DECADAL CHANGE IN LAND DEGRADATION IN PURNA VALLEY OF MAHARASHTRA

THESIS

Submitted to
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
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By

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DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation of the Thesis entitled **"Decadal change in land degradation in Purna valley of Maharashtra"** or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis / publication of any University or scientific organization. The source of materials used and all assistance received during the course of investigation have been duly acknowledged.

Place : Akola

Date : 31.05.2011

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CERTIFICATE

This is to certify that thesis entitled **"Decadal change in land degradation in Purna valley of Maharashtra"** submitted in partial fulfilment of the requirement for the degree of **"Master of Science in Agriculture (Soil Science and Agricultural Chemistry)"** of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola is a record of bonafide research work carried out by **Kadam Yogesh Bapurao** under my guidance and supervision.

The subject of the thesis has been approved by the Student's Advisory Committee.

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(D) Abbreviations

%	- Percent
/	- Per
c mol $(p^+)kg^{-1}$	- Centi moles proton donar per kilogram
Ca	- Calcium
CEC	- Cation exchange capacity
cm	- Centimetre
Dr. PDKV	- Dr.Panjabrao Deshmukh Krishi Vidyapeeth
dSm^{-1}	- Deci simen per meter
et al.	- Et alia (and others)
Fig	- Figure
g	- Gram
J	- Journal
K	- Potassium
Kg	- Kilogram
m	- Metre
Mg	- Magnessium
Mm	- millimeter
No.	- Number
^oC	- Degree centigrade
Viz.	- namely

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F) THESIS ABSTRACT

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ABSTRACT

The present investigation was carried out in the Purna valley of Vidarbha region of Maharashtra to ascertain the soil degradation caused over a period of two decades due to salinization and sodification. The eight soil profiles were dug at the selected sites in Purna valley taking into consideration the data of previous workers. The sampling sites were

treated as benchmark sites using Global Positioning System (GPS). The quality of well water was also studied.

It has been revealed that despite a low level of sodicity (ESP 4.8-11.1), soils of Purna valley have severe drainage problems because of, low hydraulic conductivity of these soils. Similarly it was also noticed that high amount of smectitic clay leads to increase in bulk density and this results in to hard and compact soil structure. In respect of soil chemical properties it has been observed that pH (1:2) ranged from (7.0 to 9.5), ECe (0.44 to 2.74) dSm^{-1} and ESP (4.8 to 11.1) which was increased especially in sub soil horizons. The kind and degree of degradation indicated that soils are none to very slightly saline sodic to moderately sodic.

Based on data of climatic parameters at Akola and Amravati it has been observed that the rainfall was gradually decreased over a period of time coupled with increase in temperature. This promotes higher evaporation caused due to aridity rates which results in to enhancement in salinization and sodification of soils.

From the present investigation it can be concluded that the soils in Purna valley area are none to slightly saline- sodic to moderately sodic. The soils recorded slight changes in soil degradation over a period of last two decades in respect of increase in pH especially in subsoil along with a tendency of varying salinization in the profile coupled with slight increase in ESP towards lower horizons with concomitant decrease in exchangeable Ca/Mg ratio.

CHAPTER I

INTRODUCTION

1.1 Background Information

Soil is most precious natural resource of any nation. It is finite resource and its judicious management is of paramount importance. It provides a basic support to agriculture and largely governs the success of crop production.

Land degradation and soil quality deterioration are one of the several reasons of agrarian stagnation and perpetuation of hunger and malnutrition and are major threat to country's food and environmental security. Soil degradation is defined as lowering and losing of soil functions or the decline the capacity of soil to produce goods of value to humans and is becoming more and more serious worldwide in recent decades, and posses a threat to agricultural production and terrestrial ecosystem. It has plagued the earth ever since human exploitation of land began (Sharma *et al.*, 2004).

Soil degradation is the glaring environmental problem adversely affecting soil productivity and continuously converting productive lands into waste lands. Intensive cultivation, raising more crops from unit area of the land, results in rapid depletion of organic matter content of soil and adversely affects soil`s physical condition causing deterioration in soil aggregation (Singh, 2008).

Indiscriminate irrigation for getting higher yield has led to water logging, nutrient losses and increased salinization of lands once fertile and has ironically threatened the sustainability of crop yield. The increasing salinization of thousands of hectares of cultivated lands with raised water table in many canal command areas is a serious threat and needs utmost attention failing which significant area may be rendered unproductive and unfit for cultivation. On the other hand, extensive lifting of underground water through tube wells has resulted in significant lowering of water table in those areas caused catastrophic results, particularly during low rainfall period (Sen, 2003).

Salinization is one of the major soil degradation processes that has turned millions of hectares of our agricultural land unfit for profitable crop production. Concentration of soluble salts in soils however can be controlled by water management. Leaching requirement of soluble salts from the root zone is essential to maintain an irrigated soil productive. Leaching influences distribution and removal of soluble salts from soil profiles and prevents their accumulation in root zone (Singh *et.al* .,2000).

Black soils (Vertisols and their Vertic intergrades) occur widely in many parts of the world, and in India particular. They occupy an area of 72.9 Mha in India, 35.5 per cent of which is in the state of Maharashtra (Sharma *et al.* 2004). These soils are mainly confined to lower topographic levels and occur in most of the river valleys, one of which is Purna valley covering parts of Amravati, Akola and Buldhana districts of Maharashtra. These soils do not show any salt efflorescence on the surface (Pal, 2004).

The poor structural stability of Vertisols particularly during monsoon season renders the agricultural activities very difficult; the low saturated hydraulic conductivity causes water logging. The soils of Purna valley are mainly derived from basaltic alluvium and have clay texture with smectitic clay mineralogy. They have swelt shrink potential, slow permeability with very low hydraulic conductivity and imperfect drainage. The soils are classified as Sodic Haplusterts and Sodic Calciusterts (Padole *et al.*, 1998).

The chemical degradation of soils of Purna valley in terms of increase in exchangeable sodium percentage (ESP) and exchangeable magnesium percentage (EMP) with depth has adversely affected the hydraulic and other properties important for crop growth (Pal, 2004).

The soils in the Purna valley are fine textured with imperfect poor drainage and high water holding capacity. The clay content ranges from 52-70 per cent. The pHs, ECe and ESP ranges from 7.7 to 9.4, 0.90 to 5.20 dSm^{-1} and 2.57 to 33.78 respectively. The soils are mostly normal at surface horizons and problem of salinity /sodicity increases with depth (Sagare *et al.*, 1991).

1.2 Importance and need of the study

The natural soil resource is shrinking day by day. The deforestation is increasing constantly due to high density population. The soil erosion is being accelerated due to natural calamity or our own mistakes, resulting into soil degradation.

The factors and processes of soil degradation in Vertisols of Purna valley have been studied by Balpande *et al.* (1996). It has been reported that the soil degradation problems in these soils especially in the sub soil sodicity are mainly due to semi-arid climate with annual rainfall of about 875 mm and tropical ustic moisture regime.

Purna valley is unique tract of Vertisols in Vidarbha region of Maharashtra, India having combination of three fold problems the native salinity / sodicity poor drainability and poor quality ground water.

The soils of Purna valley basin are very deep with high clay content having good production potential. The inherent slow permeability of these soils owing to smectitic nature of soils coupled with plain topography and prevailing semi-arid conditions make soils vulnerable to salinity and sodicity hazards. These soils pose serious problem owing to high exchangeable sodium content, poor physical condition and nutrient deficiency. Despite many limitations once ameliorated using gypsum, sodic soils can be used for growing tolerant crops (Balpande et al., 1996).

The problems of these soils are very poor hydraulic conductivity, high degree of swell-shrink potential, compact and dense soil fabric and incomplete leaching of salts in subsoil due to severe drainage impairment. However, use of well water which is also alkali in nature make situation more problematic. These soils have appreciable amount of $CaCO_3$ (5.01-17.50 per cent) (Sagare et al, 1991) and precipitation of Ca in the form of $CaCO_3$, greatly immobilizes Ca and Mg in the soils and dominance of Na is increased, which ought to affect physico-chemical properties of soil adversely. Such situation may enhance clay dispersion, leading to destabilization of soil structure, breaking of soil capillary network and ultimately affecting on water transmission characteristics of the soil.

The soils in Purna valley have been extensively studied during 1990 to 1993 by several workers, Nimkar (1990), Magar (1990), Kadu (1991) and Balpande (1993). The salinity / sodicity problems have been diagnosed in these soils although most of the soils are found to have good production potential. It was advocated by Balpande (1993) that the ESP limit of USSL at 15 is quite high and needs to be reduced in the soils of Purna valley in view of deterioration in physical properties of soils even at ESP of 6.

There is an immense need to monitor the land degradation in this valley over a period of time in respect of degradation of soil physical and chemical properties and nutrient status. In view of the increasing temperature day by day coupled with intensified agricultural practices it becomes imperative to monitor the land degradation periodically. In this context, it is proposed to conduct this study by characterizing the soils at the earlier sampling sites studied during 1990 to 1993. The changes in land degradation over a period of approximately two decades are ascertained in respect of soil properties in present study.

1.3 Objectives

1) To study physical and chemical properties of soils in Purna valley

2) To evaluate change in land degradation in Purna valley caused over a period of two decades.

1.4 Hypothesis

Occurance of salt affected soils is common in Vertisols in arid and semi- arid regions. With expanding, problems of salinity or sodicity and water logging have emerged within the Purna command areas. The Vertisols are domionated by smectitic and mainly montmorillonitic clay mineral. The abundance of smectitic clay in combination with high amount of exchangeable sodium results in high degree of shrink swell potential. This may cause the problems of internal drainage and thereby water logging and adversely affect the crop production.

The soil degradation has adverse effect on soil properties and the degree of soil degradation changed over a period of time may have its effect on soil properties in more serious magnitude. This necessitates monitoring of soil degradation through studies on physical and chemical properties of soils.

1.5 Scope and limitations

The black heavy clay soils in Purna valley have good production potential for crop production. However, because of their intrinsic low permeability they are prone to impairment in drainage. The salinization and sodification owing to their lower topographic condition coupled with high smectitic clay results into degradation of these productive lands. Thereis considerable scope for the improvement of these soils by adopting proper management practices based on systematic studies for diagnosing their problems. Because of their heavy texture their reclamation is not simple and needs adoption of integrated approach.

CHAPTER II

REVIEW OF LITERATURE

The relevant literature pertaining to soil degradation is reviewed and presented in this chapter under the following heads.

2.1 Physical properties of salt affected soils

2.2 Chemical properties of salt affected soils

2.3 Quality of well water

2. 1.Physical properties of salt affected soils

Magar (1990) studied the black soils of Purna valley of Maharashtra and observed that, the hydraulic conductivity of soils ranged from 0.06 to 7.3 mm hr^{-1} and was found to have significant negative correlation with exchangeable magnesium percentage (EMP).

Nimkar (1990) reported that the bulk density of Vertisols may vary from approximately 1-2 Mg m^{-3} depending upon moisture content. While the bulk density at air dry moisture content ranged from 1.6 to 2 Mg m^{-3} in the soils of Purna valley.

Hussein and Adey (1995) pointed out that, the development of fine tilth in Vertisols increases infiltration, plant available water and ease of cultivation and produce fine seed bed. All wetting treatments in liquid phase resulted in decrease aggregate density. Fast capillary wetting rapidly reduced size strength of aggregates to below that of field soils whereas, slow capillary wetting rapidly decreases size but reduced strength more slowly.

Coulombe *et al.* (1997) reported that the hydraulic conductivity in Vertisols is an important parameters used to assess plant growth, soil aeration, soil water recharge, surface runoff, erosion and evapo-transpiration. Numerous factors like texture, moisture content, electrolyte concentration of soil solution and management practices influences hydraulic properties of soil. The simultaneous control of these factors is practically impossible and therefore determination of hydraulic conductivity value in vertisols is laborious and cost intensive.

Padole *et al.* (1998) reported that the hydraulic conductivity of the soils of the Purna valley is adversely affected by soil attributes such as clay and smectite content, bulk density, exchangeable sodium percentage (ESP) and sodium adsorption ratio (SAR). They further reported that soils of the Purna valley in the Vidarbha region of Maharashtra were clay in texture, imperfectly to poorly drained and highly calcareous in nature.

Bharambe *et .al* (1999) studied the Vertisols of Majalgaon canal command area under Jayakwadi project and observed that the bulk density increased with depth. It varied from1.33 to1.40 Mg m^{-3} in the surface layer .Comparatively low value of bulk density in these soils can be ascribed to high clay content dominant by montmorillonite which is due to expanding type of clay mineral.

Thayalan *et al.* (2000) studied the coefficient of linear extensibility (COLE) and volumetric shrinkage potential (VSP) value and observed that soils of basaltic terrain in Nagpur district have 0.09 to 0.27 cm cm^{-1} COLE and 30 to 100 per cent VSP. These values increase with soil depth, indicating higher potential of basaltic soils. They further concluded that the shallow and medium deep soils on the shoulder slopes, scrap slopes, foot slopes and denuded mounds have less COLE value than deep to very deep soils occurring on summits crests, main valley side slopes, valley floors and flood plain which have higher values.

Anantwar *et al.* (2000) studied the six soils from two transect from basaltic plateau of Wardha district, Maharashtra and observed that soils are slightly alkaline in reaction, fine loamy on summits to fine texture on middle slopes and increasing bulk densities with depth. The negative correlation of bulk density with organic matter (r= -0.53) showed increasing trends of bulk density with decrease in organic matter content.

Singh *et al.* (2001) studied the Vertisols of Rajasthan developed from different parent materials and reported that clay size carbonates and sodicity governs the variation in hydraulic conductivity of Vertisols.

Chaudhari *et al.* (2001) studied the effect of water quality on saturated hydraulic conductivity, dispersion, swelling and exchangeable sodium build-up in clay, clay loam and silt loam soils reported the dependence of saturated hydraulic conductivity on water quality parameters total exchangeable cations (TEC), sodium adsorption ratio (SAR) and soil properties (dispersion, swelling and exchangeable sodium) were equally sensitive to change in TEC only. Multiple regression equations indicated the significant dependence of saturated hydraulic conductivity on ESP in all the soils. Dispersion and swelling were found to be the important process governing changes in saturated hydraulic conductivity which was mainly governed by dispersion in silt loam soil.

Pal *et al.* (2001) studied the polygenetic Vertisols of Purna valley of central India and reported that all the soils were deep, calcareous, clayey and very dark grayish brown to dark brown in colour. Cracks extended down to slickenside zones in northern part of valley, but cut through the slickenside zones in soils of south-western part.

Sen (2003) reported that poor structural stability of Vertisols particularly during monsoon season renders the agricultural activities very difficult. The low saturated hydraulic conductivity causes water logging.

Kadu *et al.* (2003) studied the Vertisols of Nagpur, Amravati and Akola distrcts of Maharashtra state and reported that the soils were clayey and fine clay (less than 0.2 mm) contributed more than 50 per cent of the total clay fraction. The hydraulic conductivity of Nagpur soils ranged from 4 to 20 mm hr^{-1} and rapidly decreased with depth, even though the clay content was almost uniform. The hydraulic conductivity of Amravati and Akola soils ranged from less than 1 to 12 mm hr^{-1}. They further reported that Bss horizon of soils of Amravati and Akola with ESP~6 and hydraulic conductivity value of about 1mm hr^{-1} indicated the very poor internal drainage condition.

Yadav (2004) reported that, the sodic soils are characterized by high pH and ESP values. Dominance of sodium carbonate and bicarbonate salts marked deterioration of physical condition; low content of organic carbon and calcium carbonate indicate the presence of calcareousness. The saline soils have high salts concentration of chlorides and sulphates of mainly sodium better physical condition, nutrient imbalance, toxicity of certain elements and are in many cases associated with high water table. The plant growth in both sodic and saline soils was seriously hampered, depending upon the severity of problem and tolerance ability of plant.

Pal (2004) reported that the chemical degradation of the soils of the Purna valley in terms of increase in exchangeable sodium percentage (ESP) and exchangeable magnesium percentage (EMP) with depth has adversely affected the hydraulic conductivity and other properties important for crop growth. The increase in both coefficient of linear extensibility (COLE) and water dispersible clay (WDC) and decrease in hydraulic conductivity with depth. It is suggested that the swelling of the clay smectite, together with dispersion of clay, have adversely affected the hydraulic properties of these soils. It was also observed that the relation between WDC and EMP indicated the saturation of these soils, not only with sodium ions but also with magnesium ions leads to greater dispersion of the clay, which is opposite effect from the saturation with calcium ions, leads to blocking of small pores of the soil.

Bhargava and Rajkumar (2004) studied the soils of Indo-gangatic plain and found that the sodic soils have adverse chemical and physico-chemical characteristics with high ECe. The soils remain highly dispersed and impermeable to both water and air. The infiltration rate of sodic soils was remain less which was below 0.5cm day^{-1} due to sealing of water conducting pores. The hydraulic conductivity decreases steeply at an exchangeable sodium percentage (ESP) of 15, attaining maximum fall upto 40 ESP, beyond which marginal decrease in hydraulic conductivity occurs.

Nayak *et al.* (2006) studied the swell- shrink potential of Vertisols in relation to clay content and exchangeable sodium percentage (ESP) and the soils were found to be dominantly smectitic with minor amount of kaolinite and illite. The COLE was categorize in very high (COLE>0.09) swell-shrink class. At same levels of clay and ESP, the increase in electrolyte concentration would decrese the swelling.

2.2 Chemical properties of salt affected soils

Kaswala and Deshpande (1983) studied physical, chemical and mineralogical characteristics of some coastal and inland black soils of south Gujrat and reported that these soils were fine textured but low in organic carbon content and having high cation exchange capacity (CEC). The dominant exchangeable cation was calcium in inland soil and sodium in the coastal soils. The exchangeable calcium generally decreased while exchangeable magnesium was increased with depth at inland soils.

Bharambe and Ghonsikar (1985)studied the soils of Jayakwadi canal command area and reported that the pH of very deep to deep soil varied from neutral to alkaline. Whereas, pH of shallow soils was in neutral range and comparatively high pH due to calcareous nature containing higher amount of free calcium carbonate.

Crecimanno *et al.* (1985) studied the influence of salinity and sodicity on soil structure and hydraulic characteristics and concluded that no critical ESP threshold can be defined since almost linear relationship between investigated soil properties and ESP were found at low cationic concentration. The ESP value ranging from 2 to 5 associated with low value cause hydraulic conductivity to decrease by 25 per cent or even more; similar reduction in aggregate stability occurs at ESP ranging from 5 to 10 while rating of swelling shrinkage appears less affected by ESP in the explored range.

Kotur and Seshagiri Rao (1988)evaluated the well known ESP-SAR relationship in some salt affected soils of Malaprabha and Ghataprabha river valley projects for predicting ESP in the diagnostic work. Owing to the difficulty in obtaining saturation extract in these soils, (1:2) soil: water ratio was employed. It was observed that the predicted ESP values in these soils were much lower than the observed ESP values. Thus there was under-estimation of sodic hazard. The "Adjusted SAR" value led to an over-prediction of ESP values in the Malaprabha soils which have fairly low amounts or none of soluble carbonate and bicarbonate but have appreciable amounts of soluble sulphate. The SAR values corrected for ion pair formation ($CaCO_3$ and $CaSO_4$) and ionic activity improved the prediction of sodic hazard much better.

Woldeab (1988) studied the physical and chemical properties of Vertisols of Ethiopia and reported that, these soils were generally deep, heavy textured, acidic to alkaline (pH 5.3 to 8.2) and cation exchange capacity (CEC) was uniformly high (>40 c mol(p+)kg^{-1}). The heavy water logging was observed in these soils during the rainy season.

More *et al.* (1988) studied some salt affected soils of Purna command area of Maharashtra state. The chloride was dominant anions followed by sulphate, where as bicarbonate content exceeded over other anions in sodic soil profiles. As increasing trend of electrical conductivity (EC) in upper layers of profile indicate that prevailing conditions facilitated excessive accumulation of salts in the surface horizon. Furthermore it also suggests that there was a direct and positive relation between pH and soluble Na^+ content. The profiles were characterized as saline sodic and sodic based upon their pH, ECe and ESP values.

Bharambe *et al.* (1990) characterized soils of Jayakwadi command area and reported that, the higher pH due to calcareous nature of these soils (2.5 to 21.1 per cent). The cation exchange capacity (CEC) of soils varied from 38 to 63 cmol (p^+) kg^{-1} in surface layer and decreased with depth and amount of clay content.

Nimkar (1990) reported that all fertile soils have at least a small amount of soluble salts in them. One of the reasons for loss of soil productivity has been accumulation of excess salts. Which influence the soils in many ways. The direction of presence of salts in one consideration, change in exchangeable cations on soil colloidal complex is another and the indirect effect of salts on soil microbes, plant roots activities and physical properties of soil colloids.

Sagare *et al.* (1991) indicated that salt affected Vertisols of Purna valley tract of Vidarbha region are clayey. The clay content in the surface horizon ranged from 52.5 to 63.9 per cent .The sand and silt content in lowermost horizon varied from 3.5 to 12.5 and 24 to 40 per cent respectively. The pHs of saturated paste varied in range of 8 to 8.9, ECe value ranged from 0.45 to 3.90 dSm^{-1} where as ESP values varied between 4.55 to 60.96, CEC ranged from 40.9 to 52.0 c mol (p^+) kg^{-1} indicating dominance of smectitic mineral in finer soil fractions. Free calcium carbonate $CaCO_3$ content varied from 5.01 to 14.5 per cent and it was increased with depth.

Kadu *et al.* (1993) studied the effect of exchangeable Na^+ on the hydraulic conductivity and drainage in swell shrink soils of the Purna valley of Maharashtra and reported that inherently low hydraulic conductivity was adversely affected even with slight increase in exchangeable Na^+ percentage.

Kadu *et al.* (1993) studied that the hydraulic conductivity of the soils from Purna valley. The data indicate that the soils of southern bank falls in "poorly drained" class (2.3 to 8.4 mm hr^{-1}) were as those of northern bank is very poorly drained class (less than 0.1 to 4.8 mm hr^{-1}). They further suggested that the soils with ESP less than 5 have inherent low hydraulic conductivity which could be attributed to the high amount of smectite in these soils. Smectite clearly dominates the fine clay fractions less than 0.2 μm with nearly 98 per cent. Its proportion in the coarse clay (less than 2 to 0.2µm) and silt (50 to 2µm) fraction is 35 to 40 and 8 to 10 per cent respectively. They further concluded that with a high amount of smectite a little sodification even at ESP level of 5 has impaired drastically the hydraulic property of these soils and ESP of 5 may be conveniently considered as the limit for "very poorly drained " class.

Giridhar and Idnani (1994) studied the effect of exchangeable magnesium on sodicity hazards and hydraulic properties of Ustocrepts of Gujrat and reported that the relative hydraulic conductivity decreases with an increase in the exchangeable magnesium percentage at a particular SAR and ESP of the soils.

Verma *et al.* (1995) studied salinity/sodicity levels in Etah district and concluded that the soils are characterized by presence of 7 to 18 cm thick salt efflorescence at the surface but it reduces in the underlying horizons. salt affected soils are highly calcareous and show formation of kankar pan. The soil showed strong to severe alkaline reaction with pH ranging from 9.5 to 10.5. The ESP varied from 70 to 95. Salt efflorescence at the surface and decreasing trend of ECe in the profile indicates excessive accumulation of salts in the surface horizons. The ECe varied from 2.0 to17.4 dSm^{-1}. These soils have $CO_3^{--}$and HCO_3^- as dominant anions while Na is dominant cation.

Ved prakash *et al.* (1995) studied the salt affected soils of Sultanpur district of Uttar Pradesh and reported that pHs of the soil ranged from 8.8 to10.6, ECe from 0.6 to 16.8 dSm^{-1} and ESP from 19.5 to 80.5. The values of all the parameters decreased with increasing depth.This indicate that the process of alkalinization had started at the surface and proceeded in downward direction.

Dumbhare *et al.*(1996) studied five salt affected soils from the Purna valley in Maharashtra, and characterized during 1994-1995. They were poorly drained, very deep, fine textured, calcareous, shrink and swell soils. The pH ranged from 8.3 to 9.7, electrical conductivity ranged from 0.30 to 2.25 dSm^{-1} which indicates general salt accumulation. $CaCO_3$ content was 9.5 to18.27 per cent which was increasing with depth. Organic carbon content was decreased with depth ranging from 0.44 to 0.77 per cent, Cation exchange capacity was high (50.02 to 63.30 cmol (p^+) kg^{-1}, the exchangeable cations were in the order of Ca^{2+} > Mg^{2+} > Na^+ > K^+ the Ca:Mg ratio varied from 1.91 to 4.96. Exchangeable Na^+ varied from 4.16 to 20.88 per cent, which increased with depth whereas, exchangeable Mg^{2+} varied from10.12 - 20.63 per cent.

Balpande *et al.* (1996) studied the soils of the Purna valley and reported that the development of sodicity in soils of South-Western part of valley has been attributed to the semi arid climate conditions that have induced the pedogenic process of calcium carbonate thereby resulting in an increase of both SAR and ESP with pedon depth .They also reported that the lower hydraulic conductivity of these soils related to ESP more than 5 and exchangeable Ca/Mg ratio.

Colulombe *et al.* (1997) in Vertisols of India, reported that cation exchange capacity (CEC) ranged from 47 to 65 c mol (P^+) kg^{-1} of the soil depending on clay content. Whereas, calcium and magnesium dominant exchangeable ions with Ca/Mg ratio between 3:1 and 1:1 in some Vertisols. However, magnesium saturates over 50 per cent of exchange complex. The saturation with potassium does not generally exceed 2 per cent and that the sodium remains below 5 per cent.

Balpande *et al.* (1997) reported that the hydraulic conductivity of Vertisols decreases within all pedon but the decrease is more sharp in the soils of South Western part of Purna valley even at 5 ESP due to huge amount of smectite contained in clay fraction. (Kadu et al. 2003) also reported that soluble calcium carbonate concentration in saturation extract of studied soil is 0.6 to 3.6 mm mol l^{-1} which leads to swelling of smectitic clay.

Bhaskar and Nagraju (1998)studied salt affected soils occurring in Chitravathi river basin of A.P. and concluded that soils were highly alkaline in nature (pH 8.9 to 10.7) and thus indicates high degree of sodicity. The high pH in soil was due to presence of sodium bicarbonate and carbonate which precipitates calcium and magnesium carbonate during evaporation. The soils are highly calcareous. Higher ECe values indicate high degree of salinity. Small changes in ESP result in large increase in SAR values and the proportion of sodium in soil solution. The soils showed decreasing trend of organic carbon with depth.

Padole *et al.* (1998) studied soils of Purna valley of Vidarbha region of Maharashtra and reported that the bulk density of these soils ranged from 1.28 to 1.88 Mgm^{-3}, typically low hydraulic conductivity which ranged from 5.2 to 1.7 mm hr^{-1}, low to moderate organic carbon , high CEC (more than 42.3 C mol $(p^{+})kg^{-1}$) and high base saturation . Ca^{2+} was dominant followed by Mg^{2+} and Na^{+} .The pHs, ECe, ESP of soil ranged between 7.3 to 9.6, 0.90 to 5.74 dSm^{-1} and 2.57 to 33.78 respectively.

Challa *et al.* (1999) studied the characterization and classification of problematic Vertisols in semi arid ecosystem of Maharashtra and concluded that in all pedons the sodium adsorption ratio (SAR) increased with depth and attained maximum in slickensided zone. In general chloride, sulphate and bicarbonate were dominant in the soil environment.

Badole *et al.* (1999) studied the Vertisols from the Purna valley area for their degradation status. The chemical characteristics of five pedon indicate that soils were calcareous and moderately to strongly alkaline. The cation exchange capacity (CEC) of the soils is high due to smectitic clay. Exchangeable cations Ca^{2+}, Mg^{2+} and K^{+} are dominant. The electrical conductivity of the soils was <4 dSm^{-1}. However, the exchangeable sodium percentage varied from 2.6 to 17 and increased with depth. This increase in sodicity with depth adversely affects the hydraulic conductivity and internal drainage.

Thomas *et al.* (2000) reported that a partial trend in shrink swell behaviour can be observed with CEC. High and very high shrink swell soils generally had higher CEC than moderate soils.

Garg *et al.* (2000) Studied soils of Gangatic alluvial plain at Banthra, Lucknow and concluded that soils of pedon 5 have low organic carbon and higher pH ranging from 7.9-11.0. The $CaCO_3$ in surface soil ranges from 0.13-8.4 g kg^{-1} which gradually increases with depth. ECe increases at lower depth of pedon. The exchangeable Ca^{++} and Mg^{++} were dominant cations followed by Na^+ and K^+. Exchangeable sodium percentage (ESP) less than 15 showed complete replacement of Na^+ by Ca^{++} and/ or Mg^{++} ions.

Moharana and Nepal Singh (2001) studied characteristics of degraded landforms of Balotra-Pachpadra area of western Rajasthan and concluded that based on morpho-genesis and physicochemical characteristics of the soil, degraded landforms classified into two categories viz. Natural salt affected lands and Human induced salt affected lands. In case of natural salt affected lands, the soils have very high EC (1:2) ranging from 3.0 to 41.5 dSm^{-1} which is maximum at surface and decreased in the substrata. This showed that the whole profile is highly charged with soluble salts in trend of $Na^+>Ca^{++}>Mg^{++}>k^+$ cations and $Cl^->SO_4^{--}>HCO_3^->CO_3^{--}$ anions but maximum concentration is at the surface. The pH varied from 8.2 to 8.7. The sub strata are made up of thick zone of $CaCO_3$ concretions at variable depth.

Kuligod *et al.* (2002) studied characteristics and spatial and temporal variability of soil salinity in the upper Krishna project command area and concluded that salinization in this area is widespread due to saline ground water existed over the years due to local topography, geology and unscientific irrigation practices. The soil reaction (pHs) was neutral and ECe, SAR and ESP were higher. Neutral salts of chlorides and sulphates of sodium followed by calcium and magnesium dominated the soil water. The carbonates and bicarbonates were in traces. The RSC was low but soluble sodium percentage was higher indicating the predominance of the neutral salts of sodium in the soil solutions and the sodium ions on the exchange sites.

Vaidya and Pal (2002) studied the Vertisols of Pedhi Watershed of Purna valley of Central India and reported that the soils have both pedogenic and non-pedogenic $CaCO_3$. The semi-arid climate induces the precipitation of $CaCO_3$ with a concomitant development of subsoil sodicity. The degree of development of sodicity exchangeable sodium percentage (ESP > 5) is more in soils of microhigh as evidenced by higher amount of pedogenic $CaCO_3$.

Kadu *et al.* (2003) studied the Vertisols of Nagpur, Amravati and Akola districts of Maharashtra and reported that the soils were clayey and pH values generally increases as the rainfall decreases from Nagpur to Akola. The soils were impoverished with respect to organic carbon and calcium was a dominant exchangeable cations followed by Mg, Na and K in almost all the soils. In general exchangeable Ca decreases while exchangeable Mg increase with depth. They further reported, significant positive correlation between hydraulic conductivity and exchangeable Ca/Mg ratio and significant negative correlation between HC and ESP of the soils in three districts, suggest that the hydraulic properties of the soils impaired initially by ,Mg, which was further aggravated by Na.

Singh (2004) studied sodic soils of Rajasthan and concluded that sodic soils in Rajasthan developed due to area adjoining to lake, sources of irrigation and cultivation with Saline water. In dry season as a result of evaporation soil solution is concentrated, hence solubility limit of calcium salt are often exceeded and they are precipitated with a corresponding increase in the relative proportion of sodium in the soil solution. Under such condition, a part of exchangeable calcium and magnesium is replaced by sodium. The process is repeated over number of year's results in the formation of sodic soils in the Rajasthan.

The underground water was predominated with sodium carbonate which further accelerates sodification. Soil analysis data revealed that soil pH and bicarbonates were higher in sub surface layer (15 to 30 cm) as compared to surface layer (0 to 15 cm). Soil pH ranged from 8.6 to 9.9. EC ranged from 1.3 to 8.6 dSm^{-1} and ESP ranged from 19.0 to 45.1 increased with depth. $CaCO_3$ (4.3 to 24.9 per cent) showed increasing trend with depth.

Varallyay (2004) studied origin and characteristics of sodic lands of Carpathian basin situated in central Europe and concluded that in the poorly drained low-lying areas of sodic soils the capillary flow transports high amounts of water soluble salts from the shallow "stagnant" ground water with high salt concentration and unfavorable $NaCO_3^-$ (HCO_3^-) type ion composition to the overlying soil horizons. Due to strongly alkaline soil solution, the Ca and Mg salts (carbonates and bicarbonates) are not soluble and Na^+ become predominant in migrating soil solution which leads to high ESP even at low salt concentration.

Durgude *et al.* (2004) studied sodic soils of MPKV, Rahuri farm and reported that pHs of soil ranged from 8.5 to 8.9 indicating strongly alkaline in reaction with low electrolyte concentration (ECe 0.6 to 2.66 dSm^{-1}). Cationic concentration showed decreasing trend in order of $SO_4^{--}>Cl^->HCO_3^->CO_3^{--}$. Organic carbon content in sodic soil was very low to medium. The $CaCO_3$ content ranges from 71.4 to176.3 g kg^{-1}. Which increases with depth indicating calcic subsurface diagnostic horizon in pedon. The ESP ranged from 16.3 to 29.4 indicates that soils were sodic in nature.

Kharche *et al.* (2004) studied Sodic Vertisols of Mula command area and concluded that severity of salinity and sodicity in these soils is being further aggravated by semi-arid climate, indiscriminate use of irrigation water and restricted drainage. The soil reaction was moderately to strongly alkaline with variable pH in different horizons. The soils were calcareous with a high $CaCO_3$ (9.5 to 16.2 per cent).

The high pH more than 9.0 was recorded in some soil horizons. The ECe was more than $4dSm^{-1}$ (4.84 to 13.89 dSm^{-1}) in the Vertisols. The exchange complex of soil is dominated by calcium, followed by magnesium or sodium and potassium. The ESP was high through different horizons (14.3 to 23.1) and showed slight increase with increasing depth.

Babar and Kaplay (2004) reported that pH, EC, $CaCO_3$ of salt affected soils were higher in irrigated soils than normal un-irrigated soils. They also reported that CO_3^{2-} and HCO_3^- were higher in irrigated soils than un-irrigated soils.

Sharma *et al.* (2004) presented the current assessment on salt affected soils of India and reported that salts released by weathering of silicate minerals are important original sources. Saline soils were diagnosed on the basis of soils having predominance chlorides and sulphates of Na, Ca and Mg. The soils with neutral soluble salts have pHs < 8.5 and the ECe is more than 4 dSm^{-1}. Sodic soils contain excess of salts capable of alkaline hydrolysis such as sodium carbonate, sodium bicarbonate, sodium silicate and sufficient exchangeable sodium. These soils have saturated paste pH >8.5; ESP >15. In case of saline-sodic soils chlorides and sulphates of Ca and Mg are predominant salts, the SAR remains <15. However predominance of Na results in soil solution SAR > 15.

Kawde *et al.* (2005) studied the soils from Keliveli village (Akola dist. of Maharashtra) in Purna valley of Vidharbha and found that soils were clay textured, very deep and calcareous. The saturation extract analysis denotes cations in order: $Na^+ > Ca^{2+} > Mg^{2+} > K^+$. The soluble sodium percentage ranged from 47.90 to 89.79 per cent and sodium adsorption ratio varied from 1.78 to 21.85, which showed an increasing trend with depth denoting that soils are developing salinity.

Nayak *et al.* (2006) studied the swell shrink potential of Vertisols in relation to clay content and ESP and soils are found to be dominantly smectitic with minor amounts of kaolinite and illite. At same levels of clay and ESP, the increase in electrolyte concentration would decrease the swelling.

Quadir *et al.* (2006) studied the sodicity induced land degradation and its suitable management problems and prospects and suggested that ameliorating such soils requires the application of source of Ca which replaces excess Na at cation exchange sites.

Kadu and Kanaskar (2009) studied soil degradation in Vertisols of Upper Wardha command area of Maharashtra and found that the soils are under perennial irrigation of medium salinity and low sodium water quality. Soils were moderate to strongly alkaline, non-saline (ECe < 2 dSm^{-1}) with high CEC (48-60 cmol (p^{+}) kg^{-1}) and base saturation (89-99 per cent). The ESP, EMP, Ca/Mg ratio and SAR ranged from 0.9 to 17.1 per cent, 20-49 per cent, 0.6 to 3.8 and 0.6 to 15.6 $(cmol^{-1})^{1/2}$ respectively. The natural degradation process further aggravated by injudicious irrigation, increases the sodicity in surface horizons. The high smectitic clay, pH, CEC, ESP and SAR were responsible for high shrink-swell potential of these soils as COLE (0.17 to 0.27) and VSP (60.2 to 100 per cent) values falling in very high shrink-swell classes.

2.3 Quality of well water

Tanpure *et al.* (1977) analysed the sevnty well water samples from the representative areas of Amravati, Akola and Buldhana districts in Purna valley tract. The studies indicated that nearly 50 per cent of the samples have three to four other hazards in addition to the salinity hazard. The concentration of bicarbonate and sodium increases with increase in electrical conductivity. The calcium and magnesium decrease with increasing sodium. The magnesium is higher than calcium. The concentration of potassium was very low. Besides electrical conductivity the sodium adsorption ratio was also high upto 14.70. As per USSL criteria the water was classified under moderate to high salinity and very high sodicity hazards. Therefore majority of well water for irrigation in this area were not suitable for perennial irrigation or intensive cropping.

Singh and Marok (1980)analyzed 462 samples from tube wells in the Sangrur District of Uttarpradesh for salt content. The EC varied from 200 to 2500 mhos/cm and most of the samples having less than 1000 mhos/cm. Soluble carbonate, bicarbonate and RSC varied from 0 to 16, 0.6 to 26 and 0.6 to 32.2 me L^{-1} respectively. Soluble sodium was the dominant cation and the relative proportion of Na^+ to $Ca^{++}+Mg^{++}$ in terms of SAR varied from 6.2 to 49.8. SAR was positively correlated with RSC and EC.

Varade *et al.* (1985) reviewed the work done on characteristics and reclamation of salt affected Vertisols occurring in areas of various irrigation projects and reported that approximately 10 per cent of irrigable Vertisols area in each irrigation project of Maharashtra was affected due to salt and water logging problems. The main causes of salt problems in Vertisols are un-scientific irrigation, topographic situation, aridity of climate, ground water rise due to canal seepage and leakage, poor drainability of Vertisols and choking of natural drainage. Salt affected Vertisols are saline, saline-sodic and sodic in characteristics.

Abhange (1986) in his study on drainage problem in black soils of Maharashtra stated the cause of salinization and alkalinization of normal black soils as seepage, obstruction by impervious lower zones and high base exchange capacity of these soils.

Patil *et al.* (1989) studied the seasonal variation in the irrigation water quality for 10 wells during monsoon and pre monsoon season. It was revealed that the salinity of water decreased substantially during monsoon 24 per cent in all the wells. The concentration of Na^+ decreased relatively more while of Ca^{2+} and Mg^{2+} reflecting the relative change in SAR value too. Among the anion, carbonates and bicarbonates not much influenced but chlorides was decreased.

However no relationship was observed between the depth of water table and salinity of water.

Nimkar *et al.* (1992) studied the salinity problem in swell shrink soils of part of Purna valley of Maharashtra and reported that, quality of irrigation water plays an important role in degradation of black soils. Due to bad quality of irrigation water, the salt accumulation in surface and in sub-surface lands in subsurface zone degrades both the physical and chemical properties of soil. There is four-fold increase in ESP and SAR of black soils of Purna valley when the well water was used for irrigation. Likewise ionic composition and electrical conductivity of the saturation extract show 2-3 fold increases. In addition soil has become highly alkaline and the hydraulic conductivity has further been impaired. The severe consequence of this fact is reflected in water logging and also in the appearance of salts efflorescence on the salt surface in the irrigated field. Both these situation have forced the former to abandon the agriculture in this fields. The data on quality of water collected form wells and river indicated that in general Cl^- ion dominates among anions and Na^+ ions in cations.

Tekchand and Singh (1993) analyzed the water samples for cations (Na^+, Ca^{2+}, Mg^{2+}), anions(CO_3^{-}, HCO_3^-, Cl^-), RSC and SAR from different villages of Haryana for ground water quality appraisal. As regards to distribution of sodic waters about 52 percent water samples from Asalwal village belongs to sodic water followed by Shahpur (43 percent) and Bawal (27 percent). The effect of quality of ground water and the salt build up in the soil deducted in case of Karnawas village, all water samples are of poor quality and therefore nearly 50 percent of the soils of the village had become saline. Similarly, the high proportion of poor quality water is associated with large area of salt affected soils (68 per cent) of Shahpur. In shahpur village not only 2/3 of soils are saline but also 1/2 of the ground waters are saline in nature.

Rao and Prarvathapp (1993)studied the effect of dissolved salts on hydraulic conductivity of soil and showed that application of water having dissolved salts caused both swelling and dispersion of clay and thus decreases the size of larger pores. When the soil is saturated with water dispersed Na^{+} clay moved on along with percolating solution, thus blocking the large pores and the channels in the soil. The dispersion of clay results in decreased hydraulic conductivity caused by higher sodium on the exchange complex as compared with other divalent cation (Ca^{2+} and Mg^{2+}).

Girdhar and Idnani (1994) reported that irrigation with high magnesium water leads to increase in pH, whereas magnitude of increase in pH was less than the increase in SAR. An increasing concentration of Mg^{2+} in a given SAR caused the build up of Mg/Ca ratio in soil. Increase in exchangeable magnesium percentage (EMP) as the result of irrigation with the Mg^{2+} dominated water leads to sodicity hazards to a given ESP of a Vertic Ustocrepts of Gujrat. But the degree of hazards due to high exchangeable magnesium was significantly more in high ESP soils due to lower affinity of Mg^{2+} as a compared to Ca^{2+} the relative hydraulic conductivity (RHC) decreased with increase in EMP at a particular SAR and ESP of soils. The continuous use of Mg^{2+} rich irrigation water indicated the sodicity hazards and also incrased soil pH as a result of high Mg^{2+} build up in exchange complex. The hydraulic conductivity affects more adversely at high ESP of soils.

Balpande *et al.* (1996) reviewed that the presence of divalent cations such as $Ca^{2+}$and mg^{2+} generally stabilizes or increases the soil hydraulic conductivity while the presence of Na^{+} in the percolating solution or the ion exchange complex frequently decreases the hydraulic conductivity.

Lal *et al.* (1998) analyzed 36 water samples from different villages of Varansi District for salinity and sodium hazards. SAR values were less than 10. Boron ranged from 0.11 to 0.52 ppm. Soluble sodium percentage values were less than 40 in 91 percent of samples. The quality of irrigation water was therefore assumed to be satisfactory.

Lal *et al.* (1998) studied quality of underground waters of canal command area of Bikaner District, their effect on soil properties and reported that pH and EC of water samples ranged from 8.0 to 9.0 and 0.8 to 7.7dS m^{-1} respectively. Both values were increased with depth. SAR varied from 5.3 to 41.3 mmol L^{-1}. The water samples had RSC ranged between 1.3 to 5.0 mmol L^{-1}. About 25.8 percent water samples showed EC of less than 1.0 dSm^{-1}, 35.5 per cent were 1.0 to 2.0 dSm-1, 16.1 percent were 2.0 to 4.0 dSm^{-1} and 22.6 percent water samples showed EC more than 4.0 dSm^{-1}. The water samples showed dominance of chlorides followed by carbonates and bicarbonates.

Chaudhari and Somanwanshi (2000) reported that effect of water quality was observed only when SAR was above 15 m $mol^{1/2}$ $l^{-1/2}$ in clay and clay loam and SAR 30 m $mol^{1/2}$ $l^{-1/2}$ in silt loam soil. In the range of 20-1000 kPa water retention increased sharply with increase in SAR and decrease in total electrolyte concentration there after increase was slow upto 1500 kpa

Sarasambi (2000) analysed 27 well water samples from Baramati tahsil of Pune district and reported that the relative proportion of different anions concentration had following decreasing trend SO_4^{--} > Cl^-> NO_{3-} > HCO_3^- > CO_3^{--} .

Arun Prasad *et al.* (2001) reported that in arid and semi-arid regions, the indiscriminate use of saline water for irrigation often cause accumulation of harmful salts in soils and limit crop productivity. The degree of salt build up in root zone depends upon the quantity of irrigation water used, its salt level, leaching fraction, seasonal and annual rainfall. Crop yield ultimately depend upon over salinity and content of specific ions in soil, the ability of crop to tolerate salinity and agronomic management practices. However, application of nutrients such as NPK and Ca to growth medium may minimize harmful effect of saline water irrigation on the growth and yield and consequently affect the salt tolerance of plants.

Suryawanshi (2001) analysed irrigation water samples from central campus from M.P.K.V Rahuri farm and observed that the relative proportion of cations were of following order ($Na^{+}>Ca^{++}>Mg^{++}>K^{+}$).

Brar *et al.* (2002) observed that the quality of underground irrigation water of south western region of Punjab and found that, among the anions chloride had dominance over others. The concentration of chloride in water samples varied from 0.2 to 88.8meL^{-1} and of $CO_3^{-} + HCO_3^{-}$ between 0.1 to 27.2 meL^{-1}.

Verma *et al.* (2003) collected 556 water samples from seven tahsils of Charu district in Rajasthan and observed that electrical conductivity and pH of water samples were ranged from 0.4 to 19.7 dSm $^{-1}$ and 7.2 to 9.3 respectively. Water samples collected from Sardar, Shahar and Tarangar and Rajgarh tahsils showed higher pH values i.e more than 8.5.

Verma *et al.* (2003) studied quality of underground irrigation water of Charu District in Rajasthan and reported that, EC of water samples ranged from 0.4 to17.9 dSm^{-1} while pH ranged from 7.2-9.3. Cl^{-} was dominant anion and ranged from 1.2-200.4 meL^{-1} while Na^{+} was dominant cation ranged from1.7 to 118.0 me L^{-1}. SAR of water samples ranged from 2.2-33.5 and RSC varied from nil to 13.1meL^{-1}. The continuous and indiscriminate use of these waters had resulted in build up of excessive sodium in soil

Hasan *et al.* (2004) studied ground water quality for irrigation purpose in sodic lands of Gangatic plains and concluded that use of ground water for irrigation purposes in canal command areas helped in checking the rising water table and thereby arresting the favorable conditions conductive for development of salinity/sodicity in soils. The ground water with high calcium ion concentration helps in reduction of sodium content. The chemical data showed wide variation in irrigation water quality concentration of cations and anions is found high in post

monsoon as compared to pre monsoon period. The RSC values in the water from tube wells are found to be low as compared to the water collected from dug wells. It indicates that tube wells water quality is more suitable for irrigation in sodic lands.

Rai (2004) studied inland ground water salinity in Uttar Pradesh and concluded that the salt concentration in ground water depends upon source of water. Water in the arid-semi arid zones changes from alkaline earth bicarbonate-sulphate type to finally chloride-sodium type with formation of Kankar layers of Alluvium. The ground water Salinity of Uttar Pradesh on the basis of EC is grouped into marginal saline water (2.0 to 4.0 dS m^{-1}) and Saline water (more than 4.0 dS m^{-1}). However, degree of Salinity is recorded even more ranging from 11.9 to 15.0 dS m^{-1}.

Singh and Bishonoi (2004) studied the quality of underground irrigation water in Muktsar district of Punjab and found that the total concentration of soluble salts expressed in electrical conductivity varied from 0.26-16 dSm^{-1}. Calcium + magnesium was observed in Muktsar block with an average value of 13.5 me L^{-1}. Soluble sodium varied from 0.2 to 8.7 me L^{-1}.

Singh and Bishnoi (2004) studied irrigation water quality in Muktsar district of Punjab and observed that carbonates and bicarbonates in the water sample varied from nil to 9.6 and 0.4 to 18.4 meL^{-1} respectively. Chloride and sulphate concentration varied from 0.09 to 140.2 meL^{-1} and nil to 90.8 meL^{-1} with an average value of 9.8 and 15.5 meL^{-1} respectively.

Satyavan *et al.* (2004) observed that the EC values of Barwala block of Hissar district in Haryana ranged from 0.3 to 28.5 dSm-1. The higher EC (28.5 dSm^{-1}) of water recorded in Rajli village of Barwala block.

Satyawan *et al.* (2004) studied quality of ground water for irrigation of Adampur block of Hisar and reported that the EC values of water ranged from 0.2 to 42.4 dSm^{-1}, SAR ranged from 0.58 to 17.8 $(mmol/L)^{1/2}$ and RSC from nil to 41.2 me/l. The average concentration of Na ranged from 2.56 to 56.35 meq/l and that of Cl ranged from 1.14 to 157.71 meq/l and it was increased with increasing EC of water samples. The concentration of Ca and Mg also showed similar pattern as of Na. The highly saline waters were dominated by sodium and chloride ions. There is predominance of Mg over Ca. Carbonate ion is either absent or very little. The ground water of Adampur block are Na^{+}-Mg^{++}-Ca^{++} type dominated by chloride and the Brackish water are generally saline in nature.

Singh and Bishnoi (2005) studied that the quality of sub soil irrigation water of Ferozepur district of Punjab and found that carbonates and bicarbonates in these water varied from nil to 5.6 ad 0.8 to 18.0 meL^{-1} respectively. Highest range of carbonate and bicarbonate was observed in Abonar block varying from nil to 5.6 and 1.2 to 18 with mean values of 0.79 and 6.67 meL^{-1} respectively. The anion in dominance was sulphate which varied from 0.1 to 95.2 meL^{-1} in the three development blocks of Ferozepur district.

Marathe *et al.* (2006) analysed 115 underground water samples in Kolhapur district and found that the pH and EC were ranged from 7.50 to 7.74 and 0.49 to 3.27 dSm^{-1} respectively. Further they observed that introduction of lift irrigation in black soils resulted in increased EC of well water. The average value of sodium, magnesium and calcium were 14.83, 11.82 and 6.13 me L^{-1} respectively.

Singh *et al.* (2006) studied quality of Degana tahsil of Nagapur district (Rajasthan) and found that EC and pH of ground water varied from 1.25 to 9.60 dSm-1 and 7.68 to8.90 respectively. Ca^{++}, Mg^{++}, Na^{+} and K^{+} ranged from 0.4 to 5.6, 1.1 to 12.1, 9.3 to 85.4 and 0.02 to 0.43 me L^{-1} respectively. Carbonates + bicarbonates, Chlorides and sulphate ranged from 1.1 to 12.3, 7.8 to80.0 and 0.01 to 7.98 me L^{-1} respectivaly. In general sodium was dominant cation in water samples.

Minakshi *et al.* (2006) reported that anion concentration of HCO_3^- of ground water in Rupnagar district of Punjab varied from 1.0 to 8.0 meL^{-1} with mean value of 2.28 meL^{-1}, while that SO_4^{--} and Cl^- the concentration varied from 0.30 to 4.27 and 3.00 to 9.00 meL^{-1} respectively.

Khan and Sharma (2007) conducted research work on ground water quality of irrigation under hydrological formations in Charu district of Rajasthan and found that the salinity in ground water was generally high in 77 per cent samples which have EC more than 3 dSm^{-1}.

Singh and Kumar (2007) analysed the underground irrigation water in Jagraon block of Ludhiana district (Punjab) for 16 years and observed that the EC varied from 0.344 to 3.19 dSm^{-1} with mean values of 0.94 and 0.89 dSm^{-1} during the years 1989 and 2005 respectively.

Babhulkar *et al.* (2009) studied soil and water characteristics in Purna valley and reported that dominant cations present in ground water are Na^+, Ca^{++}, Mg^{++} and they range from 22.30 to 61.24, 2 to 8.10 and 1.80 to 9.20 respectively, indicating dominance of sodium over Ca, and Mg and it may be one of the geological causes for development of native sodicity in Purna valley soils. The dominant anions present are CO_3^{2-}, HCO_3^-, SO_4^{2-} and Cl^- and respective values ranged from 0.3 to 8.9, 3.8 to 14.38, 0.42 to 9.8 and 1.20 to 32.14meL^{-1}.

CHAPTER III

MATERIAL AND METHODS

The present investigation entitled "Decadal change in land degradation in Purna valley of Maharashtra was carried out during 2010-11 in Purna valley of Vidarbha region of Maharashtra state. The materials and methods are discussed in this chapter.

3.1 Study area

The study area comprises parts of Purna valley of Vidarbha region of Maharashtra.

3.2 Geographical setting

Geographically the location of Purna valley is from 20^0 40' to 21^0 22' N latitude and 76^0 15' to 77^0 45' E longitude and the elevation varies from 250 to 450 meters above the mean sea level.

3.3 Geology

The Purna valley is a faulted basin bounded on the north by the scarp of the Satpudas and on the south by the scarp of the Ajanta plateau. It is filled with boulders, pebbles, gravels, sands and clays derived entirely from the salts surrounding the valley. The total thickness of the deposits is 140 to 420 meters below the ground level.

The exploratory borehole data indicated the basement (Dccan basalt) to be an uneven platform sloping northerly or west northwesterly towards depressed region of Akot and Bawanbir. The upper cover of the alluvial deposit comprises three lithostratigraphic formations (Tiwari and Mukhopadhyay, 1989), which is decreasing order of the antiquity are the virual formation, the kural formation and the Purna formation. The virual formation forms morphostratigrpahic units referable to the older and the younger (present) alluvium deposits, while the Purna formation is observed only in the bank formation is observed only in the bank sections. The virual formation is overlain by either the kural formation or the Purna formation with an erosional unconformity.

The borehole at Dhihanda village (District Akola) indicated that the upper three meters depth is black clay. Below this upto 140 meters is reddish to yellowish brown clay with silt, sand, gravel and kankar layer. At 48 meters a layer of 3 meter thickness comprises of coarse sand, quartz and clay. At 112 meters another layer of 3.5 meters thickness comprises mainly of sand and quartz. Below 140 meters, a 2.75 meters thick layer is made up of weathered basalt, which is mixed with clay, and below that is found the weathered basalt (Balpande 1993).

Adyalkar (1963) reported the following geological succession in this area.

Name of the formation	**Age**
Purna alluvium	Large Pleistocene to Recent
Laterites	Paleocene
------------------------Unconformity	---
Deccan trap	Late Cretaceous to Paleocene
------------------------Unconformity	---
Lametas	Cretaceous
Gondwanas (Upper)	Carboniferous

3.4 Geomorphology

The river Purna rises from the Satpudas and flows nearly through the centre of the valley. Many tributaries from northern and southern sides form a parallel to subparallel type of drainage. The river channel is as deep as 30 meters and as wide as 200 meters in many places. The gradient of the alluvial plain is 1 to 10 meters per kilometer. Locally the slope may reach up to 3 per cent. The whole tract looks flat with very gentle undulations here and there. The elevation of the alluvial plain varies from 248 to 360 meters above mean sea level.

3.5 Vegetation

The Purna plains are extensively cultivated and had artificially created forests of Babul (*Accacia arabica*) which occurs in scattered patches and in areas adjoining the village with Neem (*Azadiracta indica*)

Majority percentage of cultivated land is under kharif with Jowar (*Sorghum bicolor*) and cotton (*Gossypium spp*.) as principal crops along with kharif grain. Legumes like tur (*Cajanous cajan*), mung (*Phaseolus aurens*), urid (*Phaseolus mungo*) and cowpea (*Vigna catiang*) during rabi the crops of wheat (*Triticum spp*.) and gram (*Cicer arietinum*) are restricted to heavier black soil under stored soil moisture

3.6 Drainage

The river Purna is a perennial stream which rises in the south facing scrap of Gavilgarh hills in Betul districts of Madhya Pradesh. The river channel is as deep as 30 meters, and as wide as 200 meters in many places. The river banks are dissected, and the right bank is at a higher elevation than the left bank. The aggregated valley has many streams developing a sub-parallel drainage. The river Katepurna is the most important tributary on the left bank, three other rivers on the left bank, are Morna, Mun and Shahanur.

3.7 Groundwater

Towards north close to the Gavilgarh hills there is a vast tract of fresh water with a very low chloride content and the water table about 3-5 meters from the surface. Towards south of this, the area has been demarcated as a saline tract. The chloride content of the water is reported to as high as 5000ppm near purna river. Normally sodium chloride is available from the ground water below gravels and calcareous conglomarates of the alluvium. The salt bearing stratum is somewhat distinct from the upper fresh water alluvium and is older geographical age (Balpande, 1993)

Adyalkar (1963) summarized from the nature of the highly saline zone increasing in salinity, almost becoming brine with depth, that Purna valley sediments were earlier deposited in a salt water lake, which atleast in the initial stage formed part of the sea probably by extending its westerly arm. Its very interesting to note that in the past, wells were sunk in the area to obtain brine which had been yielding about 700 to 750 kg of salt per month per well (Madhav Rao, 1968; [illegible]).

3.8 Climate

Table 1 and Table 2 give climatic data for Amravati and Akola weather stations of this area. The area has dry season from Oct. to June and wet season from July through Sept. When approximately 85-90 per cent of average rainfall of 528.2 to 667.1 mm is received. April and May have very high temperatures (40.3 to 44.4 ^{0}C) while December and January are the coolest months (9.4 to 14.1 ^{0}C). The soils have Typic Tropustic moisture regime and isohyperthermic temperature regime (Balpande, 1993)

3.9 Sampling sites

The salt- affected area of Purna valley is mainly along Purna river. In all 8 profile sites were finalized based on the earliar characterization of soil carried out during 1990-1993. The sampling sites were georeferenced with the help of GPS. The latitude, longitude and elevation were recorded at each sites and given in Table 3. The map of Purna valley tract and location map of profile are in (Fig. 2.1 and 2.2) respectively.

3.10 Field and laboratory methods

The pits 1.2 meters long, 1 meter wide and 1.5 meter deep were dug at all the sites. Characteristics of the pedon and the individual horizons were studied morphometrically in the field as per the procedures laid out in the soil survey manual (soil survey staff, 1998). Special observations regarding cracking depth and slickensides were also recorded.

3.11 Collection of soil samples

About 2 kg representative soil sample from each of the horizons was collected in cloth bags for laboratory study.

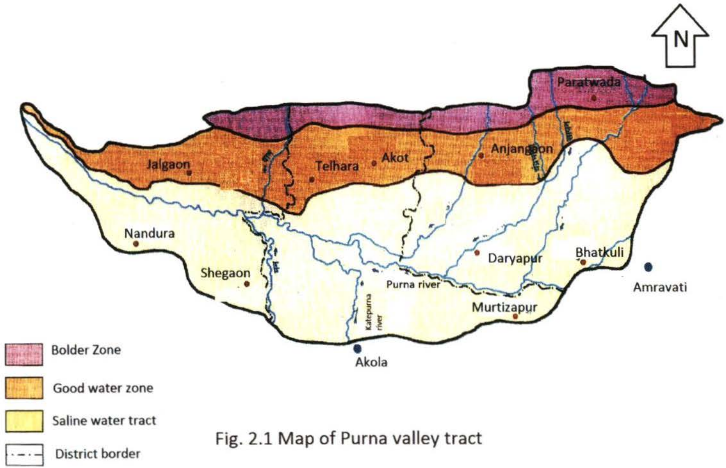


Fig. 2.1 Map of Purna valley tract

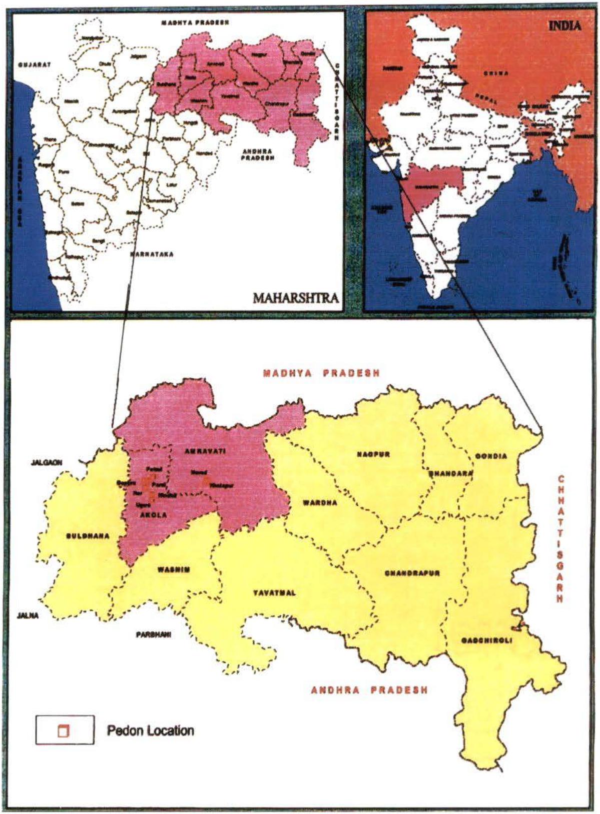


Fig. 2.2 : Pedon sites in Purna valley

Table 1: Weekly weather Data for the Year 2009 recorded at Agromet Observatory, Dr. PDKV, Akola Meteorological Data

MW	Dates	Tmax		Tmin		RF		Rainy days	
		N	A	N	A	N	A	N	A
1	1-7 jan	29.0	29.6	10.3	14.5	1.7	19.5	0.2	2.0
2	8-14	29.2	30.4	11.3	13.1	3.4	0.0	0.2	0.0
3	15-21	29.9	30.7	11.6	12.7	0.9	0.0	0.1	0.0
4	22-28	30.8	26.9	11.8	9.2	1.1	0.0	0.2	0.0
5	29-4 feb	31.1	27.4	12.1	10.7	2.8	0.0	0.2	0.0
6	5-11	31.3	26.0	11.9	11.7	4.9	0.0	0.4	0.0
7	12-18	32.5	31.5	13.4	13.8	0.1	0.0	0.0	0.0
8	19-25	33.0	34.3	13.8	14.3	3.3	0.0	0.5	0.0
9	26-04 mar	34.7	34.7	14.8	13.3	3.4	0.0	0.3	0.0
10	5-11	36.1	37.9	16.7	17.5	2.1	0.0	0.3	0.0
11	12-18	37.3	38.0	17.5	20.6	2.5	0.0	0.3	0.0
12	19-25	38.5	36.0	18.3	22.7	0.3	14.2	0.1	1.0
13	26-1 apr	39	37.6	19.7	22.2	2.9	0.3	0.3	0.0
14	2-8	40.1	36.4	21.1	22.1	0.6	0.0	0.1	0.0
15	9-15	40.8	40.3	22.5	23.6	0.3	0.0	0.1	0.0
16	16-22	41.7	42.5	23.5	25.5	0.3	0.0	0.0	0.0
17	23-29	42.1	44.3	24.8	26.1	0.0	0.0	0.1	0.0
18	30-06 May	42.7	42.6	26.0	27.6	0.3	0.0	0.2	0.0
19	7-13	42.6	40.6	26.5	27.8	0.3	0.0	0.1	0.0
20	14-20	42.6	41.2	27.3	27.8	1.8	0.0	0.2	0.0
21	21-27	42.4	41.5	27.4	28.7	4.1	0.0	0.5	0.0
22	28-03 June	41.9	41.7	27.6	29.5	5.7	0.0	0.5	0.0
23	04-10	39.0	38.8	25.8	26.2	18.3	23.6	1.2	2.0
24	11-17	38.2	35.3	25.8	25.2	43.3	2.0	2.0	1.0
25	18-24	35.3	35.1	24.9	27.4	52.3	0.5	2.2	0.0
26	25-01 July	34.1	30.9	24.2	25.6	38.2	48.1	2.3	3.0
27	2-8	33.5	32.7	24.4	24.7	34.7	20.8	2.4	2.0
28	9-15	32.3	31.7	23.7	24.7	52.2	1.6	2.8	0.0
29	16-22	32.0	34.6	23.9	26.1	58.6	57.2	2.6	2.0
30	23-29	31.7	31.7	23.3	23.8	44.2	55.2	2.6	6.0
31	30-05 Aug	31.1	29.7	23.1	24.0	49.3	27.6	2.5	3.0
32	06-12	30.2	27.8	22.9	23.5	59.9	62.6	2.9	4.0
33	13-19	30.5	31.1	22.8	23.9	40.6	3.3	2.2	1.0
34	20-26	30.5	32.5	22.6	23.0	46.7	13.6	2.0	1.0
35	27-02 Sept	30.4	31.9	22.7	23.6	47.1	11.9	2.4	2.0
36	03-09	31.1	31.8	22.5	23.5	28.5	61.4	1.5	3.0
37	10-16	32.2	30.6	22.4	22.7	18.9	87.7	1.1	7.0
38	17-23	33.4	29.7	22.3	22.6	24.6	25.1	1.4	3.0
39	24-30	33.7	31.2	21.9	21.7	24.4	0.0	1.5	0.0
40	01-07 Oct	33.9	33.8	20.2	22.6	21.8	0.0	1.1	0.0
41	08-14	34.1	33.4	18.7	20.7	16.0	18.0	0.9	1.0
42	15-21	33.9	34.3	18.1	18.2	3.1	0.0	0.4	0.0
43	22-28	33.1	33.6	18.5	14.5	10.0	0.0	0.6	0.0
44	29-04 Nov	33.0	34.6	15.8	15.8	2.3	0.0	0.3	0.0
45	05-11	32.4	33.4	14.8	15.4	3.7	0.0	0.3	0.0
46	12-18	31.7	31.8	13.7	17.8	1.1	0.0	0.2	0.0
47	19-25	31.0	32.7	13.1	17.1	10.1	5.0	0.3	1.0
48	26-02 Dec	30.3	30.8	12.4	15.4	6.8	0.5	0.3	0.0
49	03-09	29.8	32.5	11.2	14.0	1.3	0.0	0.2	0.0
50	10-16	29.4	32.1	10.3	15.8	1.3	0.0	0.2	0.0
51	17-23	29.5	31.6	10.6	13.8	0.9	0.0	0.1	0.0
52	24-31	29.2	30.2	10.7	9.4	2.6	0.0	0.2	0.0
	Total					--	528.2	--	36

Table 2 Weather record weekly rainfall and weather data for the year 2009, at Amravati

M.W.	Period	Temperature (°C)		Rainfall (mm)		Rainy days	
		Max.	Min.	Actual	Normal	Actual	Normal
22nd	28 May to 3 June 2009	40.57	30.62	11.50	2.60	0	0.6
23rd	4 June to 10 June 2009	39.40	30.40	0.00	41.00	0	1.4
24th	11 June to 17 June 2009	41.15	30.40	0.00	54.40	0	2.2
25th	18 June to 24 June 2009	39.98	29.57	0.50	68.00	0	2.2
26th	25 June to 1 July 2009	32.47	25.94	110.50	196.40	3	2
27th	2 July to 8 July 2009	30.74	24.64	208.50	154.80	7	2.6
28th	9 July to 15 July 2009	28.77	24.45	58.50	47.20	5	3.1
29th	16 July to 22 July 2009	27.81	24.07	60.00	54.60	5	2.7
30th	23 July to 29 July 2009	30.15	24.37	10.00	70.00	3	2.5
31st	30 July to 5 Aug 2009	31.44	35.08	0.00	47.00	0	2.6
32nd	6 Aug to 12 Aug 2009	32.34	25.30	0.50	165.50	0	2.25
33rd	13 Aug to 19 Aug 2009	32.62	25.22	5.50	_	1	1.3
34th	20 Aug to 26 Aug 2009	30.61	23.37	46.00	43.20	3	2.9
35th	27 Aug to 2 sept 2009	29.88	24.37	26.00	49.40	2	2.4
36th	3 Sept to 9 Sept 2009	30.05	24.04	45.50	121.20	2	1.6
37th	10 Sept to 16 Sept 2009	33.30	24.87	0.00	_	0	2.3
38th	17 Sept to 23 Sept 2009	35.20	25.70	0.00	71.60	0	1.6
39th	24 Sept to 30 Sept 2009	33.31	25.77	10.00	33.20	0	1.5
40th	1 Oct to 7 Oct 2009	31.46	24.87	7.50	_	1	1.2
41st	8 Oct to 14 Oct 2009	33.92	22.28	0.00	_	0	0.8
42nd	15 Oct to 21 Oct 2009	34.15	22.05	0.00	_	0	0.3
43rd	22 Oct to 28 Oct 2009	33.07	24.08	0.00	_	0	0.6
44th	29 Oct to 4 Nov 2009	34.20	17.65	0.00	13.00	0	0.1
45th	5 Nov to 11 Nov 2009	32.17	17.50	25.00	_	1	0.2
46th	12 Nov to 18 Nov 2009	29.60	16.88	27.80	_	3	0
47th	19 Nov to 25 Nov 2009	27.91	14.11	0.00	_	0	0.1
48th	26 Nov to 2 Dec 2009	29.64	11.54	0.00	_	0	0.3
49th	3 Dec to 9 Dec 2009	26.06	13.50	0.00	_	0	0.2
50th	10 Dec to 16 Dec 2009	30.64	15.81	0.00	_	0	0.1
51st	17 Dec to 23 Dec 2009	30.25	15.95	8.10	_	2	0.1
52nd	24 Dec to 31 Dec 2009	30.15	14.41	0.00	_	0	0.1
		Total rainfall		**667.1**	**1228**	**35**	

3.12 Collection of water samples

The well water samples were collected at each sampling sites were used for analysis. The water samples were collected in month of November 2010. The clean plastic bottles of 1000 ml were used for collection of water. After collection of the water samples were analysed for pH, EC and compositions of different cations and anions. (Richards, 1954)

Table 3: Location of sampling sites in Purna valley

Sr. no.	Village	Sampling Sites		
		Water Sample	Soil Sample	Elevation from mean sea level (m)
1.	Village- Paral Tal.Akot Dist. Akola Deorao R. Patil Survey No.96	20° 57' 16 N 076° 56' 05 E	20° 57' 04 N 076° 57' 36 E	263
2.	Village-Dapura Tal.Telhara Dist. Akola Ramesh P.Bhamburkar. Survey No.9	20° 57' 16 N 076° 56' 05 E	20° 57' 25 N 076° 56' 02 E	263
3.	Village-Ner Tal. Telhara Dist.Akola Ramesh A.Daud. Survey No.86	20° 53' 37 N 076° 55' 44 E	20° 53' 48 N 076° 56' 23 E	260
4.	Village-Patsul Tal.Akot Dist. Akola Mahadeo trust Deori Survey No.113	20° 59' 23 N 077° 01' 09 E	20° 59' 10 N 077° 00' 40 E	268
5.	Village- Hingna Tamaswadi Tal.Akot Dist. Akola Dnyandev J.Aware –Patil Survey No.28	20° 50' 26 N 077° 00'16 E	20° 50' 26 N 077° 00' 16 E	263
6.	Village – Ugwa Tal.Akot Dist. Akola Ashok Patel. Survey No 154	20° 48' 17 N 077° 00' 09 E	20° 48' 16 N 077° 00' 10 E	274
7.	Village- Naved Tal.Bhatkuli Dist. Amravati Suresh Adgokar Survey No19/1,22/1 Gat.No.72/3,74/1.	20° 57' 32 N 077° 30' 49 E	20° 57' 41 N 077° 30' 48 E	295
8.	Village-Kholapur Tal. Bhatkuli Dist. Amravati Jamil kha Vakil kha. Survey No.276 Gat No.633.	20° 57' 03 N 077° 32' 03 E	20° 57' 13 N 077° 32' 07 E	307

3.13 Processing of the samples

The samples were initially air dried in the shade. For routine estimation the whole samples were ground using wooden morter and pestle and passed through a 2mm sieve. For certain estimations such as organic carbon, samples were further ground and passed through a 0.2mm (80 mesh) sieve, as suggested by Jackson, (1973).

3.14 Soil analysis

3.14.1 Physical properties

1. Particle Size Distribution Analysis

Particle size distribution was determined as per the international pipette method. (Klute, 1986).

2. Bulk Density

The bulk density was determined by clod coating method. (Black and Hertge, 1986)

3. Hydraulic conductivity

The Hydraulic conductivity was determined by constant head method described by Klute and Dirksen (1986).

4. Mean weight diameter

The Mean weight diameter was determined by Yoder's apparatus method described by Kemper and Rosenau, (1986)

5. Coefficient of linear extensibility (COLE)

The determination of Coefficient of linear extensibility (COLE) was done as per the method of Schafer and Singer (1976). The COLE has been defined as the ratio of the difference between moist length and dry length of clod to its dry length. It is expressed as:

$$\frac{Lm-Ld}{Ld}$$

Where, Lm- Length of soil clod at saturation and

Ld- Length of soil clod when Oven dry.

6. Volumetric shrinkage potential (VSP)

The volumetric shrinkage potential (VSP) was computed from measured (COLE) and using the relationship given by Hallberg (1977)

$$VSP = \left[(COLE + 1)^3 - 1 \right] 100$$

3.14.2 Chemical properties

1. Soil reaction

Soil pH was determined in soil suspension (1:2 soil: water) by a glass electrode pH meter after equilibrating soil water for 30 min with occasional stirring (Jackson, 1973)

2. Electrical conductivity

The soil water suspension prepared for measuring pH was also used for measuring electrical conductivity. It was measured by ELICO conductivity bridge meter (Jackson, 1973)

3. Organic carbon

Organic carbon was determined by Walkely and Black (1934) rapid titration procedure.. Soil samples were oxidized by Potassium dichromate (1N) and the concentrated H_2SO_4 was used to generate the heat of dilution. The amount of unutilized dichromate was determined by back titration with Standerd ferrous ammonium sulphate solution (0.5N).

4. Free calcium carbonate

The free calcium carbonate was determined by rapid titration method (Pipper, 1966). The soil was treated with a known volume of 0.5N HCl to neutralize all the carbonates. The unutilized HCl was back titrated with Standerd NaOH of 0.25N using phenolphthalein as an indicator.

5. Exchangeable cations

The exchangeable Ca^{2+} and Mg^{2+} were determined by leaching the soils in 1N KCl TEA, buffer solution (pH 8.2) and titrating the leachate with standard EDTA solution using mureoxide and EBT as an indicator (Jackson.,1973)

Exchangeable sodium and potassium were determined by leaching the soil with 1N ammonium acetate (pH7) solution, Na^{+} and K^{+} from the leachate were estimated by using Flame photometer given by Page *et al.* (1989).

6. Cation exchange capacity (CEC)

Soil was saturated with 1N NaOAC (sodium acetate pH8.2), after removal of excess, sodium acetate by washing with alcohol, the adsorbed sodium was extracted by washing with 1N NH_4OAC(ammonium acetate pH7) and the leachate was made upto known volume. Na^{+} present in the leachate was determined with flame emission spectrophotometer (Jackson, 1973)

Percent base saturation (PBS) and Exchangeable sodium percentage (ESP) were derived by using following equations:

$$PBS = \frac{\text{Exchangeable cations}}{\text{CEC}} \times 100$$

$$ESP = \frac{\text{Exchangeable sodium}}{\text{CEC}} \times 100$$

Where, Exchangeable cations and CEC of soils were expressed in c mol (p+) kg^{-1}

7. Saturation extracts analysis

The saturated paste was prepared and the extract was obtained. The method described by Richards (1954) was followed for the saturation extract preparation. The saturation extracts of the soil samples were analysed for pHs, electrical conductivity (ECe) and cations and anions as per the methods outlined by Richards (1954)

Water analysis

1. pH:

The pH of water was measured by using Glass electrode pH meter (Jackson, 1973)

2. Electrical conductivity (EC)

The EC of water was measured by using ELICO conductivity bridge as given by Jackson, (1973)

3. Carbonate and bicarbonate

The carbonate and bicarbonate were determined by rapid titration method outlined by Richards, (1954).

4. Chloride

It was determined by titration with standard $AgNO_3$ (silver nitrate) as described by Richards, (1954).

5. Sulphate

The sulphate was determined by turbidimetric method as outlined by Page *et al.* (1989).

6. Calcium and magnesium

The calcium and magnesium were determined by versanate method as given by Richards, (1954)

7. Sodium and potassium

The sodium and potassium were determined by Flame emission spectrophotometer as described by Page *et al.* (1989).

8. Sodium adsorption ratio (SAR)

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

Where,

All the cations are expressed in meq l^{-1}.

9. Residual sodium carbonate (RSC)

$$RSC = (CO_3^{\ 2-} + HCO_3^{-}) - (Ca^{2+} + mg^{2+}).$$

Where,

RSC expressed in meq l^{-1}.

3.15 Statistical analysis

The data was analysed for statistical computations as suggested by Panse and Sukhatme (1985).

CHAPTER IV

RESULTS AND DISCUSSION

The results of the field and laboratory investigations carried out on soil and water samples collected from sites in Purna valley have been presented and discussed in this chapter under the following headings:

4.1 Morphological characteristics of soils

4.2 Physical properties of soils

4.3 Chemical properties of soils

4.4 Quality of well water.

4.5 Kind and degree of soil degradation

4.6 Periodical change in soil degradation

4.1 Morphological characteristics of soils

The morphological characteristics of soils have been studied. The various characters like colour, texture, structure, consistence etc. have been taken into consideration. The observation taken during the study is placed in Table 4. It has been indicated that all the soils were very deep (>140 cm) having dark brown to very dark grayish brown (10YR 3/2) color. It has also been observed that the structure becomes angular blocky in the subsoil layers which is mainly due to swelling clay of smectitic nature. Nearly almost all the soils were clay in texture and consistence under wet condition mostly very sticky and very plastic indicating high degree of cohesion in these soils.

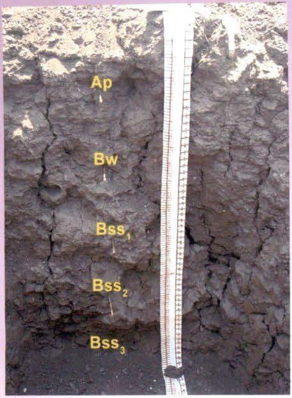
Most of the soils showed strong to violent effervescence indicating high calcium carbonate in these soils. This has been mainly due to the leaching of bicarbonates during rainy season from upper layers due to subsequent precipitation and prevailing semi-arid climatic condition (Balpande, 1996).

Table 4 : Morphological Characteristics of soils

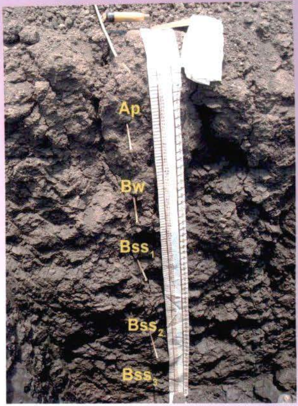
Depth (cm)	Horizon	Munsell color (moist)	Structure			Consistence			Efferve scence	Concretion		Boundary	Special features
			S	G	T	D	M	W		S	Q		
Pedon -1 (Village – Paral) Typic Haplusterts													
0-18	Ap	10YR 3/2	2	m	sbk	vh	fi	vsvp	es	f	m	cs	Well developed intersecting slikensides in third, fourth and fifth layer. 2.5 cm wide cracks extending upto 80 cm depth.
19-40	Bw	10YR 3/2	3	c	abk	vh	fi	vsvp	es	f	c	cs	
41-52	Bss1	10YR 2/2	3	c	abk	vh	fi	vsvp	ev	vf	f	cw	
53-72	Bss2	10YR 2/2	3	c	abk	vh	fi	vsvp	ev	vf	f	cw	
73-92	Bss3	10YR 2/2	3	c	abk	vh	fr	vsvp	ev	vf	f	cw	
93-110	Bss4	10YR 2/2	3	c	abk	vh	fr	vsvp	ev	vf	f	cw	
111-140	Bss5	10YR 2/2	3	c	abk	vh	fr	vsvp	ev	vf	f		
Pedon -2 (Village – Dapura) Typic Haplusterts													
0-16	Ap	10 YR 3/3	2	m	sbk	v	fi	vsvp	es	f	c	cs	Well developed intersecting slikensides in third, fourth, fifth and sixth layer. 2 cm wide cracks extending up to 70 cm depth.
17-40	Bw	10 YR 3/2	3	c	abk	v	fi	vsvp	es	f	m	cs	
41-68	Bss1	10 YR 3/1	3	c	abk	v	fi	vsvp	es	vf	f	cs	
69-102	Bss2	10 YR 2/1	3	c	abk	v	fi	vsvp	es	vf	f	cw	
103-134	Bss3	10 YR 2/2	3	c	abk	v	fi	vsvp	es	vf	f	cw	
135-155	Bss4	10 YR 2/2	3	c	abk	v	fi	vsvp	ev	vf	f		
Pedon -3 (Village – Ner) Typic Haplusterts													
0-16	Ap	10 YR 3/2	2	m	sbk	vh	fi	vsvp	e	f	m	cs	Slight effervescence, lime nodules in last two layers.1.5 cm wide cracks up to 80 cm depth. Very well developed intersecting continuous slikensides.
17-40	Bw	10 YR 3/2	2	m	sbk	vh	fi	vsvp	e	f	c	cs	
41-66	Bss1	10 YR 2/2	3	c	abk	vh	fi	vsvp	e	vf	f	cw	
67-98	Bss2	10 YR 2/2	3	c	abk	vh	fi	vsvp	e	vf	f	cw	
99-120	Bss3	10 YR 2/2	3	c	abk	vh	fi	vsvp	es	vf	f	cw	
121-154	Bss4	10 YR 2/2	3	c	abk	vh	fr	vsvp	es	vf	f		

Depth (cm)	Horizon	Munsell color (moist)	Structure			Consistence			Effervescence	Concretion		Boundary	Special features
			S	G	T	D	M	W		S	Q		
Pedon -4 (Village – Patsul) Typic Haplusterts													
0-18	Ap	10 YR 3/2	2	m	sbk	vh	fi	vsvp	es	f	m	cs	Soil highly calcareous, well developed slickensides in third, fourth layer. 2 cm wide cracks up to 92 cm depth.
19-41	Bw	10 YR 3/3	2	m	sbk	vh	fi	vsvp	es	f	m	cs	
42-68	Bss1	10 YR 2/2	3	c	abk	vh	fi	vsvp	es	f	c	cw	
69-92	Bss2	10 YR 2/2	3	c	abk	vh	fi	vsvp	es	f	c	as	
93-120	Bss3	10 YR 3/4	3	c	abk	vh	fi	vsvp	es	vf	f	as	
121-152	Bw	10 YR 3/4	3	c	abk	vh	fi	vsvp	es	f	c		
Pedon -5 (Village – Hingna- Tamaswadi) Typic Haplusterts													
0-16	Ap	10 YR 3/2	2	m	sbk	vh	fi	vsvp	e	f	c	cs	Well developed intersecting slikensides. 2 cm wide cracks upto 90 cm depth. Many concretions in last two layers.
17-42	Bw	10 YR 3/3	2	m	sbk	vh	fi	vsvp	e	f	c	cs	
43-67	Bss1	10 YR 3/1	3	c	abk	vh	fi	vsvp	e	f	c	cs	
68-90	Bss2	10 YR 2/2	3	c	abk	vh	fi	vsvp	e	vf	f	cw	
91-115	Bss3	10 YR 2/2	3	c	abk	vh	fi	vsvp	es	vf	f	cw	
116-130	Bss4	10 YR 2/2	3	c	abk	vh	fi	vsvp	es	vf	f		
Pedon -6 (Village – Ugwa) Typic Haplusterts													
0-16	Ap	10 YR 3/3	2	m	sbk	v	fi	vsvp	ev	vf	f	cs	Calcium carbonate nodules. Continuous well developed slikensides from third layer.
17-40	Bw	10 YR 3/4	3	c	abk	v	fi	vsvp	ev	vf	c	cs	
41-65	Bss1	10 YR 3/2	3	c	abk	v	fi	vsvp	ev	f	f	cs	
66-90	Bss2	10 YR 3/2	3	c	abk	v	fi	vsvp	ev	f	f	cw	
91-120	Bss3	10 YR 3/2	3	c	abk	v	fi	vsvp	ev	f	f	cw	
121-150	Bss4	10 YR 2/2	3	c	abk	v	fi	vsvp	ev	f	f	cw	
151-180	Bss5	10 YR 2/2	3	c	abk	v	fi	vsvp	ev	f	f		

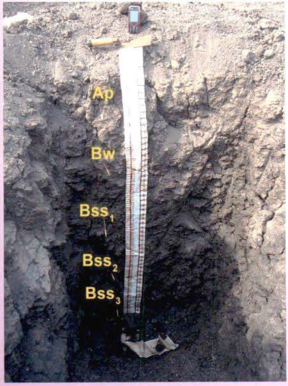
Depth (cm)	Horizon	Munsell color (moist)	Structure			Consistence			Effervescence	Concretion		Boundary	Special features
			S	G	T	D	M	W		S	Q		
Pedon -7 (Village – Naved) Typic Haplusterts													
0-16	Ap	10 YR 3/2	2	m	sbk	vh	fr	vsvp	e	vf	f	cs	Yellow calcareous materials with lime nodules in last layer. Well developed slikensides from second layer to fourth layer.
17-42	Bss1	10 YR 2/2	3	c	abk	vh	fi	vsvp	e	vf	f	cw	
43-67	Bss2	10 YR 2/2	3	c	abk	vh	fi	vsvp	es	vf	f	cw	
68-97	Bss3	10 YR 2/1	3	c	abk	vh	fi	vsvp	es	vf	c	cw	
98-121	Bss4	10 YR 2/1	3	c	abk	vh	fi	vsvp	es	f	f	cw	
122-141	Bw1	10 YR 3/4	3	c	abk	vh	fi	vsvp	es	f	f	cw	
142-160	Bw2	10 YR 3/4	3	c	abk	vh	fi	vsvp	es	f	f		
Pedon -8 (Village – Kholapur)) Vertic Haplustepts													
0-16	Ap	10 YR 3/2	2	m	sbk	vh	fr	vsvp	es	vf	c	cs	Many calcium carbonate nodules from second to last layer. Cracks and pressure faces observed.
17-45	Bw1	10 YR 3/4	2	m	sbk	vh	fi	vsvp	es	f	c	cs	
46-65	Bw2	10 YR 3/4	2	m	sbk	vh	fi	vsvp	es	vf	m	cs	
66-84	Bw3	10 YR 3/4	2	m	sbk	vh	fi	vsvp	es	vf	f	cw	
85-100	Bw4	10 YR 3/4	2	m	sbk	vh	fi	vsvp	es	f	f	cw	
101-120	Bw5	10 YR 3/4	2	m	sbk	vh	fi	vsvp	es	f	f	cw	
121-150	Bw6	10 YR 3/4	2	m	sbk	vh	fi	vsvp	es	c	c		



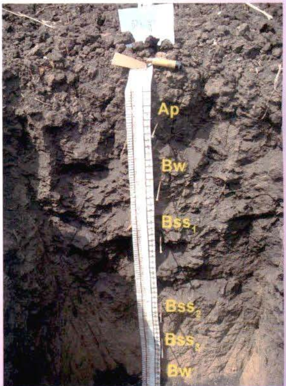
Village - Paral
Typic Haplusterts



Village - Hingna-tamaswadi
Typic Haplusterts

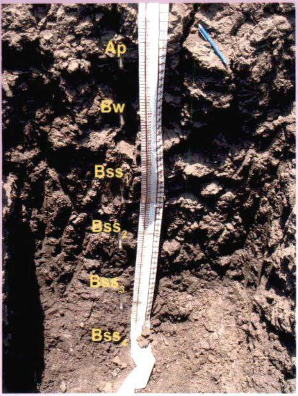


Village - Ner
Typic Haplusterts

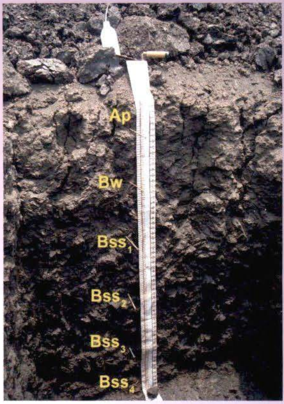


Village - Patsul
Typic Haplusterts

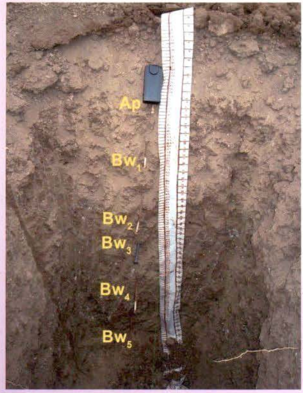
Plate 4.1 : Soil profile photographs in Purna valley



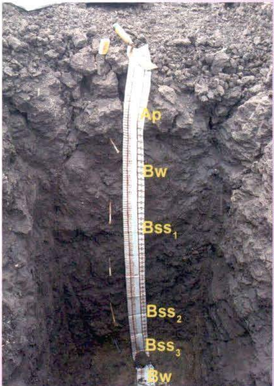
Village - Dapura
Typic Haplusterts



Village - Ugwa
Typic Haplusterts



Village - Kholapur
Vertic Haplustepts



Village - Nawed
Typic Haplusterts

Plate 4.2 : Soil profile photographs in Purna valley

The well developed intersecting slickensides were observed in majority of pedons which indicate very high swell shrink activity in these soils. In addition, 2.5 cm wide cracks were the most predominant morphological characteristics observed in these soils. The cracks in most of the pedons were extending upto 80-90 cm depth. This high swell shrink activity may attribute to the clayey nature of soil developed from the basaltic alluvium with smectite as the predominant clay mineral.

In upper horizons of smectitic Vertisols, low over burden pressure and cracks prevent the development of high lateral stresses. However, in subsoil the difference between lateral stresses is very large and slickensides are developed (Yaalon and Kalmar, 1978; Knight, 1980).

The typical morphological properties known as Vertic properties observed in these soils indicating high clay content, slickensides, pressure faces, wedge shaped natural aggregates and deep wide cracks. The prominent presence of slickensides was noticed and the horizons designated as Bss were observed. The soil profile photographs of Purna valley are in (Plate 4.1 and 4.2).

According to USDA soil taxonomy soils were classified as Vertisols and Inseptisols.

4.2 Physical properties

The physical properties of soils are very important in the context of air water relationship in the soil, soil workability, nutrient availability and drainage. Generally the physical properties of the soil do not change in a small period of time and they are modified due to management practices. The degradation of soil caused due to sodicity, is a matter of concern. The monitoring of physical properties of soils at various degrees of degradation is therefore essential for soil quality sustenance.

4.2.1 Particle size distribution

Most of the soils in the Purna valley under study have been observed to be highly clayey in nature and the clay content varied from 66.8-74.0 per cent. The clay content in the surface horizons of different pedons ranged from 66.8-69.3 per cent which was increased substantially down through the depth in the soil profile (Fig. 4.1, 4.2). The very high clay content of these soils can be attributed to their formation from basaltic parent material (Pal and Deshpande, 1987).

It is very interesting to note that the very low content of sand was noticed in these soils which varied from 2.4-4.7 per cent. The sand content in general showed decreasing trend in the profile while, the clay content increased inverse relationship indicting inverse trend of sand and clay in the profile down the depth (Table 5).

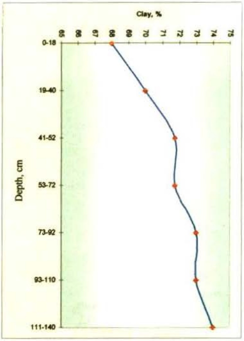
According to the USDA textural class the data for all soils indicated clayey texture throughout depth. The increasing trend of clay was also reported by Balpande *et al.* (1993). The correlation coefficient between clay and COLE was significantly positive at 5 per cent level of significance (r=0.332*) (Fig. 4.3).

4.2.2 Bulk density

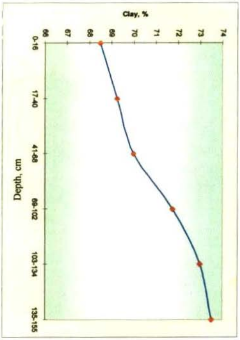
The bulk density was quite variable in different horizons and varied from 1.20-1.84 Mg m^{-3}. It was relatively lower in the surface horizons ranging from 1.28-1.68 Mg m^{-3} which may be due to comparatively more organic matter in surface horizons. However, increasing bulk density in subsoil can be attributed to higher swelling pressure and compaction caused due to smectitic clay content (Ahuja *et al.* 1988). Similar results were also reported by Bharanbe *et al.* (1999). The negative relationship between bulk density and organic carbon was observed where increasing trend of bulk density with decrease in organic matter content in the soil profile (Fig. 4.4).

Table 5 : Mechanical composition of soils

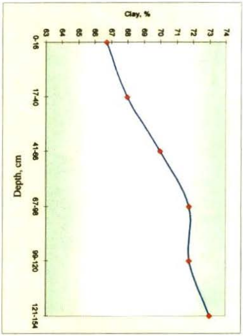
Depth (cm)	Horizon	Soil Texture		
		Sand (2.0-0.05)	Silt (0.05-0.002)	Clay (< 0.002)
		← % of less than 2 mm →		
Pedon -1 (Village – Paral) Typic Haplusterts				
0-18	Ap	5.6	26.4	68.0
19-40	Bw	3.5	25.0	70.0
41-52	Bss1	3.8	24.0	71.7
53-72	Bss2	6.0	22.2	71.7
73-92	Bss3	6.6	20.4	73.0
93-110	Bss4	6.8	20.2	73.0
111-140	Bss5	6.0	20.0	74.0
Pedon -2 (Village – Dapura) Typic Haplusterts				
0-16	Ap	7.2	24.3	68.5
17-40	Bw	6.5	24.2	69.2
41-68	Bss1	6.8	23.2	70.0
69-102	Bss2	5.6	22.6	71.7
103-134	Bss3	4.6	22.4	73.0
135-155	Bss4	6.4	20.1	73.5
Pedon -3 (Village – Ner) Typic Haplusterts				
0-16	Ap	6.4	26.8	66.7
17-40	Bw	6.6	25.4	68.0
41-66	Bss1	4.8	25.2	70.0
67-98	Bss2	3.3	24.9	71.7
99-120	Bss3	4.1	24.1	71.7
121-154	Bss4	3.0	24.0	73.0
Pedon -4 (Village – Patsul) Typic Haplusterts				
0-18	Ap	6.6	25.4	68.0
19-41	Bw	6.4	25.3	68.2
42-68	Bss1	5.8	24.9	69.2
69-92	Bss2	5.8	24.2	70.0
93-120	Bss3	5.2	23.0	71.7
121-152	Bw	7.6	22.4	70.0
Pedon -5 (Village – Hingna-Tamaswadi) Typic Haplusterts				
0-16	Ap	4.2	26.5	69.2
17-42	Bw	3.7	26.3	70.0
43-67	Bss1	2.4	25.8	71.7
68-90	Bss2	2.8	25.4	71.7
91-115	Bss3	2.8	24.2	73.0
116-130	Bss4	2.5	24.0	73.5
Pedon -6 (Village – Ugwa) Typic Haplusterts				
0-16	Ap	4.2	26.5	69.2
17-40	Bw	4.6	25.4	70.0
41-65	Bss1	3.9	24.3	71.7
66-90	Bss2	2.8	24.2	73.0
91-120	Bss3	2.6	23.9	73.5
121-150	Bss4	3.0	23.5	73.0
151-180	Bss5	4.0	23.0	73.0



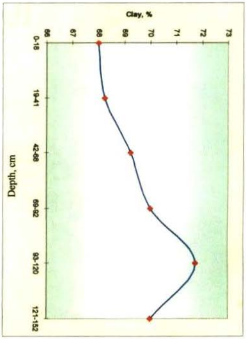
Pedon -1 (Village – Paral) Typic Haplusterts



Pedon -2 (Village – Dapura) Typic Haplusterts

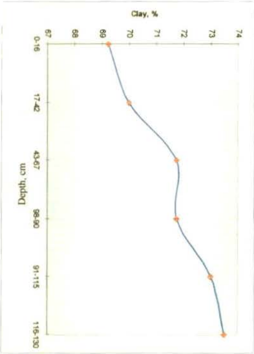


Pedon -3 (Village – Ner) Typic Haplusterts

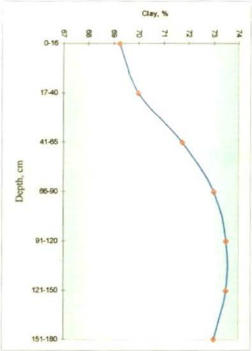


Pedon -4 (Village – Patsul) Typic Haplusterts

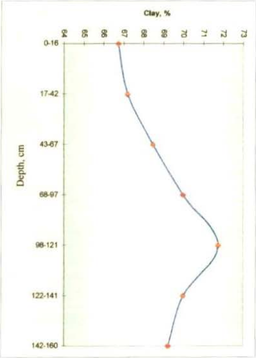
Fig. 4.1 : Depthwise distribution of Clay (%)



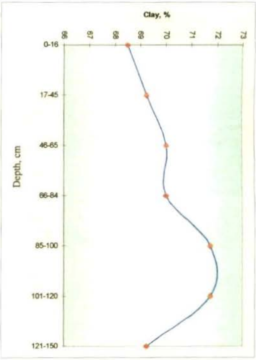
Pedon -5 (Village – H. Tamaswadi) Typic Haplusterts



Pedon -6 (Village – Ugwa) Typic Haplusterts



Pedon -7 (Village – Nawed) Typic Haplusterts



Pedon -8 (Village – Kholapur)Vertic Haplustepts

Fig. 4.2 : Depthwise distribution of Clay (%)

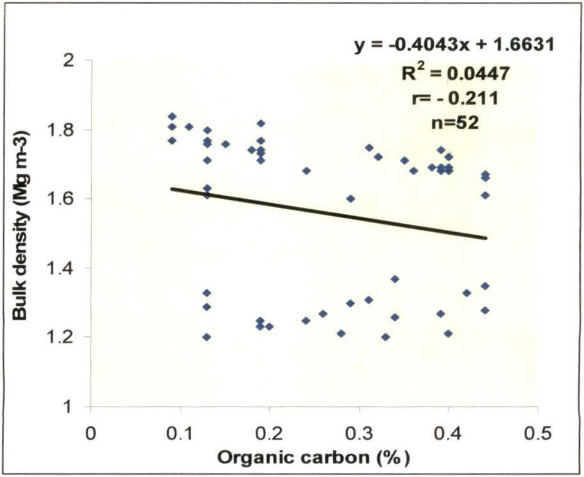


Fig. 4.4 Relationship between bulk density and organic carbon

Depth (cm)	Horizon	Soil Texture		
		Sand (2.0-0.05)	Silt (0.05-0.002)	Clay (< 0.002)
		← % of less than 2 mm →		
Pedon -7 (Village – Nawed) Typic Haplusterts				
0-16	Ap	8.7	24.5	66.7
17-42	Bss1	8.5	24.3	67.2
43-67	Bss2	7.5	24.0	68.5
68-97	Bss3	6.4	23.6	70.0
98-121	Bss4	4.7	23.5	71.7
122-141	Bw1	6.8	23.2	70.0
142-160	Bw2	8.7	22.0	69.2
Pedon -8 (Village – Kholapur) Typic Haplustepts				
0-16	Ap	6.3	25.2	68.5
17-45	Bw1	6.4	24.3	69.2
46-65	Bw2	6.1	23.9	70.0
66-84	Bw3	6.5	23.5	70.0
85-100	Bw4	5.3	22.9	71.7
101-120	Bw5	5.6	22.6	71.7
121-150	Bw6	8.7	22.0	69.2

4.2.3 Hydraulic conductivity

The hydraulic conductivity was observed to be considerably variable in different horizons and in general it was low. It was ranged from 0.5-3.4 mm hr^{-1} in different horizons of various pedons. However, it was considerably reduced in the subsoil layers upto 0.5 mm hr^{-1} (Fig. 4.5 and 4.6). This reduction in hydraulic conductivity can be attributed to the degradation of soil by increasing sodium on the exchange complex and also due to the inherent clayey nature of these soils resulting into slow water transmission. Considerable reduction in hydraulic conductivity with depth was also observed in deep black soils by Kadu *et al.* (1993).

4.2.4 Coefficient of linear extensibility (COLE)

The coefficient of linear extensibility ranged from 0.18-0.28 cm cm^{-1} indicating high swell shrink activity in these soils due to predominance of smectitic clay. The shrink swell classes are defined as low (COLE < 0.03); Moderate (COLE 0.03-0.06); high (COLE 0.06-0.09) and very high (COLE > 0.09). Based on the above classification the studied soils classified as very high swell shrink soils (Nayak *et al.* 2006). The correlation coefficient between COLE and hydraulic conductivity was found to be negative (r= -0.55**). This clearly indicates that the smectitic clay content reduced the hydraulic conductivity of studied soils (Fig.4.7).

4.2.5 Volumetric shrinkage potential (VSP)

The volumetric shrinkage potential ranged from 64.3-109.71 per cent. The volumetric shrinkage potential reflects an understandable rating of swell shrink potential of soils as compared to COLE values (Hallberg, 1977). Similar results were also reported by Nayak *et al.* (2006). Where COLE and VSP ranged from 0.09-0.27 cm cm^{-1} and 30-100 per cent respectively, which showed very high swell shrink nature of the soils.

4.2.6 Mean weight diameter (MWD)

The mean weight diameter was found to be varied from 0.38-0.69 mm in different horizons of the soil profile and it was decreased down to the depth. The downward decrease in mean weight diameter can be attributed to subsoil sodicity observed in these soils. The detrimental effect of sodification on soil structure has also been reported by many workers. The poor structural stability of Vertisols particularly during monsoon season renders the agricultural activities very difficult (Sen, 2003).

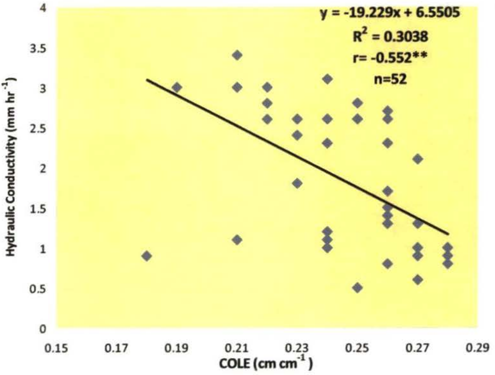
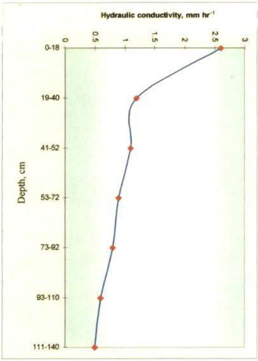


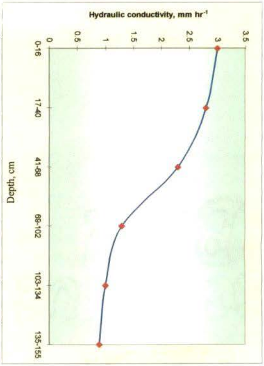
Fig. 4.7 Relationship between COLE and hydraulic conductivity

Table 6 : Physical Properties of soils

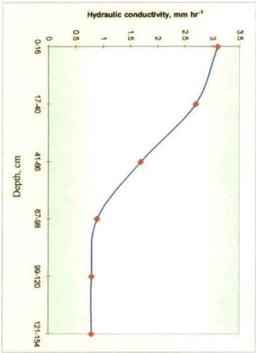
Depth (cm)	Horizon	Bulk density ($Mg\ m^{-3}$)	Hydraulic Conductivity ($mm\ hr^{-1}$)	COLE ($cm\ cm^{-1}$)	Volumetric Shrinkage Potential (%)	Mean weight Diameter (mm)
Pedon -1 (Village – Paral) Typic Haplusterts						
0-18	Ap	1.61	2.6	0.22	81.5	0.58
19-40	Bw	1.61	1.2	0.24	90.6	0.54
41-52	Bss1	1.63	1.1	0.21	77.1	0.50
53-72	Bss2	1.71	0.9	0.18	64.3	0.48
73-92	Bss3	1.73	0.8	0.26	100.0	0.46
93-110	Bss4	1.77	0.6	0.27	104.8	0.44
111-140	Bss5	1.77	0.5	0.25	95.3	0.40
Pedon -2 (Village – Dapura) Typic Haplusterts						
0-16	Ap	1.66	3.0	0.19	68.5	0.66
17-40	Bw	1.68	2.8	0.25	95.3	0.64
41-68	Bss1	1.69	2.3	0.26	100.0	0.63
69-102	Bss2	1.71	1.3	0.26	100.0	0.58
103-134	Bss3	1.74	1.0	0.27	104.8	0.54
135-155	Bss4	1.76	0.9	0.28	109.7	0.48
Pedon -3 (Village – Ner) Typic Haplusterts						
0-16	Ap	1.68	3.1	0.24	90.6	0.69
17-40	Bw	1.68	2.7	0.26	100.0	0.67
41-66	Bss1	1.72	1.7	0.26	100.0	0.64
67-98	Bss2	1.74	0.9	0.28	109.7	0.59
99-120	Bss3	1.77	0.8	0.28	109.7	0.57
121-154	Bss4	1.81	0.8	0.28	109.7	0.55
Pedon -4 (Village – Patsul) Typic Haplusterts						
0-18	Ap	1.31	2.8	0.22	81.6	0.67
19-41	Bw	1.30	2.6	0.24	90.7	0.65
42-68	Bss1	1.20	2.3	0.26	100.0	0.54
69-92	Bss2	1.21	1.3	0.27	104.8	0.52
93-120	Bss3	1.27	1.0	0.27	104.8	0.49
121-152	Bw	1.33	0.8	0.28	109.7	0.46
Pedon -5 (Village – Hingna-Tamaswadi) Typic Haplusterts						
0-16	Ap	1.35	3.4	0.21	77.1	0.66
17-42	Bw	1.33	3.0	0.22	81.6	0.62
43-67	Bss1	1.27	1.8	0.23	86.1	0.60
68-90	Bss2	1.26	1.1	0.24	90.7	0.58
91-115	Bss3	1.23	1.0	0.24	90.7	0.56
116-130	Bss4	1.20	0.8	0.26	100.0	0.54
Pedon -6 (Village – Ugwa) Typic Haplusterts						
0-16	Ap	1.68	3.0	0.21	77.2	0.59
17-40	Bw	1.69	2.7	0.26	100.0	0.54
41-65	Bss1	1.71	2.3	0.26	100.0	0.46
66-90	Bss2	1.74	2.1	0.27	104.8	0.44
91-120	Bss3	1.76	1.7	0.26	100.0	0.42
121-150	Bss4	1.80	0.9	0.27	104.8	0.39



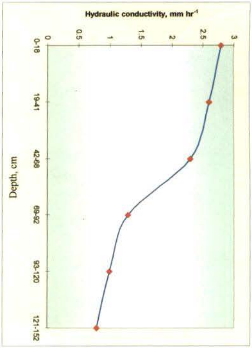
Pedon -1 (Village – Paral) Typic Haplusterts



Pedon -2 (Village – Dapura) Typic Haplusterts

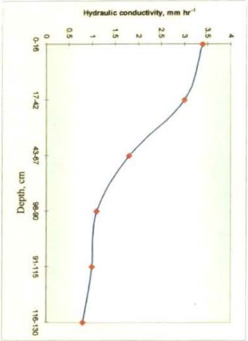


Pedon -3 (Village – Ner) Typic Haplusterts

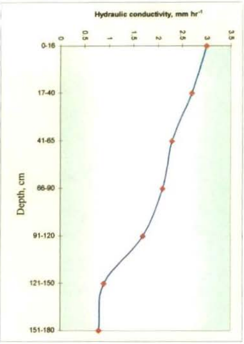


Pedon -4 (Village – Patsul) Typic Haplusterts

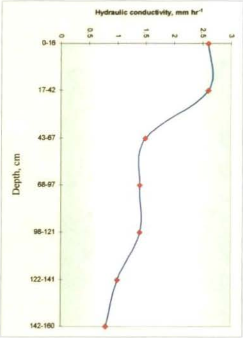
Fig. 4.5 : Depthwise distribution of Hydraulic conductivity (mm hr^{-1})



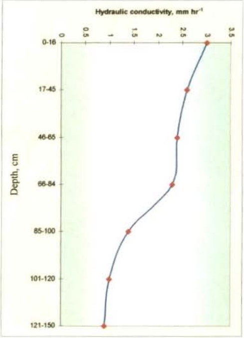
Pedon -5 (Village – H. Tamaswadi) Typic Haplusterts



Pedon -6 (Village – Ugwa) Typic Haplusterts



Pedon -7 (Village – Nawed) Typic Haplusterts



Pedon -8 (Village – Kholapur)Vertic Haplustepts

Fig. 4.6: Depthwise distribution of Hydraulic conductivity (mm hr^{-1})

151-180	Bss5	1.81	0.8	0.28	109.7	0.38
Depth (cm)	**Horizon**	**Bulk density ($Mg\ m^{-3}$)**	**Hydraulic Conductivity ($mm\ hr^{-1}$)**	**COLE ($cm\ cm^{-1}$)**	**Volumetric Shrinkage Potential (%)**	**Mean weight Diameter (mm)**
Pedon -7 (Village – Nawed) Typic Haplusterts						
0-16	Ap	1.60	2.6	0.25	95.3	0.59
17-42	Bss1	1.67	2.6	0.26	100.0	0.58
43-67	Bss2	1.69	1.5	0.26	100.0	0.54
68-97	Bss3	1.72	1.4	0.26	100.0	0.49
98-121	Bss4	1.75	1.4	0.26	100.0	0.48
122-141	Bw1	1.82	1.0	0.28	109.7	0.46
142-160	Bw2	1.84	0.8	0.28	109.7	0.44
Pedon -8 (Village – Kholapur) Vertic Haplustepts						
0-16	Ap	1.28	3.0	0.22	81.6	0.69
17-45	Bw1	1.21	2.6	0.23	86.1	0.68
46-65	Bw2	1.37	2.4	0.23	86.1	0.64
66-84	Bw3	1.25	2.3	0.24	90.7	0.58
85-100	Bw4	1.23	1.4	0.26	100.0	0.56
101-120	Bw5	1.25	1.0	0.27	104.8	0.46
121-150	Bw6	1.29	0.9	0.28	109.7	0.44

Table 6.1 : Range of hydraulic conductivity and clay

Sr.No.	Villages	Hydraulic conductivity ($mm\ hr^{-1}$)	Clay (%)
1.	Paral	0.5-2.6	68.00-74.00
2.	Dapura	0.9-3.0	68.50-73.50
3.	Ner	0.8-3.1	66.75-73.00
4.	Patsul	0.8-2.8	68.00-71.75
5.	HIngna Tamaswadi	0.8-3.4	69.25-73.50
6.	Ugwa	0.8-3.0	69.25-73.50
7.	Nawed	0.8-2.6	67.20-71.75
8.	Kholapur	0.9-3.0	68.50-71.75
9.	Overall range	0.5-3.4	66.75-74.00

4.3 Chemical properties of soil

4.3.1 pH (1:2)

The chemical characteristics of soils revealed that the pH (1:2) varied from 7.0-9.5 in different horizons. The pH of surface horizons ranged from 7.5-8.6 which was increased down through the depth in the profile (Table 7 and Fig. 4.8, 4.9). The pH in the subsoil layers was observed to be increased upto 9.5. This may be due to the alkaline hydrolysis of bicarbonates which is predominant in these soils. Comparatively high pH was due to calcareous nature containing higher amount of free calcium carbonate (Bharambe *et al.* 1985)

It is thus apparent from this the soils have undergone significant chemical degradation reflected in the greater increase in the pH.

4.3.2 Electrical conductivity (1:2)

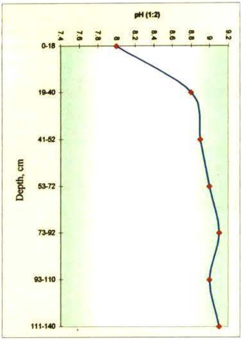
The electrical conductivity ranged from 0.10-0.48 dSm^{-1} in different horizons. The electrical conductivity in the surface horizons ranged from 0.10-0.25 dSm^{-1} which was increased down through the depth in the profile. The electrical conductivity in subsoil layers was observed to be increased upto 0.48 dSm^{-1}. The data indicated a general trend of salt accumulation in the subsurface horizons under rainfed conditions, and ill effect of past irrigation with well water (Nimkar, 1990)

4.3.3 Calcium carbonate

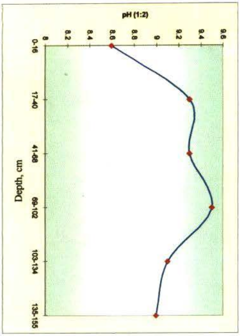
The calcium carbonate ranged from 5.75-16.37 per cent in different horizons. The calcium carbonate in surface horizons ranged from 5.8 to 13.4 per cent which was increased down through the depth in profile. The calcium carbonate in sub soil layers was observed to be increased up to 16.37 per cent. This is mainly due to semi arid climatic condition, where the leaching of bicarbonates during rainy season from

Table 7 : Chemical properties of soil

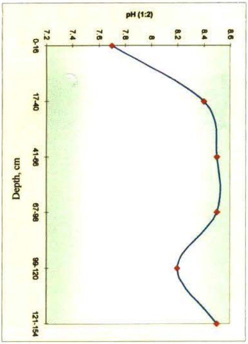
Depth (cm)	Horizon	pH (1:2)	EC (1:2) (dSm^{-1})	$CaCO_3$ (%)	Organic carbon (%)
Pedon -1 (Village – Paral) Typic Haplusterts					
0-18	Ap	8.0	0.11	9.4	0.44
19-40	Bw	8.8	0.13	9.4	0.13
41-52	Bss1	8.9	0.14	11.9	0.13
53-72	Bss2	9.0	0.13	10.6	0.13
73-92	Bss3	9.1	0.17	11.9	0.19
93-110	Bss4	9.0	0.22	14.4	0.19
111-140	Bss5	9.1	0.24	15.0	0.13
Pedon -2 (Village – Dapura) Typic Haplusterts					
0-16	Ap	8.6	0.12	9.1	0.44
17-40	Bw	9.3	0.23	9.8	0.39
41-68	Bss1	9.3	0.23	12.5	0.39
69-102	Bss2	9.5	0.24	13.1	0.19
103-134	Bss3	9.1	0.44	14.4	0.19
135-155	Bss4	9.0	0.48	16.1	0.13
Pedon -3 (Village – Ner) Typic Haplusterts					
0-16	Ap	7.7	0.25	11.6	0.40
17-40	Bw	8.4	0.11	11.6	0.36
41-66	Bss1	8.5	0.10	11.0	0.32
67-98	Bss2	8.5	0.13	15.6	0.18
99-120	Bss3	8.2	0.13	15.7	0.09
121-154	Bss4	8.5	0.25	16.0	0.11
Pedon -4 (Village – Patsul) Typic Haplusterts					
0-18	Ap	7.5	0.12	9.1	0.31
19-41	Bw	7.7	0.12	10.0	0.29
42-68	Bss1	7.9	0.11	14.0	0.33
69-92	Bss2	8.2	0.11	15.2	0.28
93-120	Bss3	8.2	0.11	16.4	0.26
121-152	Bw	8.4	0.15	16.2	0.13
Pedon -5 (Village – Hingna-Tamaswadi) Typic Haplusterts					
0-16	Ap	8.0	0.17	10.4	0.44
17-42	Bw	8.6	0.12	10.8	0.42
43-67	Bss1	8.9	0.11	12.6	0.39
68-90	Bss2	8.9	0.13	13.6	0.34
91-115	Bss3	8.8	0.18	14.4	0.19
116-130	Bss4	8.5	0.40	15.4	0.13
Pedon -6 (Village – Ugwa) Typic Haplusterts					
0-16	Ap	8.2	0.13	11.1	0.24
17-40	Bw	8.7	0.13	11.4	0.38
41-65	Bss1	8.5	0.12	11.6	0.35
66-90	Bss2	8.5	0.12	11.3	0.39
91-120	Bss3	8.4	0.12	16.3	0.15
121-150	Bss4	8.2	0.21	16.4	0.13
151-180	Bss5	8.5	0.12	11.3	0.09



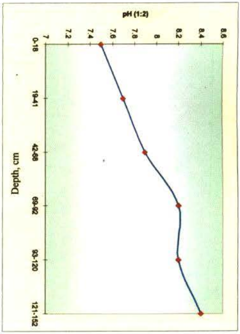
Pedon -1 (Village – Paral) Typic Haplusterts



Pedon -2 (Village – Dapura) Typic Haplusterts

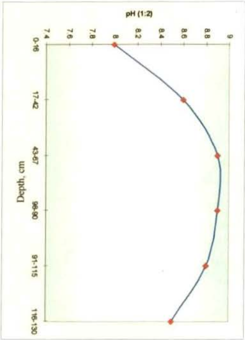


Pedon -3 (Village – Ner) Typic Haplusterts

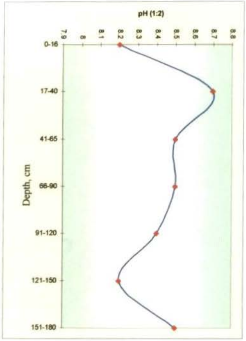


Pedon -4 (Village – Patsul) Typic Haplusterts

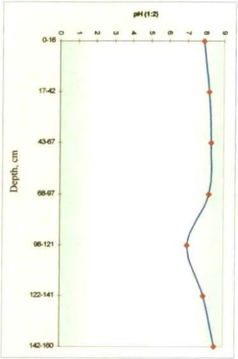
Fig. 4.8 : Depthwise distribution of pH (1:2)



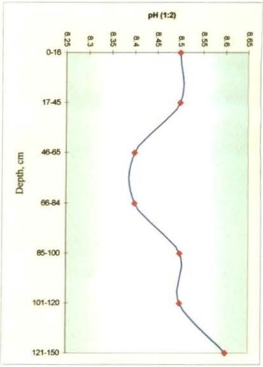
Pedon -5 (Village – H. Tamaswadi) Typic Haplusterts



Pedon -6 (Village – Ugwa) Typic Haplusterts



Pedon -7 (Village – Nawed) Typic Haplusterts



Pedon -8 (Village – Kholapur)Vertic Haplustepts

Fig. 4.9 : Depthwise distribution of pH (1:2)

Depth (cm)	Horizon	pH (1:2)	EC (1:2) (dSm^{-1})	$CaCO_3$ (%)	Organic carbon (%)
Pedon -7 (Village – Nawed) Typic Haplusterts					
0-16	Ap	7.9	0.11	5.8	0.29
17-42	Bss1	8.2	0.10	6.3	0.44
43-67	Bss2	8.3	0.14	6.9	0.40
68-97	Bss3	8.2	0.13	7.6	0.40
98-121	Bss4	7.0	0.45	13.6	0.31
122-141	Bw1	7.9	0.36	13.7	0.19
142-160	Bw2	8.5	0.25	15.0	0.09
Pedon -8 (Village – Kholapur) Vertic Haplustepts					
0-16	Ap	8.5	0.11	13.4	0.44
17-45	Bw1	8.5	0.12	13.7	0.40
46-65	Bw2	8.4	0.10	15.0	0.34
66-84	Bw3	8.4	0.12	15.4	0.24
85-100	Bw4	8.5	0.13	15.4	0.20
101-120	Bw5	8.5	0.11	16.1	0.19
121-150	Bw6	8.6	0.14	16.3	0.13

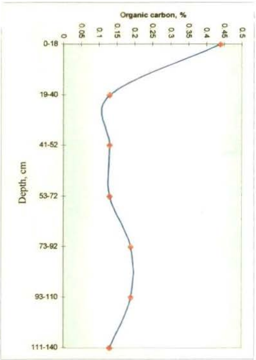
upper layers and subsequent precipitation triggers development of sodicity in sub soils of black soils (Balpande *et al*, 1996).

4.3.4 Organic carbon

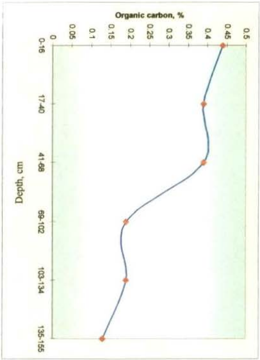
The organic carbon ranged from 0.09 to 0.44 per cent in different horizon and found to be decreased down the depth (Fig. 4.10 and 4.11) In general the organic carbon observed low in the soil which is due to dispersion of organic matter caused by exchangeable Na^+. Moreover, the considerable reduction in organic carbon can also be attributed to prevailing semi arid climatic condition in this area.

4.3.5 Ion exchange analysis

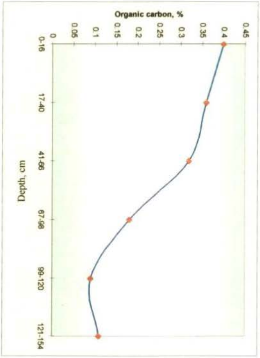
The exchange complex of studied soil was observed to be dominated by calcium, magnesium and sodium. The calcium (Ca^{2+}) and magnesium (Mg^{2+}) in general showed decreasing trend down the depth in profile while sodium (Na^+) showed increasing trend. The base saturation percentage varied from 58.2-99.2 per cent, being highly base saturated.



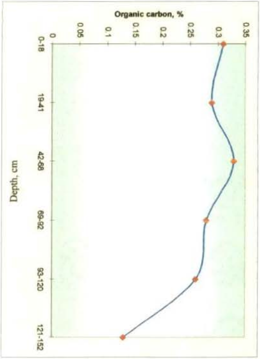
Pedon -1 (Village – Paral) Typic Haplusterts



Pedon -2 (Village – Dapura) Typic Haplusterts

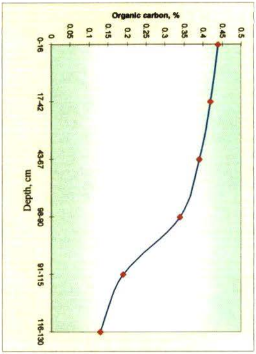


Pedon -3 (Village – Ner) Typic Haplusterts

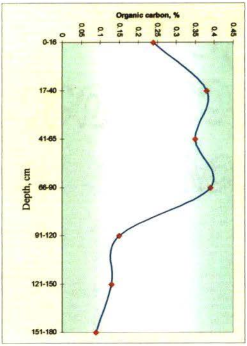


Pedon -4 (Village – Patsul) Typic Haplusterts

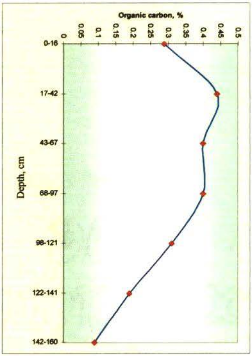
Fig. 4.10: Depthwise distribution of Organic carbon, %



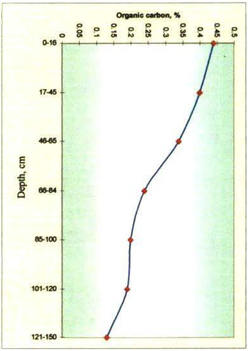
Pedon -5 (Village – H. Tamaswadi) Typic Haplusterts



Pedon -6 (Village – Ugwa) Typic Haplusterts



Pedon -7 (Village – Nawed) Typic Haplusterts



Pedon -8 (Village – Kholapur)Vertic Haplustepts

Fig. 4.11 : Depthwise distribution of Organic carbon

4.3.6 Cation exchange capacity

The cation exchange capacity was high and varied from 44.5 to 66.5 c mol (p^+) Kg^{-1} in different horizons. It was very high due to predominance of smectitic mineralogy of soils.

4.3.5 Exchangeable sodium percentage

The exchangeable sodium percentage varied from 5.0 to 9.7 per cent in surface horizons of various pedons and it was in general increased down the depth in the profile (Fig. 4.12 and 4.13) The ESP was observed to be higher at some of the sites in the study area indicating sodification in these soils. This can be attributed to lower topographical situation of these soils formed in the valley favoring the accumulation of soils and subsequent sodification under the condition of semi arid climate coupled with slow permeability of these soils.

An increase in ESP with depth is a general observation for the black and associated soils in the semi arid region of the peninsular India (Dubey *et al*, 1983; Murthey *et al.*1982; Nimkar *et al.* 1992). The negative relationship between ESP and hydraulic conductivity was specifically observed at the sites where more degree of degradation due to sodicity was observed. (Fig. 4.14) Table 8.

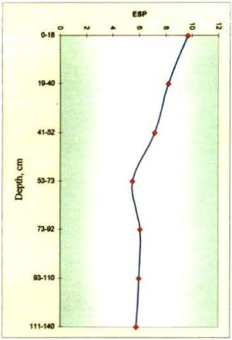
4.4 Composition of saturation extract of soils

4.4.1 Saturation percentage

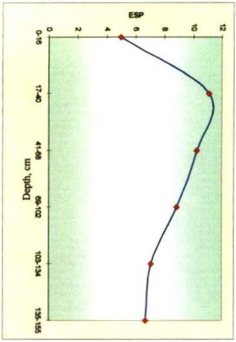
The saturation percentage varied from 65.5 to 79.2. These values indicated the dominance of smectite mineralogy of the finer fractions of these soils.

Table 8 : Ion-exchange analysis data

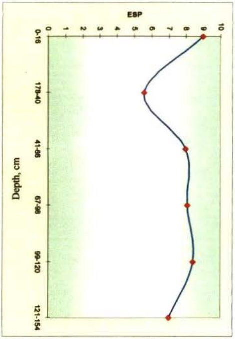
Depth (cm)	Horizon	Extractable bases				Sum	CEC Cmol (p+) kg^{-1}	Base Saturation (%)	ESP	EMP	Ca Mg
		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}						
		cmol (p+)kg^{-1}									
Pedon -1 (Village – Paral) Typic Haplusterts											
0-18	Ap	35.2	10.2	5.1	1.1	51.6	52.2	98.8	9.7	19.5	3.5
19-40	Bw	33.7	9.4	4.5	1.1	48.7	54.6	89.2	8.2	17.2	3.6
41-52	Bss1	32.8	8.6	4.0	1.2	46.6	55.6	83.8	7.2	15.5	3.8
53-73	Bss2	32.9	8.0	3.2	0.6	44.7	56.5	79.0	5.5	14.2	4.1
73-92	Bss3	30.6	8.0	3.7	0.6	43.0	60.4	70.1	6.1	13.4	3.8
93-110	Bss4	30.1	7.7	4.0	0.6	42.4	66.1	64.2	6.0	11.6	3.9
111-140	Bss5	30.0	7.4	3.9	0.6	41.9	66.4	63.1	5.8	11.1	4.0
Pedon -2 (Village – Dapura) Typic Haplusterts											
0-16	Ap	32.4	12.1	3.1	1.0	48.6	61.5	79.0	5.0	19.7	2.7
17-40	Bw	32.2	12.0	6.8	0.9	51.9	61.6	84.2	11.1	19.5	2.7
41-68	Bss1	31.1	10.7	6.4	0.7	48.9	62.3	78.9	10.3	17.2	2.9
69-102	Bss2	30.7	10.4	5.6	1.1	47.8	62.7	69.5	8.9	16.6	2.9
103-134	Bss3	27.9	9.7	4.3	1.0	42.9	60.0	71.5	7.1	16.2	2.9
135-155	Bss4	22.7	8.5	4.1	0.8	36.1	60.1	60.0	6.7	14.1	2.8
Pedon -3 (Village – Ner) Typic Haplusterts											
0-16	Ap	31.3	11.7	4.4	0.7	48.1	56.1	85.7	9.0	20.8	2.7
178-40	Bw	31.0	11.4	3.2	0.7	46.3	56.7	81.6	5.6	20.1	2.7
41-66	Bss1	27.2	10.6	4.7	1.1	43.6	57.7	75.6	8.0	18.4	2.6
67-98	Bss2	25.4	10.2	4.7	0.7	41.0	58.0	70.7	8.1	17.6	2.5
99-120	Bss3	25.0	9.4	4.9	0.8	40.1	58.3	68.8	8.4	16.1	2.7
121-154	Bss4	24.0	9.1	4.2	0.7	38.0	59.6	63.9	7.0	15.3	2.6
Pedon -4 (Village – Patsul) Typic Haplusterts											
0-18	Ap	32.0	11.7	3.2	1.0	47.9	57.2	83.8	5.6	20.5	2.7
19-41	Bw	35.6	11.4	4.5	1.0	52.5	64.9	80.9	6.9	17.7	3.1
42-68	Bss1	30.0	10.7	4.2	0.9	45.8	64.7	70.8	6.5	16.5	2.8
69-92	Bss2	28.9	10.3	4.3	0.8	44.2	65.7	67.3	6.5	15.7	2.8
93-120	Bss3	27.5	9.7	4.2	0.7	42.1	66.1	64.0	6.3	14.7	2.8
121-152	Bw	24.6	8.4	5.5	0.7	39.2	66.5	58.9	8.2	12.6	2.9
Pedon -5 (Village – Hingna-Tamaswadi) Typic Haplusterts											
0-16	Ap	46.4	11.1	3.3	0.9	61.7	63.0	97.9	5.2	17.6	4.2
17-42	Bw	44.3	10.7	3.4	0.7	59.0	59.0	99.2	5.6	18.1	4.1
43-67	Bss1	42.8	10.2	3.4	0.5	57.0	57.0	94.8	5.7	17.9	4.2
68-90	Bss2	39.7	9.4	4.2	0.8	54.1	54.1	87.4	6.7	17.4	4.2
91-115	Bss3	38.2	9.2	4.6	0.7	52.7	52.7	84.0	7.3	17.5	4.2
116-130	Bss4	30.3	8.7	4.4	1.1	44.5	44.5	70.1	6.9	19.5	3.5
Pedon -6 (Village – Ugwa) Typic Haplusterts											
0-16	Ap	42.4	12.6	3.1	0.9	59.0	60.4	97.6	5.1	20.9	3.4
17-40	Bw	42.2	12.1	3.2	0.6	58.1	60.9	95.4	5.1	19.9	3.5
41-65	Bss1	40.3	10.4	3.7	0.5	54.9	59.6	92.3	6.2	17.4	3.9
66-90	Bss2	40.0	10.1	3.2	1.0	54.3	65.7	82.7	4.8	15.4	4.0
91-120	Bss3	38.7	10.3	3.9	0.8	53.7	63.5	84.7	6.1	16.2	3.8
120-150	Bss4	34.5	9.8	4.3	0.7	49.3	63.7	77.5	6.7	15.4	3.5
150-180	Bss5	30.1	8.7	4.2	0.7	43.8	64.9	67.5	6.5	13.4	3.5



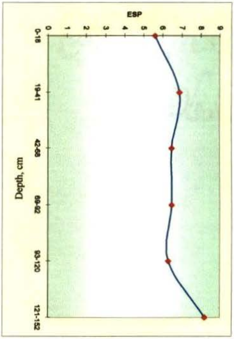
Pedon -1 (Village – Paral) Typic Haplusterts



Pedon -2 (Village – Dapura) Typic Haplusterts

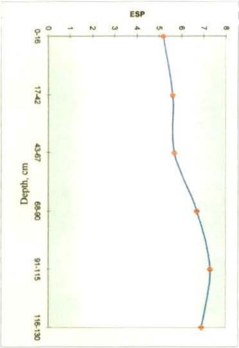


Pedon -3 (Village – Ner) Typic Haplusterts

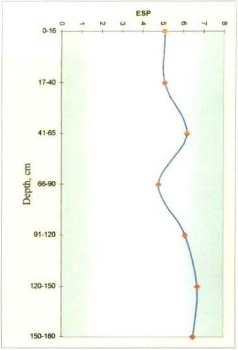


Pedon -4 (Village – Patsul) Typic Haplusterts

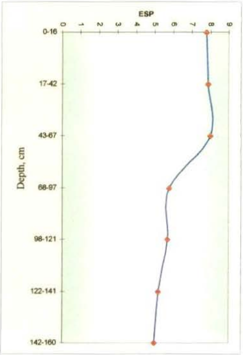
Fig. 4.12: Depthwise distribution of ESP



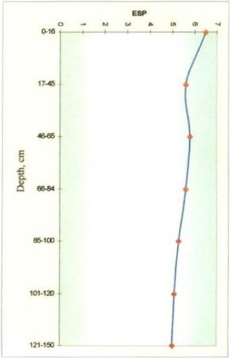
Pedon -5 (Village – H. Tamaswadi) Typic Haplusterts



Pedon -6 (Village – Ugwa) Typic Haplusterts



Pedon -7 (Village – Nawed) Typic Haplusterts



Pedon -8 (Village – Kholapur)Vertic Haplustepts

Fig. 4.13: Depthwise distribution of ESP

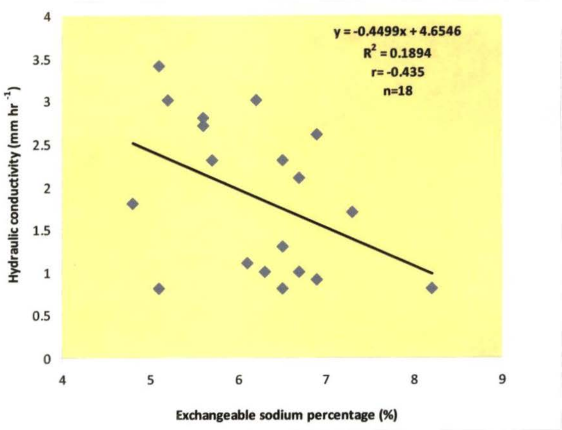


Fig. 4.14 Relationship between exchangeable sodium percentage and hydraulic conductivity

Depth (cm)	Horizon	Extractable bases				Sum	CEC Cmol (p+) kg^{-1}	Base Saturation (%)	ESP	EMP	Ca/ Mg
		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}						
		cmol (p+)kg^{-1}									
Pedon -7 (Village – Nawed) Typic Haplusterts											
0-16	Ap	35.3	13.5	4.3	0.7	53.7	54.3	98.8	7.8	24.9	2.6
17-42	Bss1	33.7	12.7	4.4	0.6	51.3	55.2	93.0	7.9	23.0	2.7
43-67	Bss2	32.1	12.5	4.5	0.8	49.9	56.1	89.0	8.0	22.3	2.6
68-97	Bss3	30.4	11.4	3.3	0.8	45.9	56.5	81.2	5.8	20.2	2.7
98-121	Bss4	30.0	10.2	3.4	1.1	44.8	59.6	75.2	5.7	17.1	2.9
122-141	Bw1	28.5	9.4	3.2	0.9	42.0	61.3	68.6	5.2	15.3	3.0
142-160	Bw2	28.3	9.2	3.1	0.8	41.4	62.8	66.0	5.0	14.6	3.1
Pedon -8 (Village – Kholapur) Vertic Haplustepts											
0-16	Ap	42.3	12.6	4.0	1.1	60.0	61.0	98.0	6.5	20.7	3.4
17-45	Bw1	40.4	11.5	3.3	1.1	56.3	58.2	96.8	5.6	19.8	3.5
46-65	Bw2	40.1	10.7	3.4	1.0	55.2	58.4	94.4	5.8	18.3	3.7
66-84	Bw3	38.7	10.2	3.4	0.9	53.2	59.4	89.5	5.6	17.2	3.8
85-100	Bw4	32.4	9.7	3.3	0.9	46.3	60.8	75.6	5.3	16.0	3.3
101-120	Bw5	32.0	9.3	3.2	0.8	45.3	60.9	74.5	5.1	15.3	3.4
121-150	Bw6	30.1	8.4	3.0	0.7	42.2	60.0	70.4	5.0	14.0	3.6

4.4.2 pHs

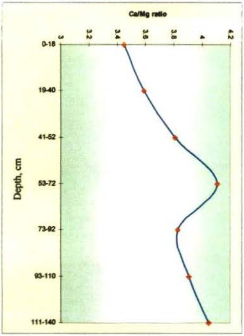
The saturation extract analysis data revealed that the pH varies from 7.0-9.1 in different horizons. The pH in the surface horizons ranged from 7.67-8.82 which was increased down through the depth in the profile. The increase in pH in subsurface horizons mainly due to alkaline hydrolysis of bicarbonates predominant in these soils.

4.4.3 Electrical conductivity (ECe)

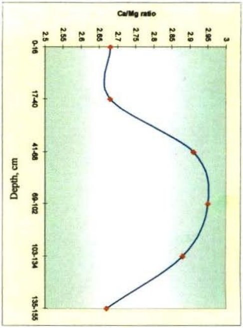
The ECe of saturation paste extract varied from 0.42-2.7 dSm^{-1} in different horizons which was increased down the depth in the profile (Fig.4.15 and 4.16) Table 9 . The subsoil increase in ECe indicates that there is salinization process operative in these soils resulting into accumulation of salts in lower horizons.

4.4.4 Soluble cations and anions

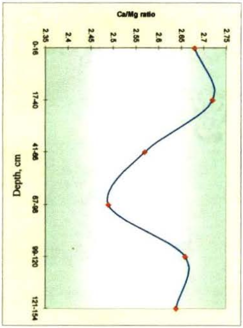
The soluble cations showed that sodium (Na^{+}) was predominant over calcium (Ca^{2+}) and magnesium (Mg^{2+}) and it ranged from 4.2-14.9 me L^{-1} in different horizons. The soluble sodium was also in increasing trend down to the depth indicating the process of sodification. It was also interesting to note that Mg^{2+} was higher as compare to Ca^{2+} in soluble phase.



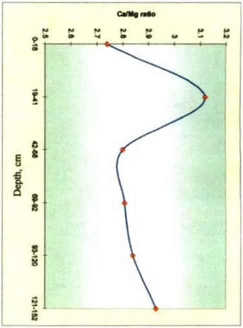
Pedon -1 (Village – Paral) Typic Haplusterts



Pedon -2 (Village – Dapura) Typic Haplusterts

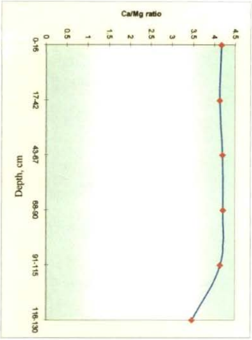


Pedon -3 (Village – Ner) Typic Haplusterts

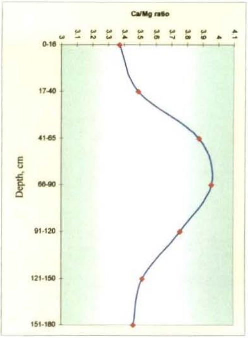


Pedon -4 (Village – Patsul) Typic Haplusterts

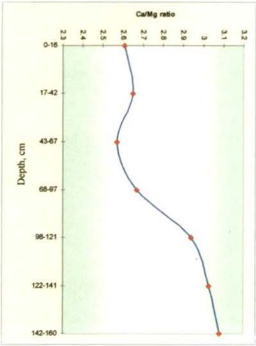
Fig. 4.15: Depthwise distribution of Ca/Mg ratio



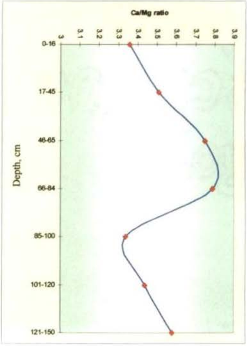
Pedon -5 (Village – H. Tamaswadi) Typic Haplusterts



Pedon -6 (Village – Ugwa) Typic Haplusterts



Pedon -7 (Village – Nawed) Typic Haplusterts

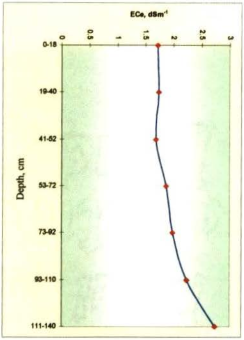


Pedon -8 (Village – Kholapur)Vertic Haplustepts

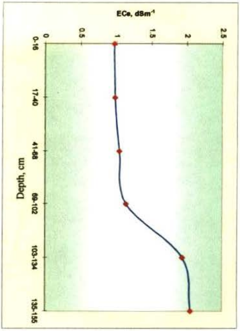
Fig.4.16 : Depthwise distribution of Ca/Mg ratio

Table 9 : Saturation paste extract analysis data

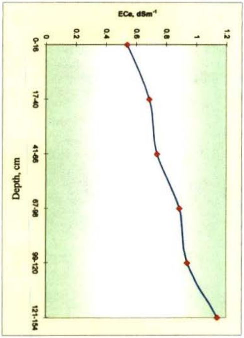
Depth (cm)	Horizon	Saturation %	pHs	Ece (dS m^{-1})
Pedon -1 (Village – Paral) Typic Haplusterts				
0-18	Ap	65.5	8.07	1.72
19-40	Bw	67.8	8.78	1.74
41-52	Bss1	69.2	8.89	1.69
53-72	Bss2	70.4	8.98	1.87
73-92	Bss3	72.4	8.98	1.99
93-110	Bss4	74.6	8.96	2.24
111-140	Bss5		8.94	2.74
Pedon -2 (Village – Dapura) Typic Haplusterts				
0-16	Ap	69.2	8.82	0.97
17-40	Bw	68.2	8.94	0.99
41-68	Bss1	66.5	8.97	1.05
69-102	Bss2	72.5	8.77	1.14
103-134	Bss3	78.9	8.99	1.94
135-155	Bss4	77.9	9.12	2.05
Pedon -3 (Village – Ner) Typic Haplusterts				
0-16	Ap	78.2	7.77	0.54
17-40	Bw	74.5	8.31	0.69
41-66	Bss1	77.2	8.42	0.74
67-98	Bss2	74.5	8.51	0.89
99-120	Bss3	76.2	8.16	0.94
121-154	Bss4	70.4	8.24	1.14
Pedon -4 (Village – Patsul) Typic Haplusterts				
0-18	Ap	68.5	7.67	0.69
19-41	Bw	72.6	7.77	0.68
42-68	Bss1	74.2	7.87	0.76
69-92	Bss2	77.5	8.21	0.81
93-120	Bss3	78.6	8.24	0.84
121-152	Bw	79.2	8.37	1.11
Pedon -5 (Village – Hingna- Tamaswadi) Typic Haplusterts				
0-16	Ap	72.4	7.97	0.71
17-42	Bw	74.5	8.54	0.62
43-67	Bss1	68.9	8.89	0.61
68-90	Bss2	70.4	8.82	0.42
91-115	Bss3	77.6	8.84	0.51
116-130	Bss4	78.2	8.49	0.55
Pedon -6 (Village – Ugwa) Typic Haplusterts				
0-16	Ap	72.4	8.40	0.84
17-40	Bw	77.6	8.67	0.94
41-65	Bss1	74.2	8.69	0.99
66-90	Bss2	78.2	8.63	0.97
91-120	Bss3	79.6	8.55	1.01
121-150	Bss4	74.5	8.34	1.04
151-180	Bss5	78.5	8.44	1.15



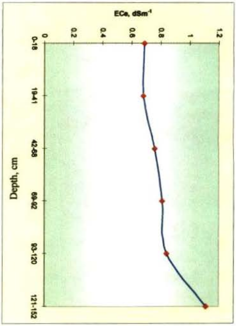
Pedon -1 (Village – Paral) Typic Haplusterts



Pedon -2 (Village – Dapura) Typic Haplusterts

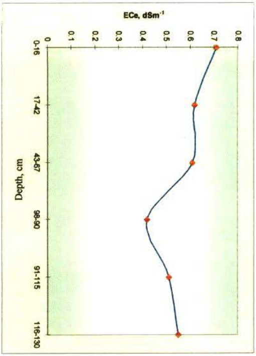


Pedon -3 (Village – Ner) Typic Haplusterts

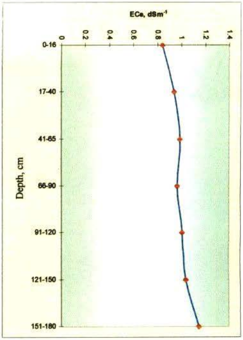


Pedon -4 (Village – Patsul) Typic Haplusterts

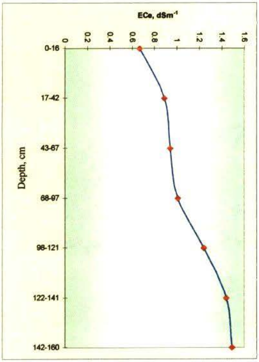
Fig. 4.17: Depthwise distribution of ECe (dSm^{-1})



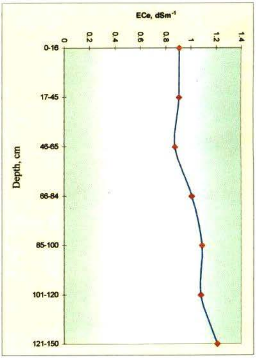
Pedon -5 (Village – H. Tamaswadi) Typic Haplusterts



Pedon -6 (Village – Ugwa) Typic Haplusterts



Pedon -7 (Village – Nawed) Typic Haplusterts



Pedon -8 (Village – Kholapur)Vertic Haplustepts

Fig. 4.18 : Depthwise distribution of ECe (dSm^{-1})

Depth (cm)	Horizon	Saturation %	pHs	Ece ($dS\ m^{-1}$)
Pedon -7 (Village – Naved) Typic Haplusterts				
0-16	Ap	69.4	7.99	0.67
17-42	Bss1	68.7	8.26	0.89
43-67	Bss2	72.4	8.31	0.94
68-97	Bss3	74.6	8.24	1.01
98-121	Bss4	75.4	7.02	1.24
122-141	Bw1	77.4	7.44	1.44
142-160	Bw2	78.9	8.94	1.49
Pedon -8 (Village – Kholapur)) Vertic Haplustepts				
0-16	Ap	74.2	8.54	0.91
17-45	Bw1	75.8	8.59	0.91
46-65	Bw2	74.6	8.44	0.88
66-84	Bw3	78.9	8.49	1.01
85-100	Bw4	74.6	8.59	1.09
101-120	Bw5	78.4	8.48	1.08
121-150	Bw6	79.2	8.54	1.21

The ionic composition of paste extract indicate that among all the soluble anions the HCO_3 were higher ranging from 3.9-10.9 me L^{-1}. The higher HCO_3 are indicative of increased pH in these soils. The presence of CO_3 was undetected because dissolved CO_3 react with Ca^{2+} from different sources (exchange sites, mineral weathering) and precipitates immediately as $CaCO_3$ in the course of preparation of paste extract (Gupta and Abrol, 1990) The chlorides ranged from 0.5-7.9 me L^{-1} which were higher in the soil profiles at village Hingna tamaswadi, Ugwa and Kholapur. The SO_4^{2-} was also higher in the profile at village Nawed. The correlation coefficient between Ca^{2+}/Mg^{2+} ratio and hydraulic conductivity was found to be positively significant (r = 0.46**). (Fig. 4.17) indicating the detrimental effect of reduction in $Ca^{2+}/\ Mg^{2+}$ ratio on the hydraulic conductivity of soils (Table 10).

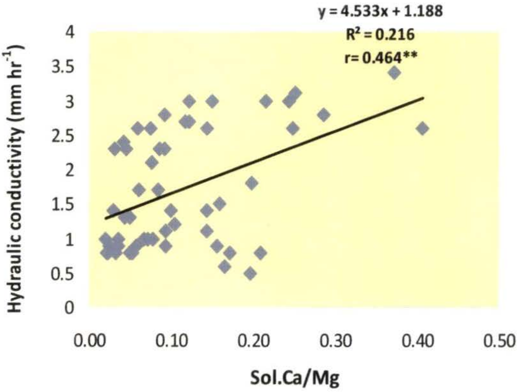


Fig. 4.19 Relationship between sol.Ca/Mg ratio and hydraulic conductivity

Table 10 Saturation paste extract analysis data

Depth (cm)	Horizon	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^-	Cl^-	SO_4^{2-}	SAR	Ca/Mg	HCO_3/Ca
		Soluble Cations and Anions (me L^{-1} of saturation extract)									
Pedon -1 (Village – Paral) Typic Haplusterts											
0-18	Ap	1.1	3.2	4.9	0.41	6.4	0.8	1.01	4.75	0.34	5.8
19-40	Bw	1.4	3.0	5.2	0.44	6.2	0.6	1.42	5.00	0.47	4.4
41-52	Bss1	1.8	3.4	5.4	0.29	6.6	0.5	1.61	4.73	0.53	3.7
53-72	Bss2	2.0	3.7	5.8	0.26	6.9	0.9	2.02	4.87	0.54	3.5
73-92	Bss3	2.2	3.9	6.0	0.24	7.2	1.4	2.42	4.87	0.56	3.3
93-110	Bss4	2.2	3.9	6.4	0.15	7.5	1.2	2.61	5.20	0.56	3.4
111-140	Bss5	2.4	3.8	6.2	0.12	7.7	1.4	2.91	5.00	0.63	3.2
Pedon -2 (Village – Dapura) Typic Haplusterts											
0-16	Ap	1.2	2.0	4.6	0.44	4.8	1.4	0.80	5.16	0.60	4.0
17-40	Bw	1.0	2.1	4.4	0.41	5.2	1.2	1.20	5.00	0.48	5.2
41-68	Bss1	0.8	2.4	4.8	0.34	5.8	1.6	1.42	5.39	0.33	7.3
69-102	Bss2	0.8	2.2	4.4	0.21	5.8	2.0	1.60	5.11	0.36	7.3
103-134	Bss3	1.2	3.0	5.2	0.23	6.2	2.2	2.54	5.09	0.40	5.2
135-155	Bss4	1.4	3.2	5.9	0.14	6.5	2.4	2.68	5.10	0.44	4.6
Pedon -3 (Village – Ner) Typic Haplusterts											
0-16	Ap	1.4	2.0	4.5	0.44	3.9	1.4	1.81	4.89	0.70	2.8
17-40	Bw	1.1	2.2	4.3	0.41	4.7	1.2	1.60	4.77	0.50	4.3
41-66	Bss1	1.0	2.4	4.2	0.24	4.9	1.2	1.40	4.56	0.42	4.9
67-98	Bss2	0.9	2.7	4.1	0.27	5.2	2.3	1.10	4.36	0.33	5.8
99-120	Bss3	0.8	2.2	5.2	0.18	5.5	2.4	0.90	6.50	0.36	6.9
121-154	Bss4	0.6	2.9	5.3	0.12	5.8	3.1	2.10	5.80	0.21	9.7
Pedon -4 (Village – Patsul) Typic Haplusterts											
0-18	Ap	1.8	2.1	4.9	0.27	5.4	2.5	2.70	5.44	0.86	3.0
19-41	Bw	1.4	2.3	4.8	0.22	5.9	2.9	2.00	5.00	0.61	4.2
42-68	Bss1	1.2	2.8	4.8	0.26	6.0	3.5	2.50	4.80	0.43	5.0
69-92	Bss2	0.9	2.8	4.2	0.29	6.5	3.4	2.20	4.37	0.32	7.2
93-120	Bss3	0.9	3.4	5.2	0.16	6.5	3.2	3.60	5.04	0.26	7.2
121-152	Bw	2.2	3.2	5.3	0.14	7.2	2.9	2.40	4.56	0.69	3.3
Pedon -5 (Village – Hingna- Tamaswadi) Typic Haplusterts											
0-16	Ap	2.8	3.4	4.9	0.24	6.2	4.9	3.40	3.95	0.82	3.1
17-42	Bw	2.4	3.6	5.7	0.27	7.4	4.8	2.50	4.67	0.67	3.5
43-67	Bss1	2.6	3.7	5.9	0.21	9.2	4.6	2.30	4.72	0.70	5.1
68-90	Bss2	1.9	4.0	6.4	0.19	9.7	5.8	2.10	5.28	0.48	6.0
91-115	Bss3	1.7	4.2	6.8	0.17	10.2	4.0	1.80	5.61	0.40	7.1
116-130	Bss4	1.4	4.0	6.2	0.12	9.9	4.2	1.20	5.34	0.35	3.7
Pedon -6 (Village – Ugwa) Typic Haplusterts											
0-16	Ap	2.1	4.7	5.4	0.29	7.7	4.0	2.16	4.15	0.45	3.5
17-40	Bw	2.1	4.9	5.5	0.24	7.4	4.4	1.91	4.16	0.43	4.5
41-65	Bss1	2.0	4.9	4.4	0.21	8.9	4.4	1.41	3.35	0.41	4.7
66-90	Bss2	1.8	5.0	4.9	0.19	8.4	3.7	1.41	3.76	0.36	5.1
91-120	Bss3	1.6	5.1	6.2	0.17	8.2	3.8	1.24	4.80	0.31	7.7
121-150	Bss4	1.2	4.4	6.6	0.14	9.2	2.9	1.81	5.64	0.27	7.6
151-180	Bss5	1.1	4.4	6.9	0.12	8.4	2.1	1.26	5.89	0.25	3.8

Depth (cm)	Horizon	Soluble Cations and Anions							SAR	Ca/Mg	HCO_3 /Ca
		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{2-}			
		me L^{-1} of saturation extract									
Pedon -7 (Village – Naved) Typic Haplusterts											
0-16	Ap	2.4	3.0	14.9	0.32	10.7	4.8	6.62	12.41	0.93	5.5
17-42	Bss1	3.0	4.9	6.2	0.34	10.9	4.8	6.54	4.42	0.41	6.7
43-67	Bss2	2.0	5.0	7.4	0.31	9.4	3.2	5.72	5.60	0.28	7.2
68-97	Bss3	2.5	5.4	12.2	0.24	8.6	3.5	5.28	8.71	0.22	7.8
98-121	Bss4	2.2	5.2	12.4	0.24	9.4	3.8	4.49	7.25	0.23	9.0
122-141	Bw1	1.9	5.8	10.2	0.14	9.9	3.8	4.94	7.39	0.19	7.6
142-160	Bw2	1.2	5.8	9.4	0.12	8.4	3.1	3.21	7.70	0.19	2.8
Pedon -8 (Village – Kholapur)) Vertic Haplustepts											
0-16	Ap	2.8	3.4	6.03	0.19	6.81	5.1	3.6	4.27	0.71	2.3
17-45	Bw1	2.0	3.2	6.05	0.21	6.91	5.6	3.22	5.81	0.94	3.5
46-65	Bw2	1.4	3.6	6.82	0.14	6.99	6.6	2.22	5.28	0.56	3.0
66-84	Bw3	1.2	5.8	7.74	0.14	7.49	6.8	2.36	5.68	0.43	3.8
85-100	Bw4	1.2	5.7	7.08	0.18	8.44	7.0	3.41	4.14	0.39	4.8
101-120	Bw5	1.1	5.4	8.63	0.16	9.21	7.4	3.49	5.16	0.35	7.7
121-150	Bw6	1.1	6.7	8.94	0.15	9.26	7.9	3.66	6.12	0.18	2.3

Table 10.1 : Range of pHs, ECe, SAR and ESP in different villages

Sr. No.	Villages	pHs	ECe	SAR	ESP
1	Paral	8.0-8.9	1.6-2.7	4.7-5.2	5.5-9.7
2	Dapura	8.7-9.12	0.9-2	5.0-5.3	5.0-11.1
3	Ner	7.7-8.5	0.54-1.14	4.3-6.5	5.6-9.0
4	Patsul	7.6-8.3	0.6-1.11	4.3-5.4	5.6-8.2
5	HIngna Tamaswadi	7.9-8.8	0.4-0.7	3.9-5.6	5.2-7.3
6	Ugwa	8.3-8.6	0.8-1.15	3.3-5.8	4.8-6.7
7	Nawed	7.0-8.9	0.67-1.49	4.4-12.4	5.0-8.0
8	Kholapur	8.4-8.5	0.88-1.21	4.1-6.1	5.0-6.5
9	Overall range	7.0-9.12	0.42-2.7	3.3-12.41	4.8-11.1

4.4.5 Sodium adsorption ratio (SAR)

The sodium adsorption ratio of the saturation paste extract was ranged from 3.3-12.41. The SAR increased sharply with the depth in all the pedons reflecting clearly that initiation of the process of alkalinization in subsurface layers as a consequence of salt accumulation and its progress in upward direction along with capillary rise of soil solution during dry periods. The similar results were also recorded by Nimkar, (1990). The correlation coefficient between Sodium adsorption ratio and hydraulic conductivity found to be negative (r= -0.148) indicating that the hydraulic conductivity is reduced with the increase in sodium adsorption on the soil particles. (Fig. 4.18)

4.5 Quality of well water

The data presented in Table 11 showed the pH of the well water collected from of Purna valley tract in Vidarbha region. It varied from 7.17- 8.07 indicating ground water of tract is moderately to highly alkaline in reaction.

Based on EC of ground water, it can be classified as high to very high. EC of well water ranged from 2.40 to 9.44 dSm^{-1} (Richards, 1954) (Appendix IV).

The dominant cations present in ground water are Na^{+}, Ca^{2+} and Mg^{2+} and corresponding values ranged between 9.4-32.4, 1.5-4.0 and 2.3-6.2 respectively. The results indicated dominance of sodium in ground water over calcium and magnesium, which might be responsible for development of native sodicity in Purna valley soils.

The major anions present in valley water were CO_3^{2-}, HCO_3, $SO_4^{2-}$and Cl^{-} . The corresponding values are none to 0.48, 7.2-14.2, 2.8-12.1 and 4.4-16.0 respectively.

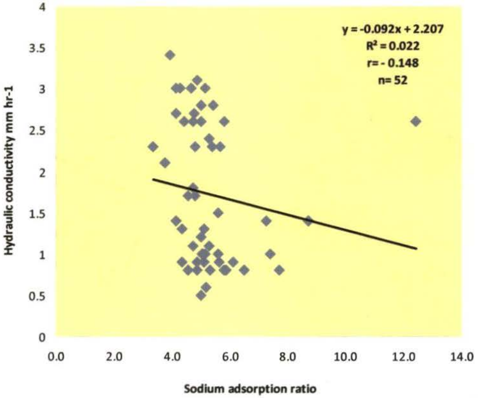


Fig. 4.20 Relationship between sodium adsorption ratio and hydraulic conductivity.

Table 11: Well water quality analysis data (USSL criteria)

Sampling sites (Village)	pH	EC dSm^{-1}	SAR	RSC $me\ L^{-1}$	Class	Salinity and sodicity hazards
Paral	7.21	9.21	20.8	4.0	C_4S_3	V. high salinity high sodicity
Dapura	7.38	4.49	9.4	2.9	C_3S_1	High salinity low sodicity
Ner	7.17	7.76	14.02	4.6	C_4S_2	V. high salinity medium sodicity
Patsul	7.24	3.86	6.52	3.7	C_3S_1	High salinity low sodicity
Hingna -Tamaswadi	8.07	5.78	11.2	7.3	C_4S_2	V. high salinity medium sodicity
Ugwa	7.35	2.40	22.96	3.8	C_2S_3	Medium salinity high sodicity
Kholapur	7.60	2.63	10.08	1.4	C_2S_2	Medium salinity medium sodicity
Naved	8.07	9.44	14.08	6.5	C_4S_2	V. high salinity medium sodicity

Table 11.1: Well water quality analysis data

Sampling sites (Village)	Cations and anions								
	Ca^{2+}	Mg^{2+}	Na+	K+	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Mg/Ca
	$me\ L^{-1}$								
Paral	4	6.2	31.2	0.27	-	14.2	4.4	5.9	1.6
Dapura	2.7	4.6	12.7	0.12	-	10.2	5.7	4.4	1.7
Ner	2.9	5.4	20.2	0.39	-	12.9	5.9	4.6	1.9
Patsul	3.4	4.9	9.4	0.34	-	12.0	5.4	2.8	1.4
Hingna -Tamaswadi	2.3	4.8	14.2	0.37	-	14.4	6.4	7.2	2.1
Ugwa	2.4	4.4	29.4	0.21	-	10.4	5.9	12.1	1.8
Kholapur	3.5	2.3	12.1	0.34	-	7.2	16.0	3.48	0.7
Naved	1.5	2.4	32.4	0.54	0.48	9.92	6.4	7.41	1.6

The RSC values of ground water ranged from 1.4-7.3. Eaton (1950) pointed out that if irrigation water has an appreciable amount of CO_3^{2-} and HCO_3 the Ca^{2+} and Mg^{2+} carbonates will be precipitated when the concentration of soil solution is enhanced through evapotranspiration. Based on Residual sodium carbonate (RSC) values of the basin, the ground water of Purna valley can be classified into marginally alkali to highly alkali (Tyagi and Minhas, 1998). The criteria by Tyagi and Minhas (1998) is given in (Appendix III). As per the criteria of Tyagi and Minhas (1998) the well water quality at most of the sites was highly alkali (Table 11.2).

Table 11.2 CSSRI Criteria for determining quality of water

Sampling sites (Village)	EC dSm^{-1}	SAR	RSC me L^{-1}	Class
Paral	9.21	20.8	4.0	Highly alkali
Dapura	4.49	9.4	2.9	Saline
Ner	7.76	14.02	4.6	Highly alkali
Patsul	3.86	6.52	3.7	Marginally alkali
Hingna -Tamaswadi	5.78	11.2	7.3	Highly alkali
Ugwa	2.40	22.96	3.8	Highly alkali
Kholapur	2.63	10.08	1.4	Marginally saline
Naved	9.44	14.08	6.5	Highly alkali

The sodium adsorption ratio (SAR) of well waters of valley varied from 6.52-22.96. Considering overall grouping of ground waters, based on EC, SAR and RSC, the ground waters of the valley can be classified under marginally alkali to highly alkali in nature, which is unsuitable for irrigation without providing suitable amendment and drainage. Dev Burman and Mehta (1996) also reported that, ground water of Purna valley tract in Vidarbha region was of Ca/Na-HCO_3 type, however, at time Cl^- type ground water was also encountred.

4.6 Kind and degree of soil degradation

As per the USSL criteria (Richards, 1954) for diagnosis of saline/sodic soils, the soils of Purna valley qualify as normal soils. However, by using the modified criteria based on the available literature and data obtained it was revealed that most of the soils qualifiy for none to very slightly saline- sodic (SS_1), slightly sodic (S_2) and moderately sodic (S_3)

Table 12 Criteria for kind and degree of land degradation assessment as per USSL.

Sr. No.	Salinity class	pH	ECe (dS m^{-1})	ESP(%)
1.	Saline soils	< 8.5	< 4	< 15
2.	Sodic soils	> 8.5	> 4	> 15
3.	Saline sodic soils	Variable	> 4	> 15

(Source: Richards, 1954)

Table 13 Criteria for kind and degree of land degradation assessment as per modified criteria (Sodicity classes)

Sr. No.	Sodicity class	Range of ESP (%)
1	None to very slightly sodic (S1)	<6
2	Slightly sodic (S2)	6-10
3	Moderately sodic (S3)	10-15
4	Strongly sodic (S4)	>15

(Source: Biswas and Mukherjee, 1987)

For kind and degree of land degradation assessment purposes the range of diagnostic characteristics for each pedon are given in Table 15

The degradation processes may occur in many soils at ESP levels much lower than 15. The ESP of 6 has been suggested as limiting value to indicate sharp impairment of physical condition.

Threshold limit for swell-shrink clay soils lies between 6-10 (Balpande *et al.*, 1996).

Table 14: Criteria for kind and degree of land degradation assessment as per modified criteria (Saline-sodic classes)

Sr. No.	Saline-sodic class	ECe (dSm^{-1})	ESP (%)
1	None to very slightly saline-sodic (SS1)	<4	<6
2	Slightly saline-sodic (SS2)	4-8	6-10
3	Moderately saline-sodic (SS3)	8-15	10-15
4	Strongly saline-sodic (SS4)	15-25	>15

(Source: Biswas and Mukherjee, 1987)

While working on Purna valley (Vidarbha) soils, Balpande (1997) suggested that current lower limit of 15 ESP of USSL is arbitrary and it would be prudent to evaluate the lower limit of ESP in view of loss of productivity in different groups of Vertisols compared with criteria limit of ESP 15 for deterioration in soil structure, a considerably lower ESP value of 6 has been suggested for soil with abundance of fine clay and lacking in soluble weatherable minerals. (Northcote and Skene, 1972; Shanmuganahan and Oades, 1983).

ESP 5 should be used as the lower limit for sodic subgroups of Vertisols of central India, rather than 15 due to severe limitations of these soils owing to the development of adverse physical condition in respect of very poor drainage even at low ESP (< 5) (Balpande et al. 1996).

Kharche and Pharande (2010) revealed that the soils with high sodium on exchange complex (ESP>10) in association of high clay content of smectitic nature showed problems and caused severe restriction in drainage. This was supported by farmers experience and also field observations in the form of reduction of mottles in soil profile and conditions of poor drainage especially at ESP above 10. This indicates the necessity of lowering the ESP in black swell-shrink soils for categorizing them as sodic mainly because the sodification problem is further aggravated by the high clay content causing the soils to be inherently slow in permeability. They also suggested the necessity of lowering the ESP limit in Vertisols for categorizing them as sodic.

Table 15: Kind and degree of land degradation assessment as per pedons.

Pedon No.	ECe ($dS\ m^{-1}$)	ESP (%)	Soil degradation class
1	1.6-2.7	5.5-9.7	Slightly sodic (S_2)
2	0.9-2.0	5.0-11.1	Moderately sodic (S_3)
3	0.5-1.1	5.6-9.0	Slightly sodic (S_2)
4	0.6-1.1	5.6-8.2	Slightly sodic (S_2)
5	0.4-0.7	5.2-7.3	Slightly sodic (S_2)
6	0.8-1.1	4.8-6.7	None to very slightly saline- sodic (SS_1)
7.	0.6-1.4	5.0-8.0	Slightly sodic (S_2)
8.	0.8-1.2	5.0-6.5	Slightly sodic (S_2)

The existing widely used criterion by USSL (Richards, 1954) is not clearly indicating the degradation hazards in the soils. It has thus been also reported by many workers that the criteria of USSL fails to categorize the degradation problems in black (Vertisols) soils. Based on the results of present study it was observed that by modifying the criteria using available literature as shown in Table the kind and degree of degradation can be assessed in a better way in order to diagnose the problems of salinity or sodicity. The soils have been found to be categorized as none to very slightly saline- sodic (SS_1), slightly sodic (S_2) and moderately sodic (S_3).

The soil degradation and its kind and degree needs to be necessarily studied in relation to crop performance i.e. yield of crops. This helps in categorizing the degradation classes pertaining to local condition. In this view the yield data was collected at each site which is presented in (Appendix II).

It was observed that the yield of many crops although relatively good under rainfed condition which is mainly because inherently productive nature of these soils. However, it was observed that the in general the crop yields were certainly reduced due to soil degradation. Thus there are better chances of improving the crop productivity upon proper management of these soils based on accurate diagnosis of the problem.

4.6 Periodical change in soil degradation

The soils of the Purna valley have been extensively studied by many workers before two decades (Nimkar, Magar 1990; Kadu 1991 and Balpande 1993). The characterization carried out in these investigations indicated that soils in Purna valley suffer from the degradation problem due to salinity and sodicity. However, it was also reported that the soils were not qualified for sodic class as per USSL criteria but showed the impairment in physical properties.

In order to study the periodical changes in soil degradation in Purna valley the interpretation of climatic parameters over a period of two decades (1990-2009) has been carried out. The data and trend of climatic parameters has been presented in (Table 16 and 17) (Fig. 4.17- 4.28).

The periodical change in climatic parameters revealed that there has been considerable reduction in annual rainfall and increase in temperature over a period of more than two decades.

Table 16 Periodical change in climatic parameters at Akola

Year	Rainfall (mm)	Rainy Days	Temperature			
			Mean minimum (^{0} C)	Mean maximum (^{0} C)	Lowest recorded (^{0} C)	Highest recorded (^{0} C)
1990	1151.2	41	19.0	33.3	10.6	42.5
1995	824.7	39	19.1	34.1	10.3	42.6
2000	666.8	32	19.1	34.0	9.5	42.4
2005	694.9	38	19.9	34.0	11.0	42.5
2009	528.2	36	21.3	34.7	13.6	42.7

(Source: Agro meteorology department, Dr.P.D.K.V. Akola)

Table 17 Periodical change in climatic parameters at Amravati

Year	Rainfall (mm)	Rainy Days	Temperature			
			Mean minimum (^{0} C)	Mean maximum (^{0} C)	Lowest recorded (^{0} C)	Highest recorded (^{0} C)
1990	1095.3	42	12.7	33.1	10.4	37.4
1995	811.3	36	14.7	42.2	8.4	44.5
2000	902.6	43	14.6	42.3	8.2	43.5
2005	875.6	40	12.4	43.4	8.2	44.5

(Source: Meteorological department Amravati)

In view of the fact that the formation of salt affected soils in the semi arid condition is favoured by reduction in precipitation and increase in evapo transpiration the soil degradation due to salinity and sodicity is likely to increase. There has been increase in number of dry spells and considerable reduction in rainy days during period of two decades from 1990-2009. The continuous rise in temperature caused due to the effect of climate change and global warming may aggravate the degradation process undergoing in soils in Purna valley. An attempt has been made in present investigation to study periodical change in soil degradation at the selected sites during period of 1990-2010.

It was observed that there was considerable increase in pH of soils over the period of two decades (Table 18). The increase in degree of degradation due to sodicity may be responsible for increase in pH of the soil. The EC was observed to be of nearly equal magnitude as that of in the past while at many places the ESP was found to be slightly increased especially in subsoil horizons. This may be due to cycles of

Periodical change in climatic parameters at Akola

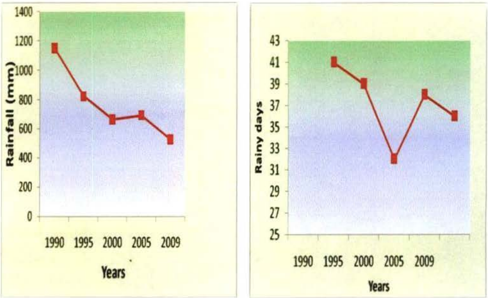


Fig. 4.21 Periodical change in rainfall, rainy days at Akola

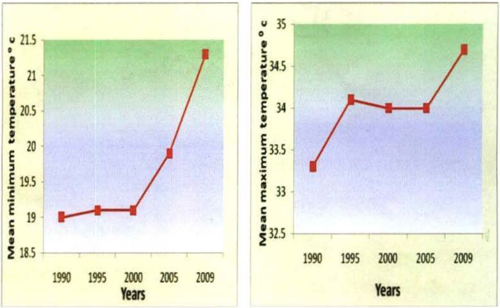
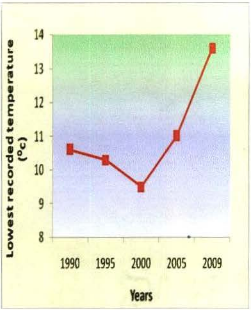


Fig.4.22 Periodical change in mean minimum, mean maximum temperature (^{0}c) at Akola



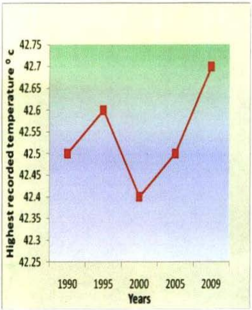
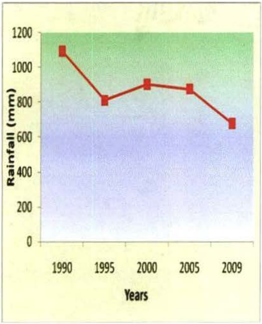


Fig. 4.23 Periodical change in lowest , highest recorded temperature at Akola

Periodical change in climatic parameters at Amravati



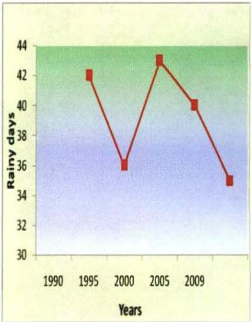


Fig. 4.24 Periodical change in rainfall, rainy days at Amravati

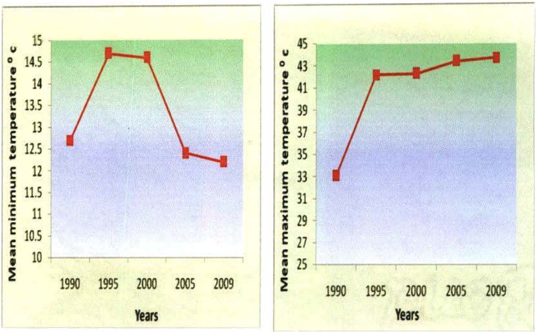


Fig. 4.25 Periodical change in mean minimum, mean maximum temperature at Amravati

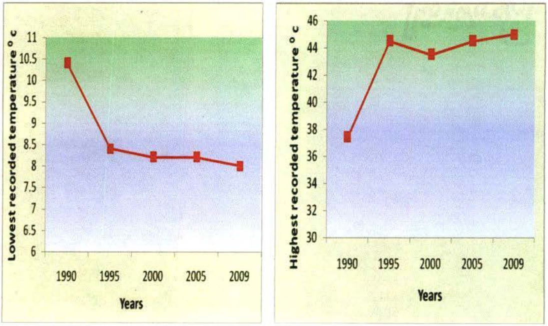


Fig. 4.26 Periodical change in lowest, highest recorded temperature at Amravati

salinization and sodification resulting into formation of more non saline sodic soil. The concomitant increase in Na^+ along with $CaCO_3$ was observed to be predominant process resulting into sodiumization of clay and day by day degradation of soils which is evident from the hard consistence observed in the surface, wide polygonal cracks and temporary water stagnation caused due to increasing impairment in drainage condition of soil.

Table 18: Decadal change in different soil properties

Soil parameters	Years		
	1990	2000	2010
Physical properties			
Hydraulic conductivity mm hr^{-1}	0.6-7.3	0.95-3.71	0.5-3.4
Bulk density (Mg cm^{3})	1.60-2.06	1.13-1.81	1.20-1.84
COLE	0.21-0.23	0.09-0.24	0.18-0.28
Chemical properties			
pH	7.7-8.6	8.1-8.9	7.0-95
EC	0.27-0.48	0.31-1.15	0.10-0.48
Organic carbon	0.21-0.75	-	0.09-0.44
$CaCO_3$	3.0-18.2	4.0-17.3	9.1-16.4
ESP	1.7-9.1	3.97-15.35	4.8-11.1
Paste extract			
PHs	7.4-7.9	7.5-8.3	7.0-9.12
ECe	0.40-1.04	1.72-4.83	0.42-2.7
SAR	0.8-4.8	3.06-13.19	3.3-12.41
Water quality			
pH	7.5-8.0	7.1-8.8	7.1-8.0
EC	1.0-6.37	1.35-3.8	2.4-9.4
SAR	4.5-17.5	11.7-27.5	5.52-22.96
RSC	-0.6-10.5	1.5-8.9	1.4-7.3
Reference:	Nimkar and Magar (1990)	Sagare et al., (2000)	Present Study

There was also considerable reduction in organic carbon content of the soils which can be attributed to the resultant dispersion of organic matter caused due to increasing sodium on the exchange complex and prevailing increase in temperature. There has been also reduction in the productivity of the important crops grown in the area over a period of two decades. This is justified from the increased degree of degradation over a period of time which reflected in impairment of physical properties like reduction in hydraulic conductivity causing poor to imperfect drainage of these soils. The inherent clayey nature of the soils having slow permeability coupled with lower topographic situation under prevailing condition of low rainfall and high temperature has been observed to favors the soil degradation processes in Purna valley.

The internal drainage of these soils was severely impaired even at a low level of ESP (ESP >5). This drastically reduced the water intake and therefore, storage of moisture in the soil profile. This would lead to reduction of crop yields many times due to surface ponding of water. The well water irrigation is not feasible in this area due to poor quality of well water. To improve internal drainage of these soils it is necessary to adopt management practices which can improve the hydraulic conductivity of these soils. As hydraulic conductivity at specific sites is affected by exchangeable sodium the provision of drainage is essential. The change over decadal period since 1990 revealed that there is slight increase in the pH, EC and ESP of the soils while the physical properties reflected through hydraulic conductivity were found to be further impaired.

CHAPTER V

SUMMARY AND CONCLUSIONS

The present investigation was carried out to study the decadal change in soil degradation due to salinity and sodicity in Purna valley. The suitability of well water for irrigation was also assessed. The major focus of present investigation is to provide appropriate data set with respect to degradation of these soils with hope that this would ultimately help in making decisions for the management of these soils towards sustained crop production based on the detail diagnosis of soil degradation.

The eight pedon sites were selected as per the data pertaining in the previous studies (Nimkar, Magar 1990, Kadu 1991 and Balpande 1993). The sites in the Purna valley earlier studied by these workers were treated as Benchmark sites. Global positioning system (GPS) was used to georeference the sampling spots. The pedons were dug and studied for morphological characteristics during May- June 2010. Soil samples from each horizon were collected for various laboratory studies. The well water samples near by the pedon sites were also collected and evaluated for quality parameters. The results of the soil degradation by salinity and sodicity are summarized in this chapter.

- The soils were very deep (> 140 cm) having dark brown to very dark grayish brown colour. The subsoil horizons had well developed intersecting slickensides with wedge shaped structural peds that break into angular blocky structural peds. The slickensides faces were larger in all pedons down through the depth. Most of the soils showed strong to violent effervescence indicating high calcium carbonate in these soils. The cracks were extending upto the slickensided zone upto 80 to 90 cm depth in most of the pedons.

- The clay content ranged from 66.7 to 75.0 per cent, which gradually increased with depth in all the pedons. The silt content of the soils ranged from 20.0 to 26.5 per cent and the sand content ranged from 2.5 to 6.8 per cent. The inverse relationship observed between sand and clay.

- The hydraulic conductivity of the soils varied from 0.5-3.4 mm hr^{-1}. This was decreasing in the subsoil horizons. This decreased hydraulic conductivity results into poor to very poor drainage of these soils.

- The bulk density of the soils varied from 1.20 – 1.84 Mg m^{-3}. The highest values of bulk density were observed in the lower layers of the pedons. The increasing bulk density in subsoil layer attributed to higher swelling pressure and compaction caused due to smectitic clay content.

- The coefficient of linear extensibility (COLE) ranged from 0.18 – 0.28 cm cm^{-1} indicating high swell shrink activity in these soils due to predominance of smectitic clay.

- The volumetric shrinkage potential ranged from 64.3 – 109.71 per cent. The volumetric shrinkage potential reflects an understandable rating of swell shrink potential of soils as compared to COLE.

- The mean weight diameter was found to be varied from 0.38 to 0.69 mm in the different horizons of the soils profile. It was gradually decreased down to the depth. The downward decrease in mean weight diameter attributed to subsoil sodicity.

- The pH (1:2) of the soil ranged from 7.0 to 9.5 in different horizons. The pH in the subsoil horizons was observed to be increased upto 9.5. Similar trend of electrical conductivity (EC), which was ranged from 0.10 to 0.48 dSm^{-1} in different horizons. This was increased down through the depth in the profile.

- The organic carbon content was found to be low (0.09- 0.44 per cent). While the free calcium carbonate levels of fine earth ranged between 5.75–16.37 per cent which gradually increased with depth.

- The CEC of the soils varied from 44.5 to 66.5 cmol (p^+) kg^{-1}. The exchangeable cations were in the order of Ca^{2+} > Mg^{2+} > Na^+ > K^+. The Ca/Mg ratio varied from 2.5 to 4.2 and decreased with depth. The exchangeable sodium percentage varied from 4.8 to 11.1 and it was observed to be higher at some sites in the study area indicating sodification. The exchangeable magnesium percentage ranged from 11.1 to 24.9.

- In the saturation extract, bicarbonate was dominant one followed by chlorides or sulphate. The sodium adsorption ratio ranged from 8.3 to 12.41 and increased sharply with depth. Decrease in soil Ca/Mg ratio caused increase in SAR. The HCO_3/Ca ratio varied from 2.3 to 9.7 and generally increased with depth.

- The water samples collected from well nearby the pedons had high to very high salinity and low to medium sodicity hazards. The residual sodium carbonate ranged from 1.4 to 7.3 meL^{-1}. It may promote accumulation of salts and impair the drainage. Hence, it is not advisible to irrigate the crop using this water.

- The relationship between soil attributes were observed as with increasing value of COLE the hydraulic conductivity decreases (r = - 0.435**). Similarly the relationship between clay and COLE is positive (r = 0.332**). In case of soil Ca/Mg ratio and HC observed to be positive (r = 0.464 **). The relationship between sodium adsorption ratio (SAR) and hydraulic conductivity. found to be negative (r = - 0.148) indicating that the hydraulic conductivity is reduced with the increase in sodium adsorption on the soils particle.

- The kind and degree of soil degradation assessed using modified criteria revealed that the soils are none to slightly saline sodic to moderately sodic.

Conclusion

From the present investigation it can be concluded that the soils in Purna valley area are none to slightly saline- sodic to moderately sodic. The soils recorded slight changes in soil degradation over a period of last two decades in respect of increase in pH especially in subsoil alongwith a tendency of varying salinization in the profile coupled with slight increase in ESP towards lower horizons with concomitant decrease in exchangeable Ca/Mg ratio.

CHAPTER VI

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APPENDIX I – PEDON DESCRIPTION

PEDON – 1 Village- Paral

Classification	:	Typic Haplusterts, very fine montmorillonitic, isohyperthermic
Location	:	Village- Paral, Tehsil- Akot, Dist. Akola
Drainage	:	Poorly drained, slow permeability, slow to medium runoff.
Vegetation	:	Babul (Accacia arabica), Jowar (Sorghum bicolor), tur (Cajanous cajan), urid (Phaseolus mungo), wheat (Triticum spp.), cotton (Gossypium spp.)
Parent material	:	Alluvium derived from basalt.
Sampling date	:	13 June 2010
Remark	:	Well developed intersecting slikensides in third, fourth and fifth layer. 2.5 cm wide cracks extends upto 80 cm depth.

Horizon		Depth	Description
Ap	:	0-18 cm	Very dark grayish brown (10YR3/2), strong coarse sub angular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); strong effervescence, common medium roots, alkaline pH (8.0); clear smooth boundary.
Bw	:	19-40 cm	Very dark grayish brown (10YR3/2), strong coarse sub angular blocky structure, hard (dry) firm (moist) very sticky and very plastic (wet); strong effervescence, common medium roots, strongly alkaline pH (8.8); clear smooth boundary.
Bss1	:	41-52 cm	Very dark brown (10YR2/2), strong coarse angular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); violent effervescence; very fine concretion, clear boundary.
Bss2	:	53-72 cm	Very dark brown (10YR2/2), strong coarse angular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); violent effervescence; very fine concretion, clear boundary.

Bss3 :	73-92cm	Very dark brown (10YR2/2), strong coarse angular blocky structure, very hard (dry) firm (moist) very sticky and plastic (wet); violent effervescence; fine concretion, clear boundary.
Bss4 :	93-110cm	Very dark brown (10YR2/2), strong coarse angular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); violent effervescence; very fine concretion, clear boundary.
Bss5 :	111-140 cm	Very dark brown (10YR2/2), strong coarse angular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); violent effervescence; very fine concretion,

PEDON - 2 : Village- Dapura

Classification	:	Typic Haplusterts, very fine montmorillonitic, isohyperthermic
Location	:	Village- Dapura, Tahsil- Akot, Dist. Akola
Drainage	:	Poorly drained, slow permeability, slow to medium runoff.
Vegetation	:	Babul (Accacia arabica), Jowar (Sorghum bicolor), tur (Cajanous cajan), urid (Phaseolus mungo), wheat (Triticum spp.), cotton (Gossypium spp.)
Parent material	:	Alluvium derived from basalt.
Sampling date	:	13 June 2010
Remark	:	Well developed intersecting slikensides in third, fourth, fifth and sixth layer. 2 cm wide cracks extends up to 70 cm depth.

Horizon		Depth	Description
Ap	:	0-16cm	Very dark grayish brown to dark brown (10YR3/3), medium moderate subangular blocky structure, hard (dry) firm (moist) very sticky and very plastic (wet); slight effervescence, common medium roots, highly alkaline pH (8.6); clear smooth boundary.
Bw	:	17-40cm	Very dark grayish brown to dark brown (10YR3/3), strong coarse angular blocky structure, hard (dry) firm (moist) very sticky and very plastic (wet); fine moderate and clear smooth boundary.
Bss1	:	41-68cm	Very dark grayish brown to dark brown (10YR3/3), strong coarse angular blocky structure, hard (dry) firm (moist) very sticky and very plastic (wet); slight effervescence, fine moderate and clear smooth boundary.
Bss2	:	69-102cm	Very dark grayish brown to dark brown (10YR3/3), strong coarse angular blocky structure, hard (dry) firm (moist) very sticky and very plastic (wet); strong effervescence,

		fine moderate and clear wavy boundary
Bss3 :	103-134cm	Very dark grayish brown to dark brown (10YR3/3), strong coarse angular blocky structure, hard (dry) firm (moist) very sticky and very plastic (wet); strong effervescence, fine moderate and clear wavy boundary
Bss4 :	135-155cm	Very dark grayish brown to dark brown (10YR3/3), strong coarse angular blocky structure, hard (dry) firm (moist) very sticky and very plastic (wet); violent effervescence fine moderate and clear

PEDON - 3 : Village- Ner

Classification	:	Typic Haplusterts, very fine montmorillonitic, isohyperthermic
Location	:	Village-Ner, tahsil- Akot, dist. Akola
Drainage	:	Poorly drained, slow permeability, slow to medium runoff.
Vegetation	:	Babul (Accacia arabica), Jowar (Sorghum bicolor), tur (Cajanous cajan), urid (Phaseolus mungo), wheat (Triticum spp.), cotton (Gossypium spp.)
Parent material	:	Alluvium derived from basalt.
Sampling date	:	13 June 2010
Remark	:	Very low effervescence and slight effervescence only, lime nodules in last. Two layers.1.5 cm wide crack up to 80 cm depth. Very well developed intersecting continuous slikensides

Horizon	Depth	Description
Ap :	0-16 cm	Very dark grayish brown (10 YR3/2), medium moderate subangular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); slight effervescence, fine medium roots, clear smooth boundary.
Bw :	17-40 cm	Very dark grayish brown (10YR 3/2), medium moderate subangular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); slight effervescence, fine medium concretions, clear smooth boundary.
Bss1 :	41-66cm	Very dark brown (10YR2/2), strong coarse angular blocky structure, very hard (dry), firm (moist) very sticky and very plastic (wet); slight effervescence, very fine few concretions, clear wavy boundary.
Bss2 :	67-98 cm	Very dark brown (10 YR 2/2), strong coarse angular blocky structure, very hard (dry), firm (moist) very sticky and very plastic (wet); slight effervescence, very fine few concretions, clear wavy boundary.

Bss3 :	99-120 cm	Very dark brown (10 YR 2/2), strong coarse angular blocky structure, very hard (dry), firm (moist) very sticky and very plastic (wet); strong effervescence, very fine few concretions, clear wavy boundary.
Bss4 :	121-154 cm	Very dark brown (10 YR 2/2), strong coarse angular blocky structure, very hard (dry), firm (moist) very sticky and very plastic (wet); strong effervescence, very fine few concretions.

PEDON - 4 : Village- Patsul

Classification	:	Typic Haplusterts, very fine montmorillonitic, isohyperthermic
Location	:	Village-Patsul, Tahsil- Akot, Dist. Akola
Drainage	:	Poorly drained, slow permeability, and slow to medium runoff.
Vegetation	:	Babul (Accacia arabica), Jowar (Sorghum bicolor), tur (Cajanous cajan), urid (Phaseolus mungo), wheat (Triticum spp.), cotton (Gossypium spp.)
Parent material	I:	Alluvium derived from basalt.
Sampling date	:	13 June 2010
Remark	:	fifth and sixth layer yellowish, soil highly calcareous, well developed slikensides third, fourth layer. 2cm wide cracks up to 92 cm depth.

Horizon	Depth	Description
Ap :	0-18 cm	Very dark grayish brown (10YR 3/2), medium moderate subangular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); slight effervescence, fine medium concretion, clear smooth boundary.
Bw :	19-41 cm	Dark brown (10YR 3/3), medium moderate subangular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); slight effervescence, fine medium concretion, clear smooth boundary.
Bss1 :	42-68 cm	Very dark brown (10YR 2/2), strong coarse angular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); slight effervescence, fine medium concretion, clear wavy boundary.
Bss2 :	69-92 cm	Very dark brown (10YR 2/2), strong coarse angular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); slight effervescence, fine medium concretion, clear wavy boundary.
Bss3 :	93-120 cm	Dark yellowish brown (10YR 3/4), strong coarse angular blocky

			structure, very hard (dry) firm (moist) very sticky and very plastic (wet); slight effervescence, fine medium concretion, abrupt smooth boundary.
Bw	:	121-152 cm	Dark yellowish brown (10YR 3/4), strong coarse angular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); slight effervescence, fine medium concretion.

PEDON- 5 : Village- Hingna-tamaswadi

Classification	:	Typic Haplusterts, very fine montmorillonitic, isohyperthermic
Location	:	Village-Hingna-tamaswadi, Tahsil-Akot, Dist. Akola
Drainage	:	Poorly drained, slow permeability, slow to medium runoff.
Vegetation	:	Babul (Accacia arabica), Jowar (Sorghum bicolor), tur (Cajanous cajan), urid (Phaseolus mungo), wheat (Triticum spp.), cotton (Gossypium spp.)
Parent material	:	Alluvium derived from basalt.
Sampling date	:	13 June 2010
Remark	:	Well developed intersecting slikensides, 2 cm wide cracks upto 90 cm depth, many concretions in last two layers.

Horizon	Depth	Description
Ap :	0-16 cm	Very dark grayish brown (10 YR 3/2), medium moderate subangular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); slight effervescence, fine medium roots, clear smooth boundary.
Bw :	17-42 cm	Very dark grayish brown (10 YR 3/3), medium moderate subangular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); slight effervescence, fine medium concretions, clear smooth boundary.
Bss1 :	43-67cm	Very dark brown (10YR 2/2), strong coarse angular blocky structure, very hard (dry), firm (moist) very sticky and vey plastic (wet); slight effervescence, very fine few concretions, clear wavy boundary.
Bss2 :	68-90 cm	Very dark brown (10 YR 2/2), strong coarse angular blocky structure, very hard (dry), firm (moist) very sticky and vey plastic (wet); slight effervescence, very fine few concretions, clear wavy boundary.
Bss3 :	91-115 cm	Very dark brown (10 YR 2/2), strong coarse angular blocky structure, very

		hard (dry), firm (moist) very sticky and vey plastic (wet); strong effervescence, very fine few concretions, clear wavy boundary.
Bss4 :	116-130 cm	Very dark brown (10 YR 2/2), strong coarse angular blocky structure, very hard (dry). firm (moist) very sticky and vey plastic (wet); strong effervescence, very fine few concretions.

PEDON - 6 : Village- Ugwa

Classification	:	Typic Haplusterts, very fine montmorillonitic, isohyperthermic
Location	:	Village- Ugwa, Tahsil- Akot, Dist. Akola
Drainage	:	Poorly drained, slow permeability, slow to medium runoff.
Vegetation	:	Babul (Accacia arabica), Jowar (Sorghum bicolor), tur (Cajanous cajan), urid (Phaseolus mungo), wheat (Triticum spp.), cotton (Gossypium spp.)
Parent material	:	Alluvium derived from basalt.
Sampling date	:	13 June 2010
Remark	:	White calcium nodules. Continuous well developed slikenside from third layer.

Horizon	Depth	Description
Ap :	0-16 cm	Very dark grayish brown (10 YR 3/2), medium moderate subangular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); violent effervescence, very fine few concretions, clear smooth boundary.
Bw :	17-40 cm	Dark yellowish brown (10 YR 3/4), strong coarse angular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); violent effervescence, very fine few concretions, clear smooth boundary.
Bss1 :	41-65 cm	Very dark grayish brown (10 YR 3/2), strong coarse angular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); violent effervescence, very fine few concretions, clear smooth boundary
Bss2 :	66-90 cm	Very dark grayish brown (10 YR 3/2), strong coarse angular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); violent effervescence, very fine few concretions, clear smooth boundary
Bss3 :	91-120 cm	Very dark grayish brown (10 YR 3/2), strong coarse angular blocky

		structure, very hard (dry) firm (moist) very sticky and very plastic (wet); violent effervescence, very fine few concretions, clear smooth boundary
Bss4 :	121-150 cm	Very dark grayish brown (10 YR 3/2), strong coarse angular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); violent effervescence, very fine few concretions, clear smooth boundary
Bss5 :	151-180 cm	Very dark grayish brown (10 YR 3/2), strong coarse angular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); violent effervescence, very fine few concretions.

PEDON - 7 : Village- Nawed

Classification	:	Typic Haplusterts, very fine montmorillonitic, isohyperthermic
Location	:	Village- Nawed, tahsil-daryapur, dist. Amravati
Drainage	:	Poorly drained, slow permeability, slow to medium runoff.
Vegetation	:	Babul (Accacia arabica), Jowar (Sorghum bicolor), tur (Cajanous cajan), urid (Phaseolus mungo), wheat (Triticum spp.), cotton (Gossypium spp.)
Parent material	:	Alluvium derived from basalt.
Sampling date	:	21 June 2010
Remark	:	Yellow calcareous materials with lime nodules in last layer. Well developed slikensides from second layer to fourth layer.

Horizon	Depth	Description
Ap :	0-16 cm	Very dark grayish brown (10 YR3/2) , medium moderate subangular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); slight effervescence, very fine few concretions, clear smooth boundary.
Bss1 :	17-42 cm	Very dark brown (10YR 2/2), strong coarse angular blocky structure, very hard (dry), friable (moist) very sticky and very plastic (wet); slight effervescence, very fine few concretion, clear wavy boundary.
Bss2 :	43-67 cm	Very dark brown (10YR 2/2), strong coarse angular blocky structure, very hard (dry), friable (moist) very sticky and very plastic (wet); slight effervescence, very fine few concretion, clear wavy boundary.
Bss3 :	68-97 cm	Black (10YR 2/1), strong coarse angular blocky structure, very hard (dry), friable (moist) very sticky and very plastic (wet); strong effervescence, very fine few concretion, clear wavy boundary.

Bss4 :	98- 121 cm	Black (10YR 2/1), strong coarse angular blocky structure, very hard (dry), friable (moist) very sticky and very plastic (wet); strong effervescence, very fine few concretion, clear wavy boundary.
Bw1 :	121-141 cm	Dark yellowish brown (10YR 3/4), strong coarse angular blocky structure, very hard (dry), friable (moist) very sticky and very plastic (wet); strong effervescence, very fine few concretion, clear wavy boundary.
Bw2 :	142-160 cm	Dark yellowish brown (10YR3/4), strong coarse angular blocky structure, very hard (dry), friable (moist) very sticky and very plastic (wet); slight effervescence, very fine few concretion.

PEDON - 8 : Village- Kholapur

Classification	:	Typic Haplusterts, very fine montmorillonitic, isohyperthermic
Location	:	Village- Kholapur, tahsil-daryapur, dist. Amravati
Drainage	:	Poorly drained, slow permeability, slow to medium runoff.
Vegetation	:	Babul (Accacia arabica), Jowar (Sorghum bicolor), tur (Cajanous cajan), urid (Phaseolus mungo), wheat (Triticum spp.), cotton (Gossypium spp.)
Parent material	:	Alluvium derived from basalt.
Sampling date	:	21 June 2010
Remark	:	Many calcium nodules from second to last layer.

Horizon	Depth	Description
Ap :	0-16 cm	Very dark grayish brown (10YR 3/2), medium moderate subangular blocky structure, very hard (dry) friable (moist) very sticky and very plastic (wet); slight effervescence, very fine few concretion, clear smooth boundary.
Bw1 :	17-45 cm	Dark yellowish brown (10YR 3/4), medium moderate subangular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); slight effervescence, fine concretion, clear smooth boundary
Bw2 :	46-65 cm	dark yellowish brown (10YR 3/4), medium moderate subangular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); slight effervescence, fine concretion, clear smooth boundary
Bw3 :	66-84 cm	dark yellowish brown (10YR 3/4), medium moderate subangular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); slight effervescence, fine concretion, clear smooth boundary
Bw4 :	85-100 cm	dark yellowish brown (10YR 3/4),

		medium moderate subangular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); slight effervescence, fine concretion, clear smooth boundary
Bw5 :	101-120 cm	dark yellowish brown (10YR 3/4), medium moderate subangular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); slight effervescence, fine concretion, clear smooth boundary
Bw6 :	121-150 cm	dark yellowish brown (10YR 3/4), medium moderate subangular blocky structure, very hard (dry) firm (moist) very sticky and very plastic (wet); slight effervescence, fine concretion, clear smooth boundary

APPENDIX -II

Yield of different crops in the Purna valley

Sr.No.	Site	Crops	Yield (q/ha)
1.	Paral	Chickpea	18
2.	Dapura	Green gram	10
3.	Ner	Cotton	15
4.	Patsul	Cotton	18
5.	Hingna Tamaswadi	Cotton Soybean	12 18
6.	Ugwa	Chickpea Soybean	13 17
7.	Naved	Wheat (Rainfed)	15
8.	Kholapur	Wheat (Rainfed) Soybean	15 15

APPENDIX III

CSSRI Criteria for determining quality of water

Water quality	EC (dSm^{-1})	SAR	RSC ($meq\ L^{-1}$)
A. Good	< 2	< 10	< 2.5
B. Saline			
i) Marginally	2 – 4	< 10	< 2.5
ii) Saline	> 4	< 10	< 2.5
iii) High SAR saline	> 4	> 10	< 2.5
C. Alkali waters			
i) Marginally alkali	< 4	< 10	2.5 – 4.0
ii) Alkali	< 4	< 10	> 4.0
iii) Highly alkali	Variable	> 10	> 4.0

(Source: Minhas and Tyagi, 1998)

APPENDIX IV

USSL Criteria for determining quality of water

Salinity hazards	**Class**	**EC (dSm^{-1})**	**Sodium hazards**	**Class**	**SAR**
Low	C_1	0.10 - 0.25	Low	S_1	<10
Medium	C_2	0.25 - 0.75	Medium	S_2	10 -18
High	C_3	0.75 - 2.25	High	S_3	18 - 26
Very high	C_4	2.25 - 5.0	Very high	S_4	26 - 31

(Richards, 1954)

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