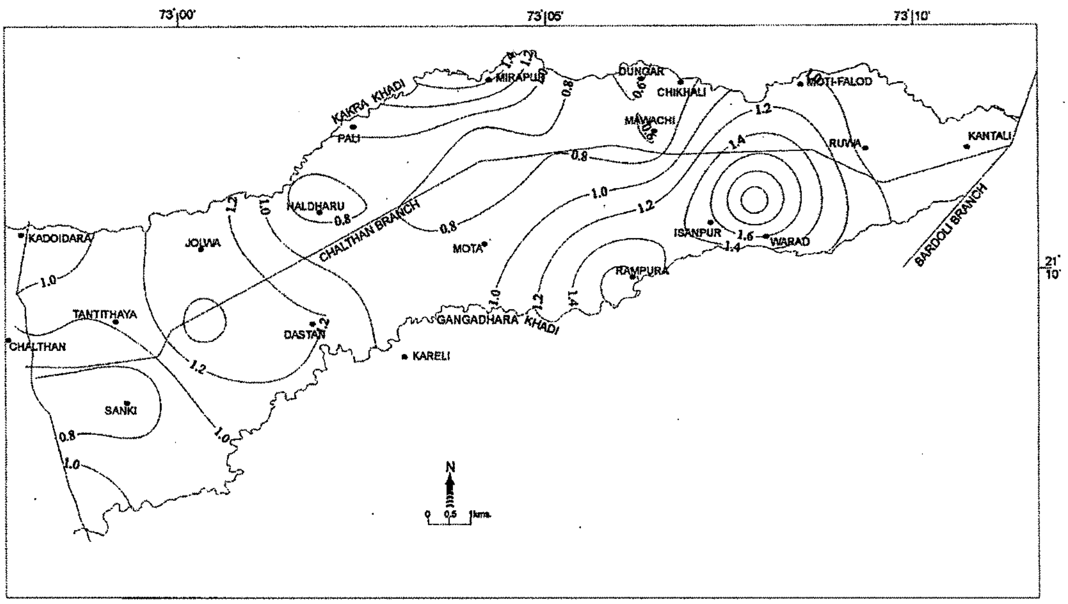

Fig. 8.27 Aerial Distribution of Soil Exchangeable Sodium (meq/100 gm) During Pre monsoon 1999, Chalthan Branch Canal Command Area (0-50 cm).

The plotted profiles of exchangeable sodium (Fig. 8.28) for evaluating spatial behaviour along A-A' transact; shows considerable variation in exchangeable sodium at different subsoil depths. The exchangeable sodium as seen by the presence of a sharp peak, west of Mota village is quite high during pre monsoon 1991 and within a soil depth of 0-150 cm. Whereas the area between Isanpur and Ruwa villages is marked by reduction in exchangeable sodium during this period.

So far as seasonal changes in ES are concern i.e. pre to post monsoon 1999, there is an over all reduction in ES. This may be attributed to leaching of the soils due to rainfall and applied irrigation water (Rai, 1995).

A summary of observed exchangeable sodium for different soil series at various depths is given in Table 8.9.

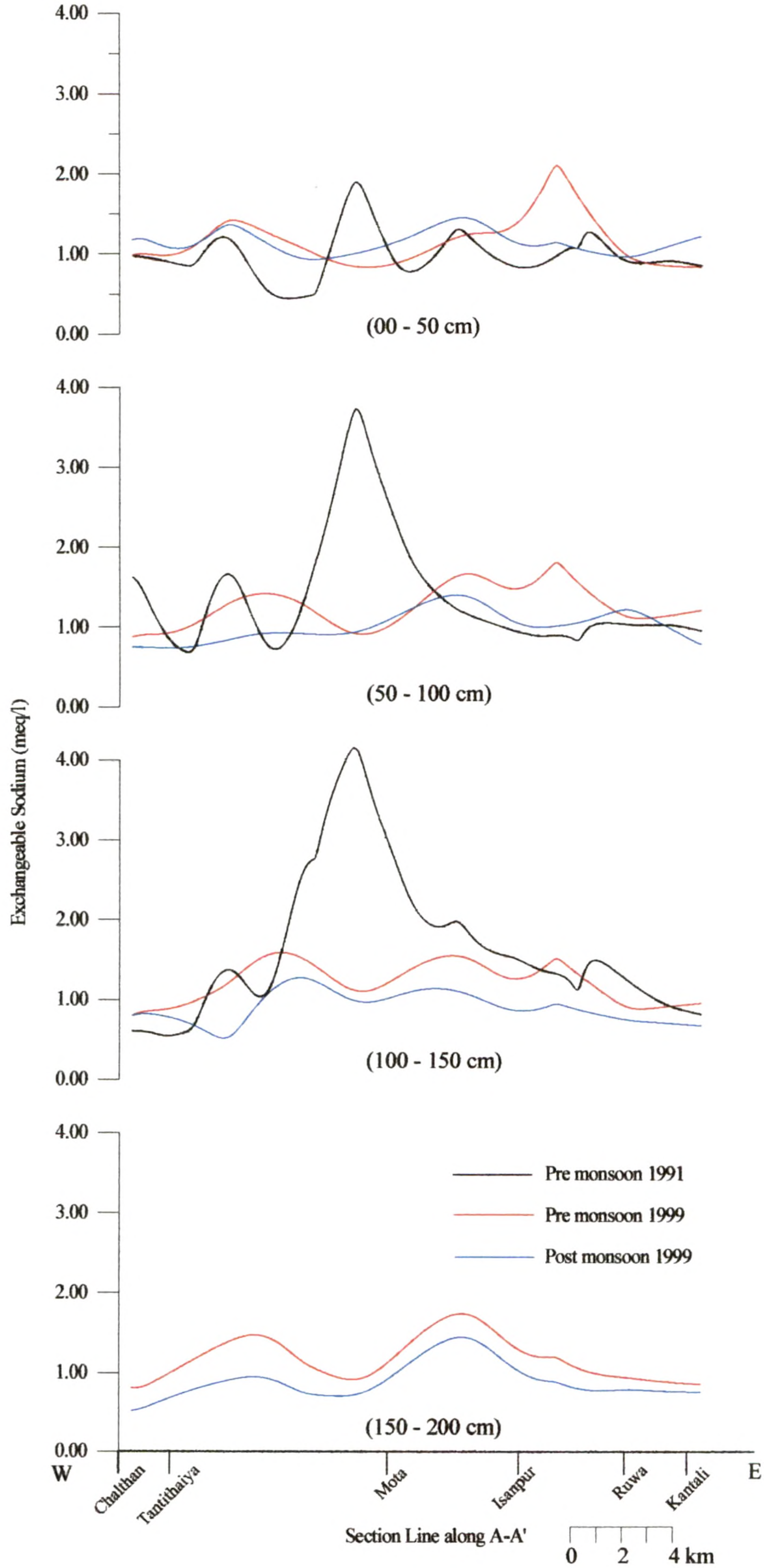

Fig. 8.28 Depth Wise Seasonal and Secular Behaviour of Exchangeable Sodium (meq/100 gm) of Soils, Chalthan Branch Canal Command Area (along A-A' transact).

Table 8.9 Secular and Seasonal Variations in Soil Exchangeable Sodium, Chalthan Branch Canal Command Area.

Soil Series *Soil type* (Village)	Depth (cm.)	Exchangeable Sodium (meq/100 gm) of soil		
		Pre monsoon 1991*	Pre monsoon 1999	Post monsoon 1999
Kapletha *Clayey soil* (Mota)	0-50	0.63	0.63	0.78
	50-100	1.90	1.10	1.30
	100-150	1.50	1.95	1.70
	150-200	NA	1.65	1.15
Sanki *Clayey soil* (Kantali)	0-50	1.00	0.82	1.20
	50-100	1.05	1.20	0.78
	100-150	0.93	0.96	0.68
	150-200	NA	0.86	0.76
Deladwa *Clayey soil* (Khoj-Pardi)	0-50	1.04	0.86	0.93
	50-100	0.83	1.08	1.30
	100-150	1.33	0.91	0.78
	150-200	NA	0.98	0.82
Devadh *Loamy soil* (Bagumara)	0-50	0.64	1.50	1.48
	50-100	0.43	1.35	0.87
	100-150	0.67	1.30	0.48
	150-200	NA	1.50	1.04
Magob *Clayey loam to Sandy loam* (Sanki)	0-50	0.96	0.64	0.58
	50-100	0.70	0.89	0.79
	100-150	0.34	1.09	1.20
	150-200	NA	1.20	0.98

* - Data source: State Soil Survey Dept., NA - Not Available

Exchangeable Potassium (EP)

Most potassium used by plants, in a given season comes from exchangeable potassium and soluble potassium. In most soils, particularly acid ones, exchangeable potassium is the major source of potassium to plants. The exchangeable potassium in soils is accumulated as a product of weathering of mica and feldspar minerals and as a plant residue released in the form of soil solution. Exchangeable potassium has a dominant role in the soils potassium fertility (Miller and Donahue, 1997). In the study area an overall concentration EP has been observed to be less, as compare to exchangeable sodium. The observed range of soils exchangeable potassium during pre monsoon 1999 is between 0.15 and 2.87 meq/100 gm while during post monsoon 1999 it is ranging between 0.15 and 1.53 meq/100 gm.

CATION EXCHANGE CAPACITY (CEC)

Cation-exchange capacity is defined as, the degree to which a soil can adsorb and exchange cations. Soil particles and organic matter have negative charges on their surfaces. Mineral cations can adsorb to the negative surface charges or the inorganic and organic soil particles. Once adsorbed, these minerals are not easily lost when the soil is leached by water and they also provide a nutrient reserve available to plant roots and can be replaced or exchanged by other cations (Miller and Donahue, 1997).

CEC is highly dependent upon soil texture and organic matter content. In general, the soils having more clayey nature and high organic matter, are characterized by higher CEC. Clays although has small particles but has a high ratio of surface area to volume. CEC also differ from clay to clay. Smectites have the highest CEC (80-100 meq/100 gm), followed by illites (15-40 meq /100 gm) and kaolinites (3-15 meq /100 gm) (Hesse, 1994; Miller and Donahue, 1997). Also, the CEC of most soils increases with an increase in soil pH (Jackson, 1973).

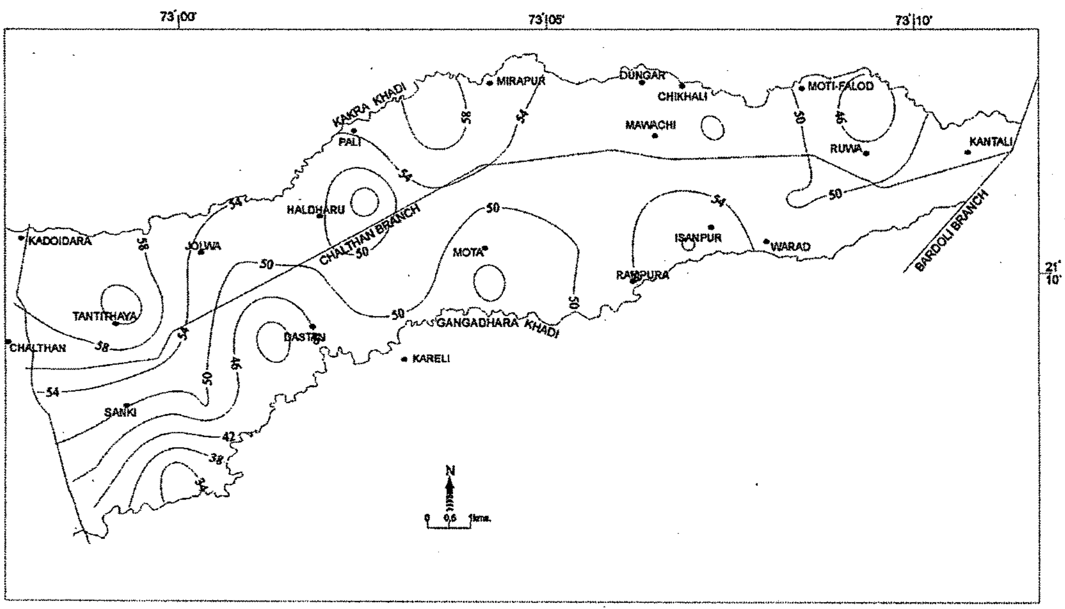

Fig. 8.29 Aerial Distribution of Cation Exchange Capacity (meq/100 gm) During Pre monsoon 1991, Chalthan Branch Canal Command Area (0-50 cm).

Soil CEC in the study area was evaluated as secular and seasonal changes, by considering pre monsoon 1991 and 1999 data for the soil depth of 0-50 cm. Iso-CEC contour diagram (Fig, 8.29) for pre monsoon 1991 shows that CEC was ranging between 46 and 58 meq/100 gm. The observed minima (<34 meq/100 gm) in the extreme west i.e. south of Sanki village may be attributed to the presence of comparatively coarse textured soils than the other parts of command area. CEC levels during pre monsoon 1999 (Fig. 8.30) shows almost similar trends, the CEC is ranging between 46 and 54 meq/100gm which indicates negligible fluctuation in cation exchange capacity from pre monsoon 1991 to 1999.

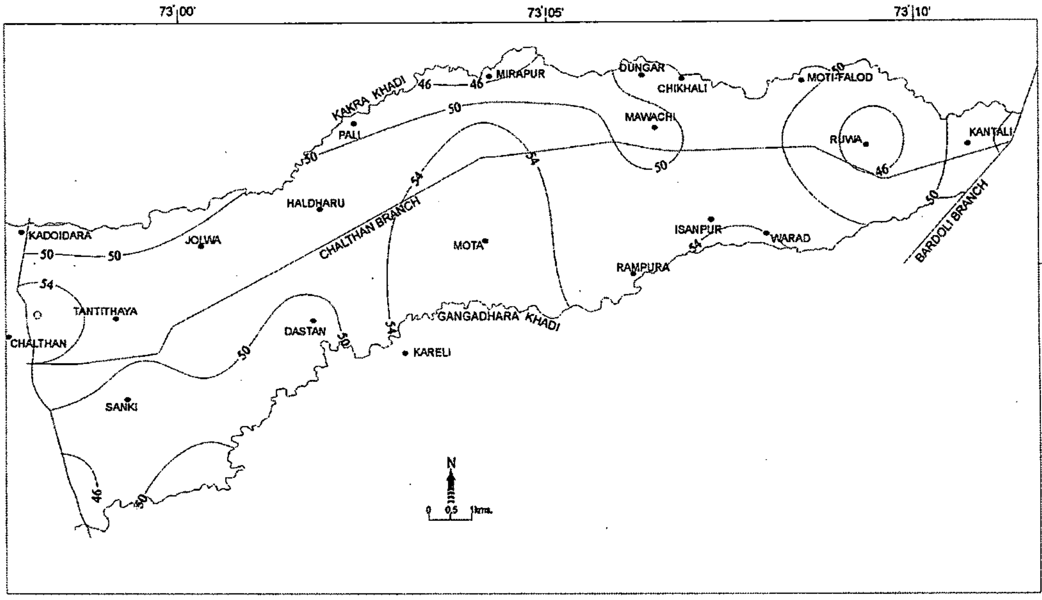

Fig. 8.30 Aerial Distribution of Cation Exchange Capacity (meq/100 gm) During Pre monsoon 1999, Chalthan Branch Canal Command Area (0-50 cm).

In order to study secular and seasonal spatial changes in CEC, the author has prepared a cross section profile along A-A' transact (Fig. 8.31) for various sub soil depths. Based on the study of these profiles following broad inferences may be derived.

i) The CEC profiles for pre monsoon 1991 and pre and post monsoon 1999 shows an overall reduction in the cation exchange capacity with depth, which may be attributed to the change in soil texture from fine to moderate, as the clays are having higher amount of CEC as compared to silt and sand.

ii) CEC profile for pre monsoon 1991 shows higher levels around Tantithaiya village as compared to pre monsoon 1999. While around Mota the situation is reversed. This reverse trend in CEC with in a soil depth of 0-100 cm near Mota village may be attributed to the change in humus content and soil pH.

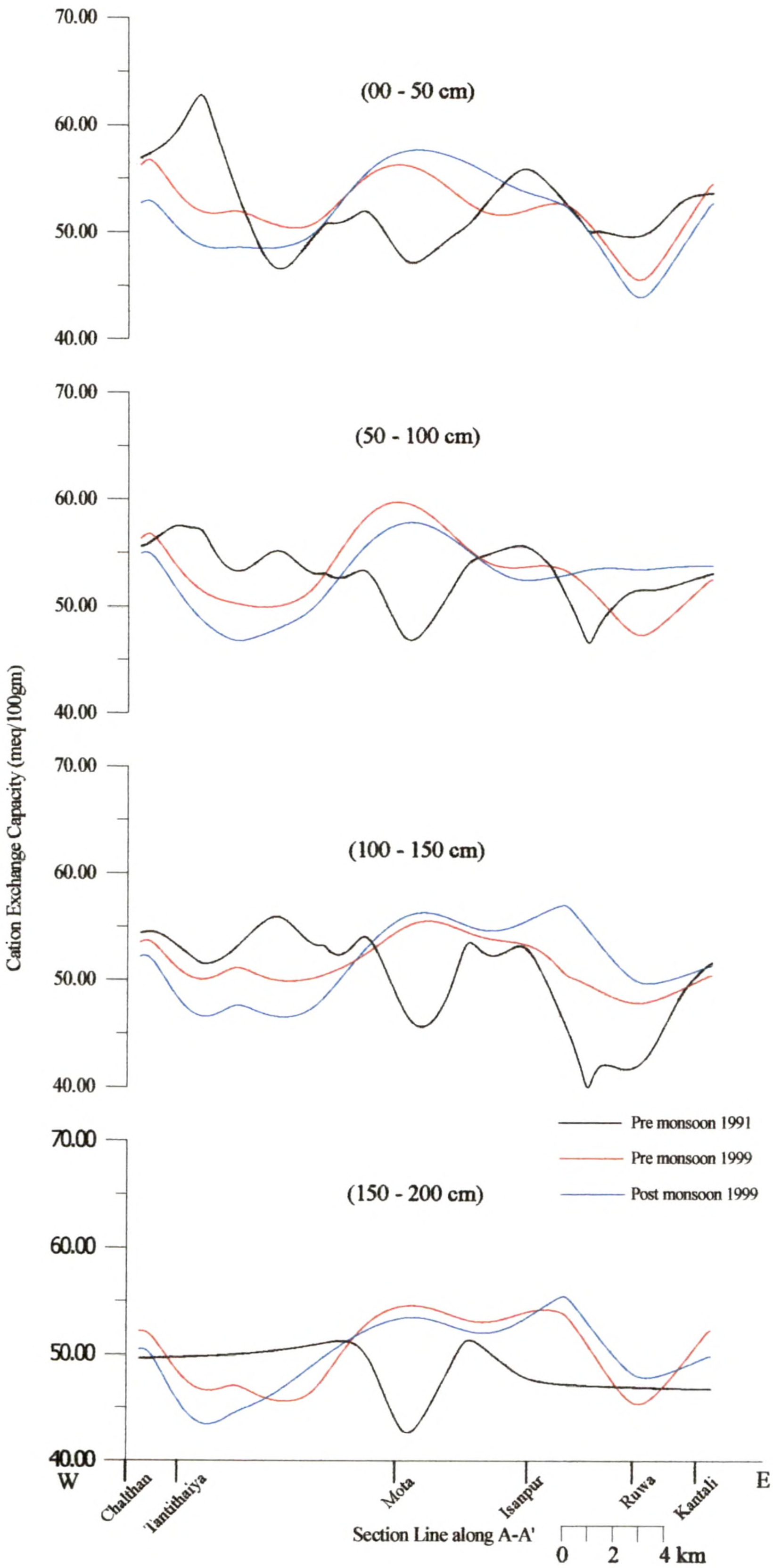

Fig. 8.31 Depth Wise Seasonal and Secular Behaviour of Cation Exchange Capacity (meq/100 gm) of Soils, Chalthan Branch Canal Command Area (along A-A' transact).

iii) The soil profile at a depth of 100-150 cm shows reduction in cation exchange capacity between Mota and Kantali villages from pre monsoon 1991 to 1999.

iv) Seasonal changes in CEC i.e. pre to post monsoon 1999, with in soil depth of 0-50 cm is marked with reduction in CEC in between Chalthan and west of Mota villages and also between Isanpur and Kantali villages, while the CEC is increased between Mota and Isanpur villages.

v) At a sub soil depth (100-150 cm) the area between Chalthan and Mota villages shows reduction in CEC while the area between Mota and Kantali villages, the CEC is increased from pre to post monsoon 1999. These seasonal fluctuations in CEC may be attributed to the change in pH conditions of soils (Miller and Donahue, 1997).

A summary of observed exchangeable sodium for different soil series at various depths for secular and seasonal behaviour is given in Table 8.10.

Table 8.10 Secular and Seasonal Variations in Soils' Cation Exchange Capacity Chalthan Branch Canal Command Area.

Soil Series *Soil Type* (Village)	Depth (cm.)	Cation Exchange Capacity (meq/100 gm) of soil		
		Pre monsoon 1991*	Pre monsoon 1999	Post monsoon 1999
Kapletha *Clayey soil* (Mota)	0-50	51.60	57.00	55.30
	50-100	54.00	58.60	57.40
	100-150	22.60	62.10	60.10
	150-200	NA	54.80	55.20
Sanki *Clayey soil* (Kantali)	0-50	52.75	54.30	52.50
	50-100	51.50	52.40	53.70
	100-150	50.50	50.40	51.30
	150-200	NA	52.20	49.80
Deladwa *Clayey soil* (Khoj-Pardi)	0-50	42.75	42.80	41.50
	50-100	46.90	45.20	53.20
	100-150	40.35	46.20	48.20
	150-200	NA	42.40	46.30
Devadh *Loamy soil* (Bagumara)	0-50	47.33	52.40	48.30
	50-100	24.50	50.40	46.30
	100-150	15.90	52.80	49.20
	150-200	NA	48.60	45.30
Magob *Clayey loam to Sandy loam* (Sanki)	0-50	31.67	48.20	44.80
	50-100	19.35	50.40	48.30
	100-150	13.27	48.20	43.10
	150-200	NA	44.20	39.80

* - Data source: State Soil Survey Dept., NA - Not Available

EXCHANGEABLE SODIUM PERCENTAGE (ESP)

ESP is the amount of exchangeable sodium expressed as a percentage of the cation exchange capacity. Exchangeable sodium percentage concentration above 15% exerts its greatest effect on plant growth by dispersing the soil. It has been observed that ESP as low as 10% in fine textured soils (clayey) and 20% in sandy soils have caused dispersion damage (Rai, 1995). Colloid dispersal makes the soil less permeable, or even impermeable and causes it to form hard surface crusts when dry (Shainberg and Letey, 1984; Miller and Donahue, 1997). The deterioration of soil structure due to high ESP has following adverse effects (Shainberg, 1985):

1. Heavy textured soils become more sticky and plastic under wet and dry conditions, leading to the cultivation problems.
2. Considerable decrease in soils' hydraulic conductivity, leading to ponding conditions on the soil surfaces thereby difficulties in leaching out the salts from soil profile.
3. Saturated soils restrict the air entry, and anaerobic conditions may develop, causing denitrification and production of plant toxins.

ESP constitutes an important norm for classifying the soil sodicity i. e. Sodic Soils, ESP > 15 % and Non-sodic Soils, ESP < 15%.

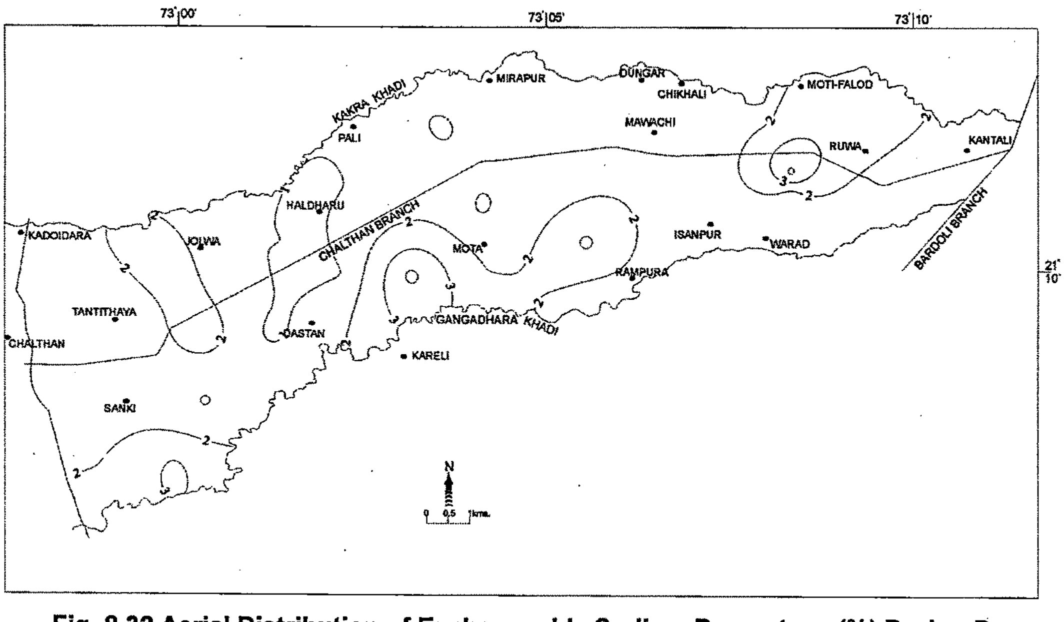

Fig. 8.32 Aerial Distribution of Exchangeable Sodium Percentage (%) During Pre monsoon 1991, Chalthan Branch Canal Command Area (0-50 cm).

Author has evaluated secular as well as seasonal behaviour of soils' ESP in study area. For the evaluation of secular behaviour in exchangeable sodium percentage, a Iso-ESP contour map (Fig. 8.32) has been prepared by considering pre monsoon 1991 and 1999 data, for the soil depth of 0-50 cm. ESP values during pre monsoon 1991 were ranging between 1 to 3% while during pre monsoon 1999 (Fig. 8.33) it is between 2 and 3%. Therefore there is not much significant change in ESP and the soils of the study area are by and large free from sodicity hazards.

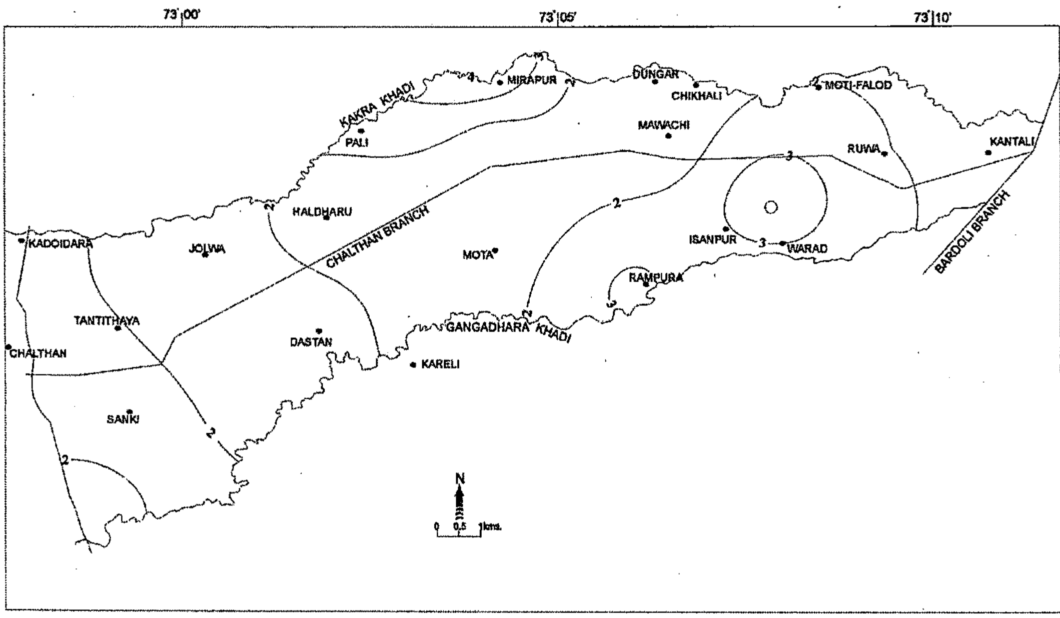

Fig. 8.33 Aerial Distribution of Exchangeable Sodium Percentage (%) During Pre monsoon 1999, Chalthan Branch Canal Command Area (0-50 cm).

The plotted ESP profile along A-A' transact (Fig. 8.34), within a depth of 50-150 cm shows comparatively very high levels around Mota during 1991 as compared to 1999. The reduction in ESP from 1991 to 1999 may be attributed to the change in soil CEC values (Chhabra, 1996). The seasonal change in ESP is marked with the reduction in ESP from pre to post monsoon 1999 which may be attributed to the dissolution of exchangeable sodium content.

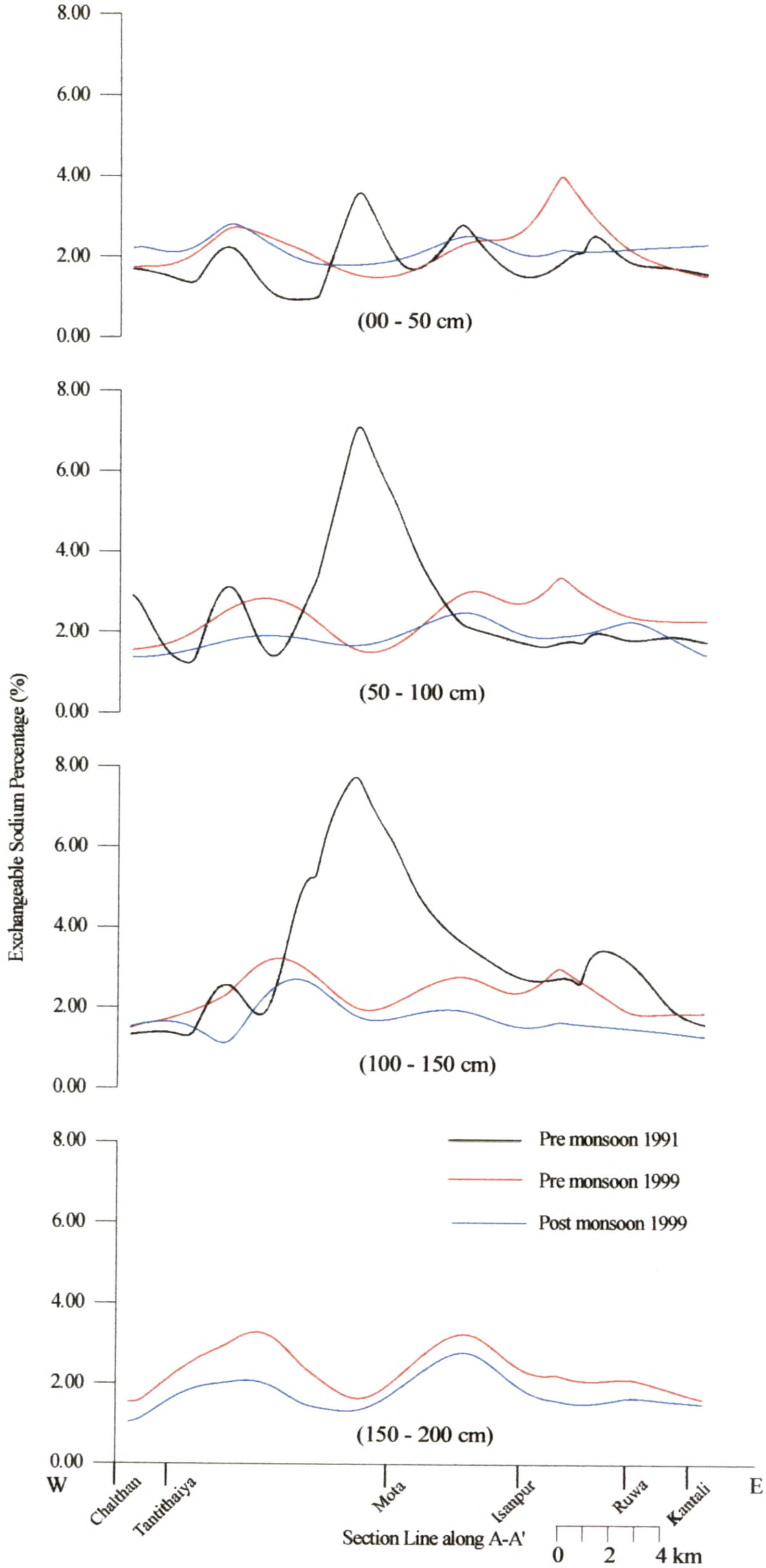

Fig. 8.34 Depth Wise Seasonal and Secular Behaviour of Exchangeable Sodium Percentage (%) of Soils Chalthan Branch Canal Command Area (along A-A' transact).

FERTILITY OF SOILS

Productive, fertile soils offer basic physical support for plants as well as supplying moisture, air, and nutrients to the roots. Soil fertility and plant nutrition are very important components of the crop production scenario, but the basic principles of soil fertility and plant nutrient management are often taken for granted and sometimes totally ignored by farmers. Improperly managed nutrients also may create environmental problems if they are allowed to contaminate surface and ground waters (Bandel, 2000). Also the transfer from rainfed to irrigated crop production of intensification of existing irrigated crop production requires a higher level of nutrient availability in the soil profile. If this aspect is not given adequate attention, the irrigation efficiency of area to be irrigated remains low (Dougherty and Hall, 1995)

However, soil degradation, which is the out come of unhealthy anthropogenic interaction viz., excessive use of fertilizers, pesticides, growth regulator and water; with natural soil environment invariably causes problems of salinisation, alkalinisation, waterlogging etc., particularly in semi-arid regions. Thus evaluation of soil fertility includes:

- Measurement of the available plant nutrients content of the soil and
- Estimation of the capacity of a soil to maintain a continuous supply of plant nutrients for a crop.

The status of soil fertility is determined by the levels of available nutrient elements (N, P, K, Ca, Mg, S) and micronutrients. The availability of N, P, and K in soil is often too low for economic yields of agricultural crops. Three major nutrient commonly supplied as fertilizers are Nitrogen (N), Phosphorus (P) and potassium (K) (Miller and Donahue, 1997). As the present study area constitutes a part of intensive irrigation practices, study of fertility aspects holds vital importance. Detailed quantitative data on the soil fertility constituent for both pre and post monsoon 1999 are given in APPENDIX IX.

The standards used for evaluating soil fertility in relation with nutrients level suggested by the Indian Council for Agricultural Research (ICAR) are given as under:

Critical Levels of Plant Nutrients in Soil

Nutrients	Low	Moderate	High
O. M. (%)	< 0.80	0.81 - 1.30	> 1.31
Available N (kg/acre)	< 100	100 - 200	> 200
Available P (kg/acre)	< 8	8 - 16	> 16
Available K (kg/acre)	< 60	60 - 100	> 100

Organic Matter (OM)

The organic matter is an important component of the soil that contributes to soil fertility because organic matter is considered as principal soil storehouse for large amounts of nutrient. Most cultivated soils contain only 1.5% organic matter which is mostly in the top 25 cm of soil, that small amount can modify a soil's physical properties and strongly affect its chemical and biological properties. Soil organic matter from living or dead plant animal residue, is a very active and important portion of the soil (Miller and Doanhue, 1997).

Soil organic matter is considered to be the nitrogen reservoir; it furnishes large portions of the soil phosphorus and sulfur; protects soil against erosion; supplies the cementing substances for desirable aggregate formation and loosens up the soil to provide better aeration and water movement. As organic matter is constantly undergoing change it should be replenished continuously to maintain soil productivity (Miller and Donahue, 1997).

In view of above benefits, evaluation of organic matter in soils of the study area has been attempted by considering the soil samples collected for the pre monsoon 1991 and pre & post monsoon seasons 1999. For this an Iso-OM contour maps were prepared by considering OM data of the top soils i.e. 0-50 cm depth. The OM levels during pre monsoon 1991 (Fig. 8.35) were ranging between 0.6 to 1.4 %. By and large lower command area was characterized by a comparatively higher values of OM than the upper command area. Contrary to this in pre monsoon 1999 (Fig. 8.36) OM level is ranging between 0.8 and 2.0% and it is comparatively high in upper command area as compared to lower command area. The extremely higher values of OM have been observed around Rampura village (i.e. 2.33 %). This overall observed rise in organic matter from pre monsoon 1991 to 1999 may be attributed to change in pH and soil-water properties (Miller and Donahue, 1997).

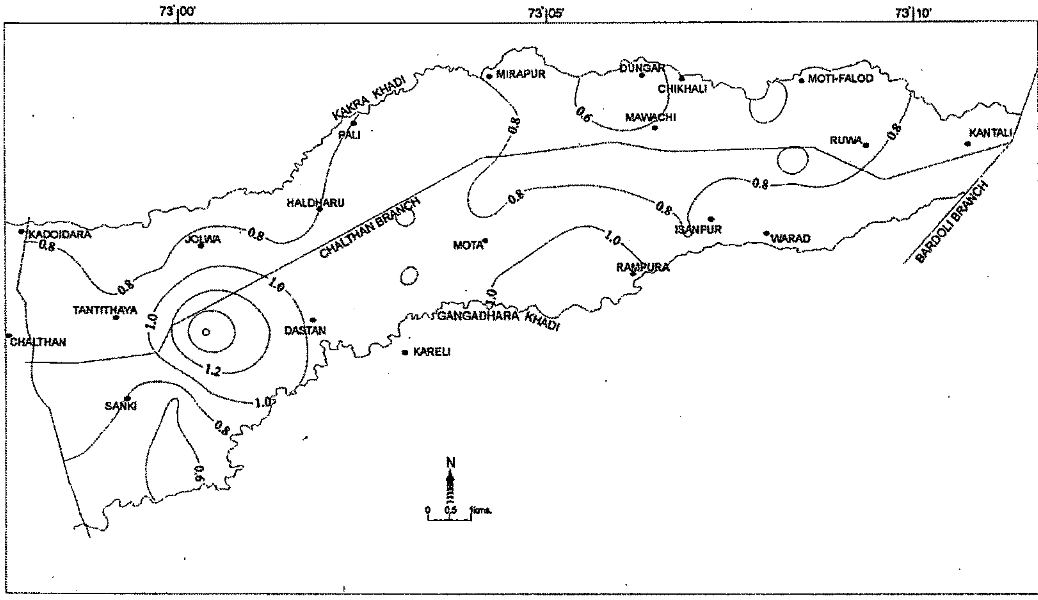

Fig. 8.35 Aerial Distribution of Organic Matter (%) During Pre monsoon 1991, Chalthan Branch Canal Command Area (0-50 cm).

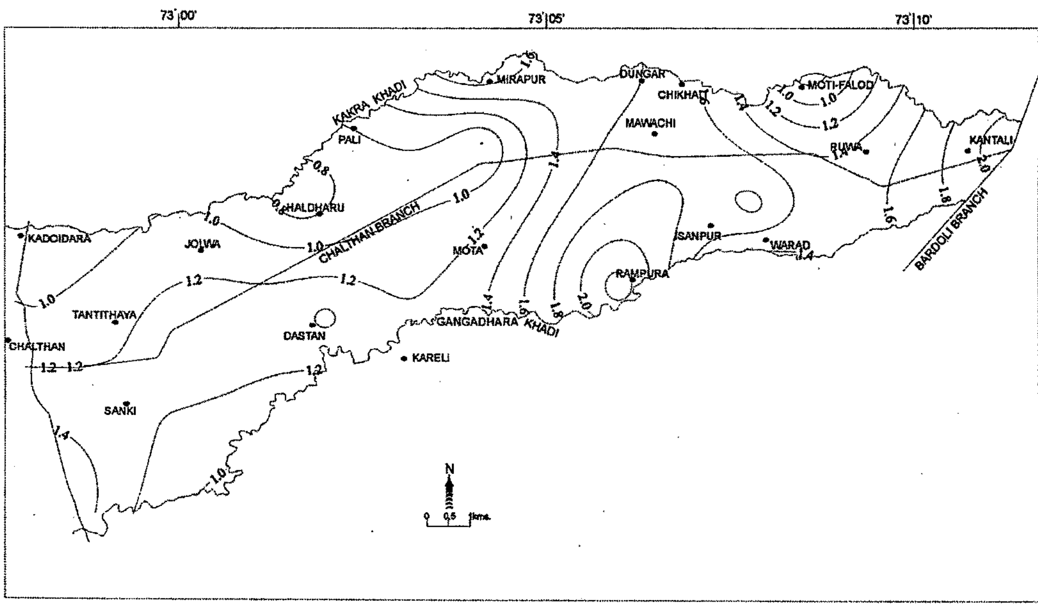

Fig. 8.36 Aerial Distribution of Organic Matter (%) During Pre monsoon 1999, Chalthan Branch Canal Command Area (0-50 cm).

To study the secular and seasonal behaviour of soils' OM, author has prepared the various OM profiles along A-A' transact considering various sub-soil depths (Fig. 8.37). These profiles shows that the organic matter are comparative less during pre monsoon 1991 than 1999 with in a depth of 0-150 cm. While the seasonal fluctuation i.e. 1999 is marked by an overall reduction in organic matter content during post monsoon. Such seasonal reduction in OM may be attributed to (i) excess application of irrigation water and (ii) the change in soil temperature because cold periods retard plant growth and organic matter decomposition.

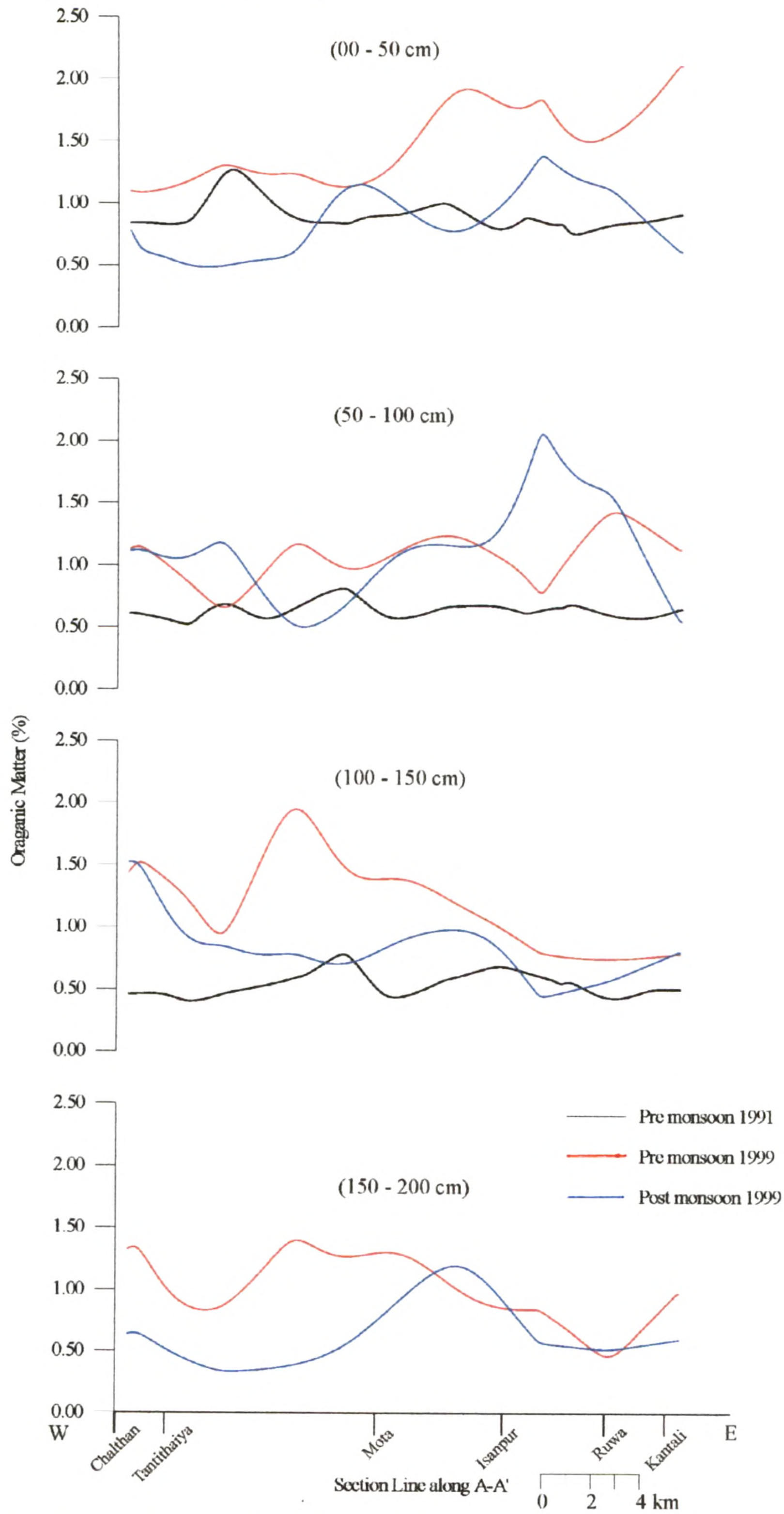

Fig. 8.37 Depth Wise Seasonal and Secular Behaviour of Organic Matter (%) of Soils, Chalthan Branch Canal Command Area (along A-A' transact).

Available Nitrogen (N)

Nitrogen is an important factor affecting the yields of most irrigated crops. Unlike other essential plant nutrients, nitrogen (N) is not found in significant amounts in the rocks and minerals of the earth's crust. Almost in all the soil's, nitrogen supply originates from the earth's atmosphere (Miller and Donahue, 1997). Nitrogen deficiency is especially common in sandy and well-weathered soils, particularly in areas of high rainfall and the soils low in organic matter. Arable soils have a variable nitrate content ranging from less than 2 to 60 mg/l of nitrogen as nitrate (FAO, 1985).

Most of the nitrogen found in the soil (97 to 98 percent) is in an organic form that is largely unavailable to plants. The remaining 2 to 3 percent of soil nitrogen is inorganic (mineral), mostly ammonium and nitrate ions. Soil moisture, temperature, pH, and aeration all have an impact on the amount of soil nitrogen available to plants at any given time.

Nitrogen percentage in the study area is ranging between 0.2 and 0.12 % during pre monsoon 1999 while during post monsoon 1999 it is ranging between 0.02 and 0.11 %. These observed ranges shows that an overall soil nitrogen content is comparatively very less for the growth of plants, that can be substituted by using nitrogen fertilizers such as urea, ammonium nitrate, ammonium sulfate etc, to come over the deficiency of nitrogen in soil.

Available Phosphorus (P)

Phosphorus is the second key plant nutrient; it is the second most often deficient nutrient (Miller and Donahue. 1997). Phosphorus deficiency most commonly occurs in highly weathered tropical soils, calcareous soils, and peat & muck soils but there is a response to fertilizer phosphorus on a very wide range of soils (FAO, 1985). Phosphorus is rarely found in the pure elemental form (P) in nature. It is very reactive chemically; thus, it is almost always found combined with other elements-especially oxygen, as $H_2PO_4^-$ or $HPO_4^{=}$. Available soil phosphorus is derived from the weathering of different minerals, but primarily from the chemical breakdown of apatite, which is composed largely of calcium phosphate i.e. $Ca_5(PO_4)_3F$ (Hesse, 1994).

Most phosphorus compounds formed in the soil are insoluble and are not readily available to plants. Plants normally do not require much phosphorus than calcium, magnesium, or sulfur, but, because of its relative unavailability in the soil, phosphorus must be applied in comparably large quantities (Hesse, 1994).

The phosphorus content of the soils of study area was measured for pre monsoon 1999. The analyzed data for pre monsoon 1999 (Fig. 8.38) shows that the phosphorus is ranging between 8 and 16 kg/acre. Which is very well falling under moderate class of soil fertility of ICAR (1987).

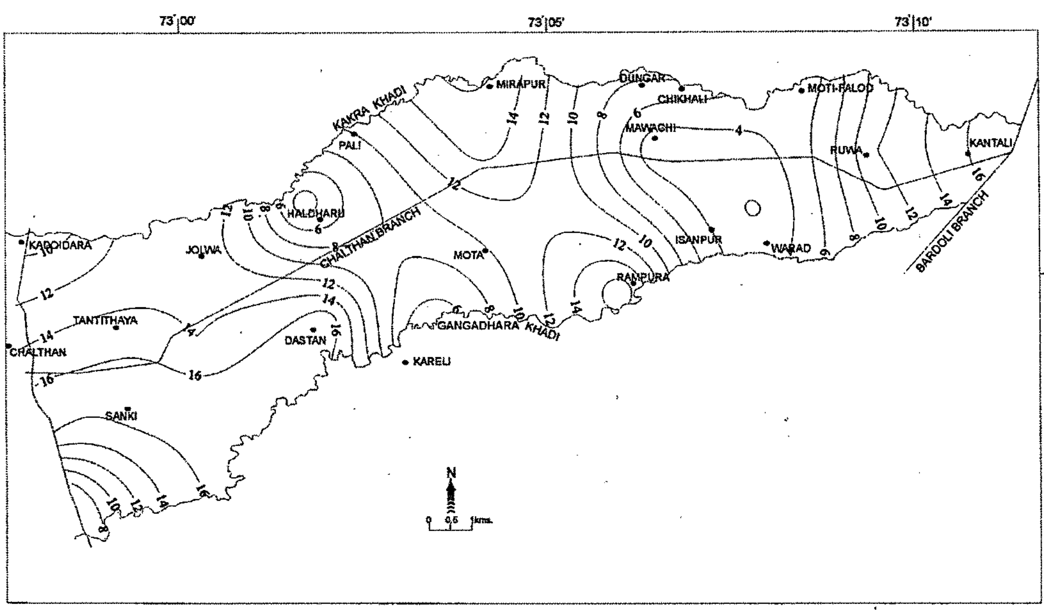

Fig. 8.38 Aerial Distribution of Phosphorus (kg/acre) During Pre monsoon 1999 in Chalthan Branch Canal Command Area (0-50 cm).

Available Potassium (K)

Potassium is required by plants in about the same quantity as nitrogen, in some cases in larger quantity. Although it is an essential nutrient, potassium is not found organically in the plant as nitrogen and phosphorus. Potassium is mobile in the growing plant and, upon physiological maturity, can rapidly be lost from the plant through leaching (Bandel, 2000).

Soil potassium characteristically exists in three forms: (1) unavailable, (2) slowly available, and (3) readily available (Williams, 1962). The unavailable form of potassium is incorporated in rocks and minerals and is released very slowly with physical and chemical weathering. Slowly available potassium is trapped or fixed between the layers of clay particles. The availability of this form of potassium depends on shrinking and swelling of clay particles during the spells of wetting and drying. Readily available potassium may be in the soil solution or in an exchangeable form on the soil colloids (Hesse, 1994, Bandel, 2000).

The deficiency of potassium in soil may results in to decrease in protein formation from amino acids, poor keeping quality of fruits, increase in disease susceptibility, increase in incidence of low temperature damage and retardation of maturity (Rouse and Bertamson, 1950).

The soil potassium content in study area is measured for pre monsoon 1999. The analyzed data for pre monsoon 1999 (Fig. 8.39) shows that the potassium is ranging between 200 and 360 kg/acre and falling under the higher class of soil fertility of ICAR (1987). The highest value of potassium is seen around Dastan and Bagumara villages i.e. 500 kg/acre.

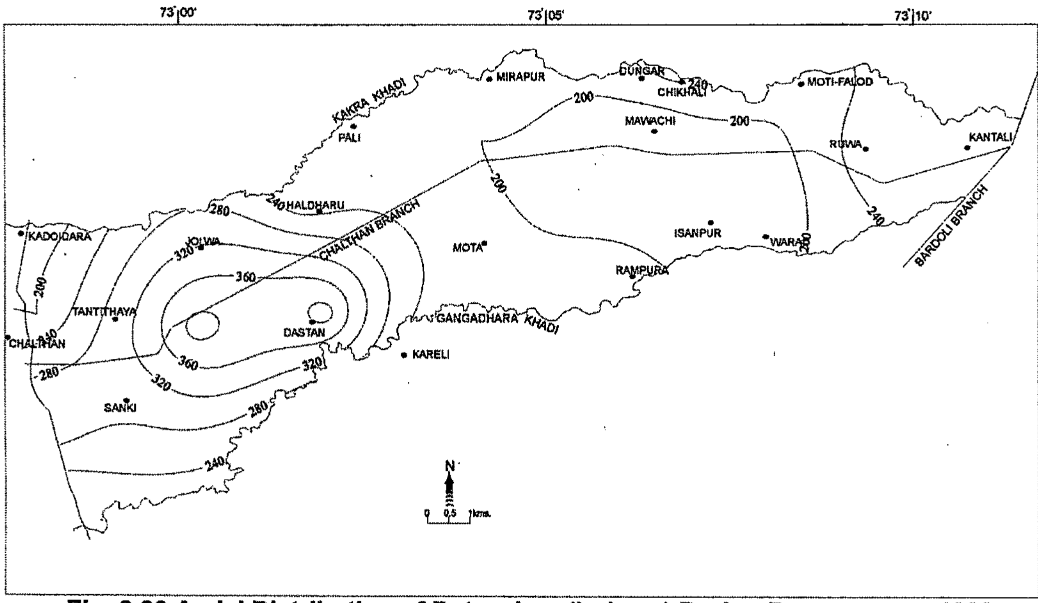

Fig. 8.39 Aerial Distribution of Potassium (kg/acre) During Pre monsoon 1999, Chalthan Branch Canal Command Area (0-50 cm).

For studying the spatial seasonal behaviour of soil potassium, author has prepared a profile along A-A' transact for 0-50 cm soil depth, considering 1999 pre and post monsoon data (Fig. 8.40). The prepared profile shows considerable and overall reduction in potassium content from pre monsoon to post monsoon season. This significant decline in K from pre to post monsoon may be attributed to dilution of soil solution and washing action due to monsoon recharge.

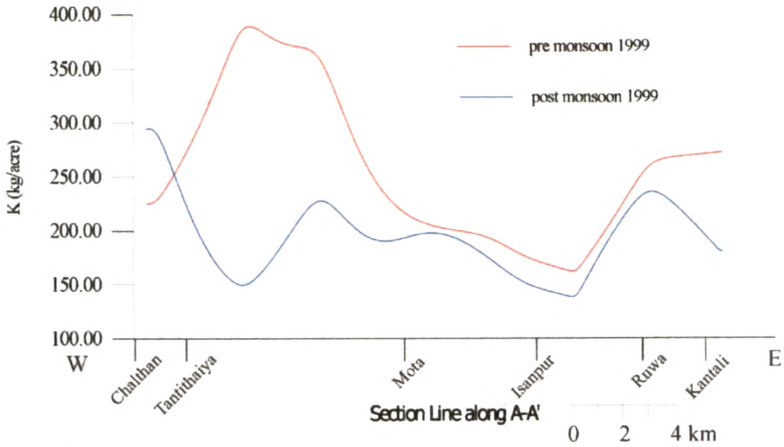

Fig. 8.40 Seasonal Behaviour of Potassium (kg/acre) of Soils (0-50 cm), Chalthan Branch Canal Command Area (along A-A' transact).

Based on the various studies fertility parameters (OM, P, K) of soils of study area at various depths viz. 0-50, 50-100, 100-150 and 150-200 cm, the author has summarized the quantitative information as percentage of the total sample studied for both pre and post monsoon 1999 (Table 8.11). The data categorically point to this very fact that the command area is characterized by a high fertility.

Table 8.11 Fertility Status of Soils in Chalthan Branch Canal Command Area.

Depth (cm)	Organic Matter (%)			Available P (kg/acre)			Available K (kg/acre)		
	< 0.80	0.81 - 1.3	> 1.3	< 8	8. - 16	> 16	< 60	60 - 100	> 100
	Low	Medium	High	Low	Medium	High	Low	Medium	High
	Pre monsoon								
0 - 50	17.39	34.78	47.83	34.78	26.09	39.13	0.00	0.00	100.00
50 - 100	34.78	39.13	26.09	52.17	26.09	21.74	0.00	0.00	100.00
100 - 150	43.48	26.09	30.43	52.17	21.74	26.09	0.00	0.00	100.00
150 - 200	52.17	26.09	21.74	60.87	26.09	13.04	0.00	0.00	100.00
	Post monsoon								
0 - 50	52.17	17.39	30.43	47.83	34.78	17.39	0.00	0.00	100.00
50 - 100	52.17	21.74	26.09	47.83	26.09	26.09	0.00	0.00	100.00
100 - 150	56.52	39.13	4.35	65.22	26.09	8.70	0.00	0.00	100.00
150 - 200	78.26	13.04	8.70	60.87	30.43	8.70	0.00	0.00	100.00

The analysis of the physical and chemical properties of the soils presented above indicates the present status of soils in Chalthan Branch Canal Command Area. They represent valuable information that may be incorporated for detailed planning of cropping pattern and soil-water management practices in command area.