SUB-FRACTIONATION OF OXIDIZABLE ORGANIC CARBON IN A FEW SELECTED SOILS OF VIDARBHA

THESIS

Submitted to
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
in partial fulfillment of the requirements
for the Degree of

MASTER OF SCIENCE
IN
AGRICULTURE
(SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)
(Land Resource Management)

By
CHIVHANE SHRIKANT PRALHAD

DEPARTMENT OF SOIL SCIENCE
AND AGRICULTURAL CHEMISTRY
POST GRADUATE INSTITUTE, AKOLA
AND
NATIONAL BUREAU OF SOIL SURVEY AND LAND USE PLANNING (ICAR), NAGPUR

DR. PANJABRAO DESHMUKH KRISHI VIDYAPEETH,
KRISHINAGAR PO, AKOLA (MS) 444 104

Enrolment Number . AA/344 **2008**

DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation of the thesis entitled "**SUB-FRACTIONATION OF OXIDIZABLE ORGANIC CARBON IN A FEW SELECTED SOILS OF VIDARBHA**" or part thereof has not been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis/publications of any University or Scientific Organization. The sources of materials used and all assistance received during the course of investigation have fully been acknowledged.

Place: Akola
Date: 1/7/2008

(Shrikant Pralhad Chivhane)
Enrolment No. AA/344

CERTIFICATE

This is to certify that the thesis entitled "**SUB-FRACTIONATION OF OXIDIZABLE ORGANIC CARBON IN A FEW SELECTED SOILS OF VIDARBHA**" submitted in partial fulfillment of the requirements for the degree of Master of Science in Agriculture (Soil Science and Agricultural Chemistry Land Resource Management) of the Dr. Panjabrao Deshmukh Krishi Vidhyapeeth, Akola is a record of bonafide research work carried out by Shri SHRIKANT P. CHIVHANE under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

Dated the 1st July, 2008

Tapas Bhattacharyya

(Dr. T. Bhattacharyya)
Chairman, Advisory Committee and
Principal Scientist,
Division of Soil Resource Studies,
National Bureau of Soil Survey & Land Use Planning,
Nagpur

Countersigned

Associate Dean
Post-Graduate Institute
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola.

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE INCLUDING EXTERNAL EXAMINER (AFTER VIVA VOICE)

Chairman	Dr. T. Bhattacharyya	Tapas Bhattacharyya
Member	Dr. S.K. Ray	
Member	Dr. P. Chandran	
Member	Dr. D.K. Pal	
Member	Dr. M.V. Venugopalan	
External Member/Examiner T. K. SEN		TK Sen

ACKNOWLEDGEMENT

It is my proud privilege that I received an opportunity to work under the inspiring guidance of Dr. Tapas Bhattacharyya, Principal Scientist, Division of Soil Resource Studies, National Bureau of Soil Survey and Land use Planning, Nagpur. I take this opportunity to express deep sense of gratitude and sincere thanks to Dr. Tapas Bhattacharyya for suggesting the dissertation topic and also taking keen interest during the course of this investigation, giving valuable suggestiosn and constant guidance during the course of my dissertation work.

I express my deep sense of gratitude to Dr. D.K. Pal, Principal Scientist and Head, Division of Soil Resource Studies, NBSS&LUP, Nagpur and member of the advisory committee for his constant encouragement and valuable suggestion during the preparation of this manuscript.

I am highly grateful to Dr. P. Chandran, Dr. S.K. Ray, Senior Scientists and my advisory committee members, Soil Resource Studies Division, Dr. M.V. Venugopalan, Principal Scientist, Division of Land Use Planning, NBSS&LUP, Nagpur.

My sincere thanks to Dr. T.K. Sen, Principal Scientist, Dr. S. Chatterji, Principal Scientist and Dr. T.N. Hajare, Senior Scientist, Division of Land Use Planning, Dr. U.K. Maurya, Dr. P. Raja, Technical Officers of Division of Soil Resource Studies, NBSS&LUP, Nagpur, for their encouragement and guidance during the entire course of this investigation.

I am highly thankful to Dr. D. Sarkar, Director of NBSS&LUP, Nagpur for providing necessary facilities for the work. I am also thankful to Dr. O. Challa, Principal Scientist and LRM project co-ordinator, Dr. M.S.S. Nagaraju, Dr. Jagdish Prasad, Dr. (Mrs.) C. Mandal, Principal Scientist and Incharge, Cartography Section, NBSS&LUP, Nagpur for their help during the course of this study.

I express my deep sense of gratitudel to Dr. Sale, Faculty Dean, PGI, Akola, Shri D.B. Tamgadge, Head, Department of SSAC, Akola and other faculty members, Dr. S.N. Dongre, Dr. V.V. Gabhane, Shri R.N. Katkar, Shri P.A. Gite, Dr. V.D. Guldekar, Dr. S.S. Rewatkar for their kind co-operation during the course of this study.

My warmest thank to Mr. S.L.Durge, Mr.G.K. Kamble, Dr. A.P. Nagar, Mr. V. Patil, Mr. D.B. Thombre, Mr. J.B. Padole and Pradeep for their kind co-operation and help during my analytical work.

My thanks are also due to Mrs. Wasudha Khandwe, Bhagyashree didi for their help and valuable suggestions during the preparation of manuscript.

I wish to express my sincere thanks to Mrs. Jiji Cyriac for her kind help during this study.

My wholehearted thanks are due to my all dear friends for their constant encouragement during entire course of this study.

I will be failing in my duty, if I do not record my feeling of love, affection and gratitude to my beloved parents, my younger brother, and other family members whose constant encouragement and kind blessings enabled me to complete the studies. I dedicate this thesis to my parents who provided the strength and inspiration for all I have done so far.

AKOLA (SHRIKANT P. CHIVHANE)

Date : 1/7/2008

CONTENTS

(A) LIST OF TABLES

(B) LIST OF FIGURES

Abbreviations List

AWC	Available Water Capacity
BCS	Black Cotton Soils
BD	Bulk Density
CEC	Cation Exchange Capacity
C_L	Labile Carbon
C_{LL}	Less Labile Carbon
C_{NL}	Non Labile Carbon
COLE	Co-efficient of Linear Extensibility
C_{tot}	Total Carbon
C_{VL}	Very Labile Carbon
FYM	Farm Yard Manure
HM	High Management
IGP	Indo Gangetic Plain
LI	Lability Index
LM	Low Management
MAR	Mean Annual Rainfall
MAT	Mean Annual Temperature
NPC	Non Pedogenic Carbon
OOC	Oxidizable Organic Cabon
SIC	Soil Inorganic Carbon
SOC	Soil Organic Carbon
TC	Total Carbon

THESIS ABSTRACT

Title of thesis	SUB-FRACTIONATION OF OXIDIZABLE ORGANIC CARBON IN FEW SELECTED SOILS OF VIDARBHA
Full name of the Student	Chivhane Shrikant Pralhad
Name and address of major Advisor	Dr. T. Bhattacharyya Principal Scientist NBSS&LUP (ICAR), Nagpur.
Degree to be awarded	M.Sc. (Agri) in Soil Science and Agricultural Chemistry (Land Resource Management)
Year of award of degree	2008
Major subject	Soil Science and Agricultural Chemist
Total number of Pages in thesis	80
Number of words in the abstract	368
Signature of Student	
Signature, name and address of forwarding authority	HEAD, Deptt. of Soil Science & Agril. Chemistry Dr. P.D.K.V., Akola

ABSTRACT

Eleven Benchmark soils (eight Vertisols and three vertic intergrades of Alfisols and Inceptisols) representing eleven districts of the Vidarbha under different systems (Agriculture, Horticulture, degraded forest) and bioclimatic regions (sub-humid moist and dry, semi-arid moist and dry) were selected for sub-fractionation of oxidizable soil organic carbon (SOC). The general trend of total SOC content decreases with depth. Very labile carbon (C_{VL}) is present only in Pahur, Asra, Paral and Linga soils. It is observed that Kurul, Dighori,

Rajegaon, Haldi and Brahmni soils do not contain C_{VL} but show quite high amount of labile carbon (C_L) ranging between 30 to 44 percent of total SOC in the surface layers. The active pool of SOC comprised of C_{VL} and C_L decreases in Dighori, Rajegaon, Haldi and Pahur soils with concomitant increase in passive pools comprising of less labile (C_L) and non-labile carbon (C_{NL}). The active pool of carbon in soils under horticulture ranges from 12 to 44 percent of SOC. There is a decreasing trend of active pool of carbon with decrease in rainfall for soils used for cotton cultivation. This leads to corresponding increase in level of passive pool. Similar relations were not found for soils under paddy.To quantify the degree of lability of SOC a lability index (LI) value was estimated for all the soils. Linga and Pahur soils registered very high LI as compared to other soils. On an average LI values increase with increase in soil depth in Asra, Hisai and Dhanora soils. An attempt was made to find out correlation with different soil properties and the active and passive pools of SOC. Active pool of SOC shows a negative correlation with BD, COLE, CEC and SIC. The correlation with passive pool and these soil properties was positive.

C_{VL} represents most readily oxidizable portion of SOC, which is very fast oxidized to CO_2 from soils. Its absence in most of the soils in Vidarbha indicates that this fraction is not built up in these soils. This might be due to prolonged hot spell during summer alongwith low rainfall in some parts of Vidarbha. The present study shows that the ratio of active and passive pool of SOC could be a better tool to judge soil quality.

Chapter I

INTRODUCTION

1.1 Background Information

The term 'soil organic matter' embraces the whole non-mineral fraction of soil. Any vegetable or animal matter forming part of the soil sample analyzed. Thus analytical results depend in part upon the mean size of sieve used in the preparatory stage although, in practice, macro-organic matter is largely excluded by fine grinding and sieving (2.0 mm) of the sample. Organic matter contributes to the physical condition of the soil by holding moisture and by affecting structure. It is a direct source of plant nutrient elements, the release of which depends upon microbial activity by affecting the cation exchange capacity, organic matter is directly involved in availability of nutrient elements.

Total soil organic matter is estimated as a routine from the measurement of its organic carbon content, but to determine the organic material, which is intimately incorporated into soil and in equilibrium with the soil environment, special techniques are required. Such material is loosely referred to as 'humus' and is a relatively stable, dark coloured substance, distinct from the immediate decomposition products of animal or vegetable residues. The chemical composition of humus is variable and fluctuates with time, a fact which complicates its extraction and determination (Hesse, 1971).

On the basis of source, carbon in the soil can be grouped as inorganic and organic. Earlier, inorganic carbon was reported to be present in two distinct forms. Pedogenic carbon (PC) and non-pedogenic carbon (NPC) (Pal et al., 2000). Later, it was found that these two forms of inorganic carbon may be separately identified and approximately quantified (Srivastava et al., 2002;

Pal et al., 2006). No efforts have been made to sub-fractionate oxidizable carbon determined by Walkley and Black method of the soils of India. There are evidences which suggest that certain fraction of organic matter are more important in maintaining soil quality and thus could be a useful indicator of the impact of management practices (Cambardella and Elliott, 1992; Chan, 1997). Most conventional methods used in soil organic carbon determination were developed to maximize oxidation and recovery of carbon (Walkley and Black, 1934; Nelson and Sommers, 1982). Interestingly total organic carbon measurement might not be a sensitive indicator for soil quality. Adoption of procedures that can extract relatively labile fraction of organic carbon might be a more useful approach to find out the influence of different management practices on total soil organic carbon. Earlier Blair et al. (1995) used the amount of organic carbon oxidizable by potassium permanganate as a measure of soil organic carbon lability. These authors showed a decline of a more labile form of organic carbon in soils under agricultural crops, in contrast to the accumulation of more labile form under a legume pasture of lucerne.

1.2 Importance of Study

It has been reported that soil organic carbon (SOC) follows different processes for its loss sequestration in soil and for that stabilization within these soil environment. To understand these mechanisms SOC has been separated into labile or actively cycling pool and stable (resistant or recalcitrant) pool which differ in their residence time. The labile carbon pool of SOC has been reported to have rapid turnover rates which effect very fast oxidation of these pools as carbon dioxide from soils to atmosphere. The labile pool of carbon has been the main source of nutrition which influences the quality and productivity of soil (Mandal et al., 2008; Majumder et al., 2008). The resistant pool of organic carbon is slowly altered by microbial activities (Weil et al., 2008). Due to its stable nature this resistant pool does not serve as a good indicator of soil quality. However, it does contribute towards significant SOC build up.

A number of studies have been conducted to find out the relative share of active (mostly labile form of SOC) and passive (mostly stable or resistant form of SOC) pools. Most of these studies are restricted to the temperate part of the globe (Weil et al., 2003; Sherrod et al., 2005). Recent efforts to aportion SOC following the method of sub-fractionation of Walkley and Black carbon (Walkley and Black, 1984; Chan et al., 2001) have been limited to soils of the Indo-Gangetic Plains (IGP) (Majumder, 2006a,b). Using microbiological methods different pools of SOC in soils have also been tried (Manna et al., 2005) which is also limited to soils of the IGP.

1.3 Objectives of the Study

An attempt has been made in the present study to quantify different forms of oxidisable carbon and to relate their quantity with land use and other physical, chemical and mineralogical properties of soils. The objectives of the study are

1) to sub-fractionate oxidizable organic carbon in a few selected soils, and
2) to find out the effect of land use and different soil parameters on the quantity of sub-fractions of total soil organic carbon.

1.4 Scope

This method could be applied for finding out different sub-fractions of soil organic carbon for the entire Maharashtra.

The sub-fractions of soil organic matter, i.e. very labile carbon (C_{VL}), labile carbon (C_L), less labile carbon (C_{LL}) and non-labile carbon (C_{NL}) may help to understand the soil quality and health in terms of their capacity to store active and passive pools of soil organic matter.

1.5 Limitations

It is time consuming method.

This method involves use of huge amount of H_2SO_4 which is very expensive.

Chapter II

REVIEW OF LITERATURE

Pedosphere plays an important role in the global carbon cycle (Lal, 2004b). It is believed that a considerable part of the current atmospheric C pool came from the terrestrial ecosystem of which soil is major component (Lal et al., 1998). So there is a growing need to increase our understanding of the dynamics of C stock in soils and the role that soils may play in the long-term accumulation and sequestration of atmospheric C. A reduction in the rate of atmospheric CO_2 accumulation can be achieved through enhancement of long-term C storage in the terrestrial biosphere (Jacinth et al., 2001). According to Lal et al. (1998a) principal factors that affect atmospheric C pool include : (i) the soil C parts (both organic and inorganic) (ii) dynamics of the soil carbon pool (aggradation or degradation) in relation to land use; and (iii) influence of management and other anthropogenic factors on soil C dynamics. Since soil is the major reservoir of terrestrial C, any attempt to enrich this reservoir through sequestration of atmospheric C will help to manage global warming and achieve global food security to a great extent; because enrichment of C stock in soil maintains the soil in good health for sustainable crop production. This is more important particularly in tropical, subtropical and arid and semi-arid regions of the world, where soils are inherently low in C as well as in productivity. Hence long term sequestration of atmospheric C in soil has very important role to play on the two aspects of our major concern viz. (i) global warming, and (ii) global food security (Lal, 2004b; Bruce et al., 1999).

2.1 Soil organic carbon and its different fractions

It has been reported that the total SOC per se may not be so important but its different pools that maintain soil quality act as sensitive indicators of impact of management practices are more important for crop productivity in soil. These pools differ in their susceptibility to oxidative forces and contribute differently in maintaining soil fertility (Leggett et al., 2006). There is strong relation in the soil C pool and the associated fluxes because of their significance to the global C cycle and their impacts on green house gases and also crop production (Lal, 2004b). Quantitative data on C pools and fluxes at scales ranging from pedon or soil-scape to ecosystem and regional, national and global scales are needed to assess the magnitude of soil C pool in relation to the biotic and atmospheric pool and to evaluate the contribution (flux) of the soil C pool to the atmospheric pool (Cambardella and Elliott, 1992; Duxbury and Nkambule, 1994; Chan, 1997; Six et al., 2000).

The SOC is composed of labile or actively cyclic and stable recalcitrant fraction that have different rates of turn over due to different degrees of physical and chemical protection. The labile pools of soil organic carbon are important as these pools fuel the soil food web and therefore greatly influence nutrient cycles to maintain the soil quality (Camberdella and Elliot, 1992; Collins et al., 2000; Zou et al., 2005). Labile soil organic carbon contains microbial biomass and is closely associated with nutrient mineralization and reflect organic input management over the past several years (Barriors et al., 1996). This fraction is the first to be depleted by continuous cultivation (Woomer et al., 1994) and the first to reform during fallow (Barrios et al., 1996) or other management practices favouring soil C increase such as minimum tillage, crop residue retention or addition of manure (Lal et al., 1998). The labile or active carbon pools typically include recent leaf, needle and root litter and microbial biomass which have been emphasised as an important source of heterotophic respiration (Gaudinski et al., 2000) and are known to control. The nutrient availability in soils. In this context, dissolved organic matter (OM) represent a small but very labile C pool <10-20 g cm^{-2} down to 1 m depth (Eillert and Gregorich, 1945). In turn, a small part of the SOM (<10%) consists of identifiable compounds of low molecular weight such as organic acids, amino acids and simple sugars. These compounds are quickly assimilated by the soil microbial biomass and recognized to fuel microbial activity in the microchizosphere due to their presence in the root exudates (Dakora and Philips, 2002; Jones, 1998). Mineralizable C in soil also represent one of the most labile pools of soil C. One of the main problems for predicting soil respiration that it is influenced by a multitude of interacting factors including soil temperature, moisture, soil carbon (or little) quality, root density, microbial community structure and size, physical and chemical soil properties and vegetation type, nutrient status and growth rate (Raien and Iutekkioglu, 2000). Consequently, in most ecosystems the rate of respiration is highly temporarily and spatially variable. Highly recalcitrant or passive pool is very slowly altered by microbial activities (Weil et al., 2003). They constitute reserve C-stock in soil and hardly participate in soil reaction.

Organic carbon has been traditionally determined in laboratory using Walkley and Black method (1934). Inorganic form of carbon in soil is contributed by calcium carbonate which is determined by acid-base titration (Hesse, 1971; Jackson, 1973). In spite of very honest efforts on the part of the chemical analysts, complete recovery of both organic and inorganic forms of carbon is difficult. Organic carbon determination in soil may be carried out (after removal of carbonate) by (a) dry combustion in a furnace and/or, (b) chromic acid oxidation followed by measurement of the CO_2 evolved. Organic carbon content of soil may be reported directly as percentage C or calculated as organic matter. The conventional carbon to organic matter factor is 1.724 based on the assumption that soil organic matter consists of 58 per cent C. The factor for a conversion of the carbon content of many surface soils to organic carbon content has been found to be 1.9 and the factor for many subsoils is about 2.5 (Jackson, 1973).

In general, soil C measurements could be broadly divided in the following 5 groups.

a) **Determination of Oxidizable Soil Organic Matter**

The oxidizable organic matter of soil is determined by (a) chromic acid oxidation with heat applied or, (b) by chromic acid oxidation with spontaneous heating or heat of reaction. It can be carried out without prior carbonate removal because the CO_2 evolved is not measured. Oxidizable matter determination in chromic acid method is the most rapid and popular laboratory method of analyzing organic carbon in soils (Jackson, 1973; Hesse, 1971).

b) **Total Soil Organic Matter by Weight Loss**

The total organic matter content of soils is determined by (a) oxidation with H_2O_2 (b) ignition at moderate temperature, or (c) ignition after decomposition of silicates with HF-$HClO_4$.

c) **Indirect Estimates of Soil Organic Matter**

Soil organic matter has been shown to be correlated with (a) total nitrogen content, (b) climate, and (c) clay content. Multiplication of total nitrogen content of soil by 20 roughly approximates the organic matter content in soils. This assumes 5 per cent N in the organic matter of a C:N ratio of 11.6, since the organic matter is conventionally assumed to contain 58 per cent carbon.

d) **Organic Carbon Determination as CO_2 (Dry Combustion by Fisher Induction Carbon Apparatus)**

The organic carbon of soil is determined after the removal or separate determination of carbonate, the subsequent ignition of soil in a furnace, and the determination of the CO_2 evolved by a gravimetric or titrimetric method. The dry combustion method includes elemental carbon such as in charcoal, graphite or coal. The ignition in the Fisher's induction carbon apparatus is carried out in a stream of purified oxygen and the gases released are purified so that only CO_2 is measured.

e) Organic Carbon Determination (Wet Oxidation by Chromic Acid and Determination by Titration)

The soil organic matter may be wet oxidized by chromic acid and the CO_2 is collected for determination (as in the dry combustion method). The CO_2 is measured in the present method, whereas the amount of chromic ion reduced is measured in the methods for oxidizable matter. The carbonate carbon must be excluded with the wet-oxidation just as for the dry combustion method, by separate determination of expulsion by means of sulfuric acid.

Oxidizable Organic Matter – different methods of determination

Of all the form of carbon in soil, the oxidizable organic matter is the chemically active form that is of most interest and this includes the immediate decomposition products of raw organic material and soil humus. It indicates that inorganically combined and elemental forms of carbon are to be excluded from the analysis of oxidizable organic matter.

A method of determining the oxidizable or active, organic carbon was introduced by Schollenberger (1927) and involves the partial oxidation of organic matter with chromic acid. Although the method is somewhat empirical, Schollenberger obtained reproducible results and found that the fraction of organic matter oxidized was approximately constant for different soils. Schollenberger obtained the chromic acid by mixing the potassium dichromate and sulphuric acid with the soil and heating the mixture to 175°C for about 2 minutes; after cooling, the unused dichromate was determined by titration with ammonium iron (II) sulphate solution. Carbonates do not interfere with the method and do not have to be destroyed first. The method was calibrated for organic carbon by correlation with results from dry combustion. Later, Schollenberger (1931) recommended the addition of sodium fluoride or phosphoric acid before titration to eliminate interference from iron (III).

Meston (1961) found that temperature of 175°C was unnecessarily high and that satisfactory result can be obtained by heating to 150°C, when thermal decomposition of the dichromate is less and evolution of acid fumes is reduced. As the soil investigated by Metson contained high amounts of organic matter, he slightly modified the Schollenberger's method by heating the soil with sulphuric acid and excess solid potassium dichromate under controlled conditions of temperature (150°C $\pm$ 5°C); excess chromic acid was then titrated with iron (II) sulphate. The necessary amount of potassium dichromate was calculated from the approximate carbon content estimated from nitrogen percentage. Metson averaged an 87% recovery of organic carbon by this method.

Tinsley (1950) investigated the factor of thermal decomposition of the dichromate. He found that on boiling in an open flak with sulphuric acid alone or with mixture of sulphuric and phosphoric acids, considerable decomposition occurred. The dichromate was less decomposed when boiled with sulphuric and perchloric acids. Tinsley reduced thermal decomposition to negligible amount by using a cold finger in the neck of the flask and he recommended using the apparatus with a mixture of perchloric and sulphuric acids with a boiling time of 2-3 hours. Jackson (1958) heated the soil and oxidant in a bath of phosphoric acid maintained at 155°C with frequent mixing, and Purvis and Higson (1939) used an electric oven. Several substances interfere with determination of oxidizable carbon, notably chloride, nitrate, iron (II) and higher oxides of manganese. Chloride competes with organic matter in reducing the chromic acid. One miliequivalent of Cl^- being equal in reducing power to 3.5 mg of carbon.

Schollenberger (1945) suggested leaching out chlorides before digesting the soil. This, however, would remove soluble organic matter and a better and more simple method is to add silver sulphate or mercury (II) oxides to the digestion mixture. Quin and Sulomom (1964) found that the addition of 2g of mercury (II) oxide to the sulphuric acid was sufficient to immobilize the maximum chloride concentration that can be expected in neutralized hydrochloric acid hydrosilicates of soil. Walkley (1935) suggested that the effect of chloride ion could be allowed for calculation from the equation :

$Cr_2O_7^{2-} + 6Cl^- + 14H^+ = 2\ Cr^{3+} + 3Cl_2 + 7H_2O$

and

$4Cr^{6+} + 3C$ ---------- $4Cr^{3+} + 3C^{4+}$,

a chloride factor of 1/12 is calculated.

that is

$$\%\ C = (\text{uncorrected}\ \%\ C - 1\%\ Cl\ /12)$$

Metson pointed out that if sufficient chloride is present to interfere seriously, it would almost certainly be determined in its own right and thus the calculation method can most easily be used. The error involved is normally low enough to ignore as 1% chloride in the soil would give an error of about 0.1% in the carbon content. Nitrate interferes only if present in amounts greater than 1/20 of the carbon present. Iron (II) interference giving high result but, as Jackson points out, air-dry soils seldom contain appreciable amount of iron (II). Waterlogged soils, on the other hand, often contain considerable quantities of iron (II), in most cases this can be oxidized by drying the soil before analysis, but if the soil is to be analyzed wet then the effects of iron (II) must be allowed for. Similarly most soils do not contain sufficient manganese oxides to interfere seriously with the method, but if necessary the interference can be estimated by treating the soil with iron (II) sulphate in amount calculated from results of a separate titration (Jackson, 1958).

Degtjarett (1930) recommended the addition of hydrogen peroxide to the soil sample followed by chromic acid in concentrated sulphuric acid, no external heat being applied. Tiurin (1931) reported Degtjarett's modification as being ineffectual and recommended boiling the soil for 5 minute chromic acid made in 1:1 sulphuric acid.

Walkley and Black (1934) and Walkley (1935, 1947) modified the Schollenberger's technique by using the heat of reaction between dilute dichromate solution and concentrated sulphuric acid to effect oxidation. Such procedure gave 76% recovery of total organic carbon as opposed to 90.4% recovery by Schollenberger (1945). The Walkley-Black procedure recovers only the more active organic matter and over 90% of elemental carbon is excluded; thus the method is more selective than others giving higher recoveries. The method of Tiurin (1931), for example, removes upto 84% of any elemental carbon present.

Allison (1935) critically examined Schollenberger's method and its subsequent modifications and concluded that all the modification were inferior to the original method. Owing to simplicity, rapidity or accuracy, Tiurin's modification at boiling for 5 minutes was found to be no better than Schollenberger's method in which boiling is for 1 ½ minute and furthermore, if a hot plate was used, evaporation occurred. Allison criticized the Walkley-Black procedure as the temperature reaches only 124°C resulting in low recovery. Nevertheless, the Walkley-Black method, owing to its simplicity, has been the most widely used procedure for obtaining a good estimate of oxidizable organic matter in a large number of samples. Several minor modifications of published methods exist but basically a weighted quantity of finely ground soil is treated with a known volume of M/6 potassium dichromate solution followed by rapid addition of an excess of concentrated sulphuric acid. As the degree of oxidation depends upon the heat generated, all samples must be allowed to cool uniformly. After cooling, the mixture is diluted, an excess of phosphoric acid or sodium fluoride added to suppress iron (III) and the excess chromic acid is titrated with ammonium iron (II) sulphate solution using di-phenylamine as indicator. One modification is to use an aqueous solution of barium di-phynylamine sulphonate as indicator, this being more stable than the sulphuric acid solution of diphenylamine (Peech et al., 1947). Alternatively o-phenanthrolin can be used as indicator and this is theoretically superior to diphenylamine as the colour change occurs at a higher oxidation-reduction potential; the end point however, is less easily determined. Markert (1962) used at 0.2% solution of phenylanthranilic acid as indicator.

With a little practice the di-phenylamine end-point can be established very accurately although the colour of some soil can make difficulties. Normally an intense dark blue colour is formed on addition of the indicator and as the titration proceed this changes to a dirty green. Towards the end of tritration the colour passes through violet to a clear deep blue and this point the titration should be continued dropwise, the end-point being sharp change to a bright, clear green. If the end point is overshot, a small measured quantity of dichromate solution can be added and the titration continued dropwise. Some workers (Jackson, 1973) recommended such additions (of about 0.5 cm^3) of extra dichromate as a routine but provided that the deep blue stage of the titration is recognisd and that further additions of iron (II) solution are made dropwise. Inexperienced analysts can confuse the dirty green colour at the beginning of a titration with the green colour of end-point but this is merely due to lack of practice. Sometimes too much soil has been weighted out considering its organic matter content and all the dichromate is reduced and the indicator turns green at once. It is not unknown for a beginner to continue titrating such a mixture and to his frstruction, never reaching the deep blue stage for soil containing high amounts of organic carbon it is preferable to use correspondingly more dichromate rather than to reduce the amount of soil analyzed. The same interferences are found with the Walkley-Black method as with the Schollenberger method and their elimination is effected in similar ways. Instead of relying entirely upon colour change, the excess dichromate can be titrated potentiometrically, in which case no phosphoric acid is necessary. As an alternative to titration of dichromate, Smith and Weldon (1941) added an excess of iron (II) sulphate to the reaction mixture and back-titrated with potassium permanganate.

Carolan (1948) investigated both alternatives of colour measurement and measured yellow colour using violet filter and green colour using a red filter.

Samples of soil were treated with M/6 potassium dichromate solution and concentrated sulphuric acid. Experiment showed that removing turbidity by standing as in Graham's method, was not practical and that is better to filter the solution after standing for half an hour and diluting. Carolan oxidized different weight of soil and plotted weight against extinction using both filters. Three completely reduced (with potassium metabisulphate) solutions of dichromate were treated with sulphuric acid and water in the same manner as soil and the average value of extinctions appeared on the graphs showing that the yellow and green colour can be measured without interference from other soil colours. Carolan (1948) corrected all extinction readings for determination of carbon, assuming organic matter to contain 58% carbon and the method to give 77% recovery (Hesse, 1971). It was concluded that measurement of the green colour is, on the whole, to be preferred. Metson (1961) showed details of measuring the green colour of reduced dichromate with an orange filter (about 6000 nm). The method was calibrated against carbon values as obtained by Schollenberger's method. Metson recommends the use of the sodium, rather than potassium, dichromate as it is more soluble. After the diluted reaction mixture has stood for about 4 hours, some of the supernatant liquid is centrifuged off as Metson found attack by chromic aid of the filter paper caused high results. Datta and co-workers (1962) measured the green colour with red (660 nm) filter and prepared a standard curve using known solution of glucose.

Soil Carbon Studies in India

Knowledge of SOC is essential to sustain the quality and productivity of soils. Recently, the green-house effect has created great concern and the role of soils in mitigating this effect has been recognized. This has led to several studies on the quality, type distribution and behaviour of SOC (Eswaran et al., 1993; Sombroek et al., 1993; Batjes, 1996). The first comprehensive study of SOC in Indian soils was conducted using data from different cultivated fields and forests with variable rainfall and temperature patterns (Jenny and Raychaudhuri, 1960). The study confirmed the effect of climate on C reserves in the soil. However, this study did not estimate the total C stock in Indian soil. Using ecosystem areas from different sources and representative global average C densities (Ajtay et al., 1979; Schlesinger, 1983), organic C in Indian soils was estimated as 23.4 – 27.1 Pg (Dadhwal and Nayak, 1993). Chhabra et al. (2003) estimated the organic C stock of Indian forest soils as 6.8 Pg C in top 1m, using estimated SOC densities and remote sensing based area at forest types. Another attempt to estimate SOC stock was made by Gupta and Rao (1994) who reported SOC stock in Indian soils with depths ranging from surface to an average depth of 44-186 cm. The study used a database that included 48 soil series. However, the first comprehensive report of SOC stock in India was carried out by Bhattacharyya et al. (2000) who estimated 9.5 Pg SOC at a depth of 0 – 0.3 m.

Sahrawat et al. (2005) investigated the effect of long-term lowland rice and arable cropping effect on carbon and nitrogen states of some semi-arid tropical soils. The results showed that soil sample from sites under lowland rice double cropping system had greater organic C and total N content than those from soils under rice in rotation with upland crop or under other arable systems. The SOC : N ratio was wider in soil samples from sites under lowland rice compared to those under other arable systems which had lower C:N ratios. Samples from soils under lowland rice systems tended to have a narrower SIC : N ratio than those under arable systems indicating a better pedo-environment under paddy rice. Their results support earlier findings that sites under continuous wetland rice cropping accumulate organic matter and contain higher soil organic matter compared to the sites under other arable systems.

Manna et al. (2005) conducted experiment on soil organic matter in West Bengal Inceptisol after 30 years of multiple cropping and fertilization. Rice-based multiple cropping systems are predominant in the Indo-Gangetic Plains of Indian sub-continent. A decline in yield of such system has been observed and ascribed to quantitative and qualitative variation of soil organic matter (SOM). The authors calculated the impact of annual rotation; rice, wheat, jute with and without fertilizers treatments (Control N-P, N-P-K, and N-P-K plus farmyard manure, FYM) on SOM and aggregate properties. At 0 to 15 cm soil depth, microbial biomass C and N, hot water soluble C and N and hydrolysable carbohydrates and particulate organic matter C (PAMC) and N (POMN) were found in the order N-P-K plus FYM > N-P-K > N-P > N > control. Over the course of the experiment, application of N alone decreased total organic carbon (TOC) by 20.4%, whereas N-P-K with or without FYM addition either maintained or enhanced carbon level as compared to initial. Total soil N and mineralizable N decline in all the treatment except N-P-K plus FYM. Irrespective of treatments, microaggregates (55-250 μm) dominated with 43.9 to 51.3% of total soil aggregates size distribution, followed by macroaggregates (250-2000 mm with 34.6 to 40.1%). The C and N mineralization rate was greater in macroaggregates than in microaggregates and correlated significantly with POMC (r=0.67, P<0.01) and POMN (r=0.88, P $\leq$0.01). Nitrogen-phosphorus-potassium plus FYM also improved overall soil aggregation as compared to other treatments. Therefore, the results suggest that the gradual depletion of nutrients and structural degradation may have collectively contributed to the crop yield decline in the rice wheat jute rotation and that the integrated use of N-P-K and FYM is an important nutrient management option for sustaining this cropping system.

Bhattacharyya et al. (2007a, 2007b and 2007c) reported relation between carbon sequestration in red and black soils of semi-arid tropical part of India and morphological, physical and chemical properties of soils. Morphological characters like colour, roots, coarse fragments, nodules, effervescence and slickensides of red and black soils from different bioclimatic systems are described in relation to their organic and inorganic carbon content. Soils under high management (HM) are darker in colour and contain more soil organic carbon (SOC) than those under low management (LM). Higher concentration of roots in soils corresponds with low content of $CaCO_3$ as manifested by dilute HCl in field. Black soils under HM show slickensides at lower depth. The formation of sodic Vertisols indicate poor organic carbon accumulation but very high inorganic carbon sequestration in soils of relatively dry bioclimatic systems. The physical and chemical properties of the associated red and black soils were related to the content of organic and inorganic form of carbon in soils. Soil organic carbon (SOC) is positively correlated with total clay but soil inorganic carbon (SIC) shows a negative correlation. SOC and bulk density (BD) are negatively correlated. The correlation between SIC and BD in various bioclimatic systems indicate a positive correlation. Soil organic carbon (SOC), soil inorganic carbon (SIC) and total carbon (TC) stock were estimated as 0.47, 0.71 and 1.18 Pg for the selected black soils and 0.33, 0.50 and 0.83 Pg for the selected red soils, respectively which constitute 15 mha study area in semi-arid tropics, India (SAT).

Bhattacharyya et al. (2007d) evaluated the Century C model using long-term fertilizer trials in the Indo-Gangetic Plains of India and applied this model to simulate soil organic C (SOC) changes in environmental conditions in the Indo-Gangetic Plains (IGP), India. Two long-term fertilizer trials (LTFT) with all necessary parameters needed to run century were used for this purpose : a jute, rice, wheat trial at Barrackpore, West Bengal and rice-wheat trial at Ludhiana, Punjab. The trial represent two contrasting climate of the IGP viz. semi-arid dry with mean annual rainfall (MAR) of <800 mm and humid with >1600 mm. Both trial involved several different treatments with different organic and inorganic fertilizer inputs. In general, the model tended to overestimate treatment effect by approximately 15%. At the semi-arid site, model data simulated actual data reasonable well in all treatments, with the control and chemical N+ farm yard manure showing the best agreement (PMSE-7). At the humid site the performance of century model was less accurate. This could have been due to range of factors including site history. However, further adjustment may improve model performance at there site and other in the IGP. The availability of long term experimental data sets (especially those involving flooded lowland rice and triple cropping system from the IGP) in testing and validation is critical to the application of the models predictive capabilities for this area of the Indian sub-continent.

Bhattacharyya et al. (2007e) reported modelled soil organic carbon stock and changes in the Indo-Gangetic Plains in India from 1980 to 2030. The global environmental facility co-financed soil organic carbon (GEFSOC) project developed a comprehensive modelling system for predicting soil organic carbon (SOC) stocks and changes over time. This research is an effort to predict SOC stocks and changes for the Indian, Indo-Gangetic Plains (IGP), an area with predominantly rice, wheat cropping system, using the GEFSOC Modelling System and to compare output with stock generated using mapping approaches based on soil survey data. The GEFSOC Modelling system predict an estimated SOC stock for the IGP, India of 1.27, 1.32 and 1.27 Pg for 1999, 2000 and 2030, respectively in the top 20 cm of soil. The SOC stock using a mapping approach based on soil survey data was 0.66 and 0.88 Pg for 1980 and 2000, respectively. The SOC stock estimated using GEFSOC Modelling system in higher than the stock estimated using the mapping approach. This is due to the fact that while the GEFSOC system accounts for variation in crop input data (crop management), the soil mapping approach only consider regional variation in soil texture and wetness. The trend of overall changes in the modelled SOC stock estimates shows that the IGP, India may have reached an equilibrium following 30-40 years of the Green Revolution. This can be seen in SOC stock changes rates. Various different estimation methods show SOC stock of 0.57 – 1.44 Pg C for the study area. The trend of overall changes in C stock assessed from the soil survey data indicate that the soils of the IGP, India may store a projected 1-1 Pg of C in 2030.

Mandal (2008) studied potential of double-cropped rice ecology to conserve organic carbon under sub-tropical climate. The process of soil organic carbon (SOC) accumulation or depletion under different management strategies is vital for maintaining soil health and curbing global warming. Using a 36 years old fertility experiment under subtropical climate, they investigated the impact of long term intensive rice-rice cropping system with different managements of the

SOC stock. The mechanistic pathway of stabilization of the SOC under different pools, with a tentative C budgeting was also established. Biochemical composition of the organic residues involved, SOC pools of oxidizability and methane (CH_4) emission were estimated for the experiment conducted using organic and inorganic sources of nutrients. Cultivation over the years caused a net decrease in SOC stock but with balanced fertilization it increased with increasing depth, the stock decrease on average, to the extent of 50%, 26% and 24% of the total at 0-0.2, 0.2-0.4, and 0.4-0.6 m, respectively. About 4.0% of the crop residues C incorporated into the soil were stabilized into SOC. This was further enhanced (1-6 times) by the application of compost. Carbon loss through CH_4 emission was very low (2-6% of the total). 'Summer fallow' had a positive significant influence on C loss from the system. As much as 29% of the compost C added to the soil was established into SOC mostly in the less labile or non-labile recalcitrant pool preferentially in the surface layer of the soil. Large polyphenol and lignin contents of crop residues including compost and the long period of soil sub-merged under rice cultivation might have contended recalcitrant character to the SOC leading to its stabilization in non-labile pools. This would result into an enrichment of SOC stock and restricted to gaseous C loading into the atmosphere.

Majumder (2008) reported the influence of organic amendment influence on soil organic carbon pools and crop productivity in a nineteen year old rice-wheat agroecosystem. Soil organic carbon pools under long term management practices provide information on C sequestration pathway, soil quality, maintenance and crop productivity. Farmyard manure (FYM), paddy straw (PS) and green manure (GM) along with inorganic fertilizers were used in a 19 year old rice-wheat cropping system in sub-tropical India to evaluate their impact on SOC stock, its different pools, total organic C (C_{tot}); oxidizable organic carbon (C_{oc}) and its four fractions of very labile ($C_{fract\ 1}$), labile (C_{fract2}), less labile (C_{fract3}) and mineralizable C (C_{min}). Cropping with only N-P-K fertilization just maintained SOC content, while N-P-K plus organic increased SOC by 24.3% over the control, their relative efficacy being FYM > PS > GM. A minimum of 3.56 Mg ha^{-1} yr^{-1} was required to be added as organic amendments to compensate for SOC loss from cropping. The passive (C_{fract3} + C_{fract4}) pool and C_{mm} constituted about 39 and 11.5%, respectively of C_{tot}. Organic C contributed towards the passive pool in order FYM > PS > GM. Most of the pool were significantly (P=0.005) correlated with each other. Yield and sustainable yield index were strongly related with C_{fract1}, C_{oc}, C_{mm} and C_{mic}. Result suggest C_{fract1}, as a useful indicator for assessing soil health and balanced fertilization with FYM as suitable management for sustaining crop productivity of the rice wheat system.

Dinkaran and Krishnayya (2008) reported variation in type of vegetal cover and heterogeneity of soil organic carbon in affecting sink capacity of tropical soils. The authors reported that the movement of carbon inside the soil across the different physical and chemical pools is crucial to maintain the soil as sink or turn it into a source. Understanding these processes at the tropics become more imperative because of the heterogeneity of the carbon pool and also of the diverse vegetal cover. The present study aims at assessing the influence of different vegetal covers, changes in land use pattern and heterogeneity of physical fractions of the soil organic carbon (SOC) pool on the soil carbon of tropical sanctuary area with some anthropogenic activities was taken as the study area. A total of 306 soil samples were collected for analysis. SOC was measured at different depths for soils with different vegetal cover. Physical fractionation (soil aggregate separation) was done to measure carbon in four different pools. ANOVA was performed to test the level of significance across different vegetal covers, different depths of soil and different physical protected carbon pools. All the differences were found to be significant (at 0.05 level), SOC was much higher in soils with natural tree cover not only influenced SOC content of the top layer, but also of the deeper layers. Changes in land use pattern severely reduce sink capacity of the soils. Physical SOC fractionation gave a better understanding of SOC movement in the soil. They concluded that type of vegetal cover has significant impact on SOC upto a depth of 1.5 m. SOC content in soil with natural vegetation cover (trees) is sufficiently large indicating their sink capacity. From physical fractionation of the carbon pool they hypothesize that the SOC gets decomposed from one fraction to another in an unidirectional manner towards the recalcinant (<53 mm) pool. Seasonal herbaceous cover in tropical system can be taken as a potential sink as more proportion of carbon moves downwards compared to the inputs.

Carbon Research in Maharashtra

Work on carbon on the soils occurring in Maharashtra indicates a few studies on carbon stock and carbon content in soils under different management practices.

The Black Cotton Soils (BCS) of Maharashtra covering an area of 25.7 m ha are deep, medium and shallow in depth. Most of the cotton growing areas in Maharashtra is however, of inorganic carbon mostly in the form of calcium carbonate (CO_3-C) in the BCS are due to rapid decomposition of OC and precipitation of calcium carbonate in the prevailing arid and semi-arid climates. This develops sub-soil sodicity and reduce the soil productivity. The study suggests that the estimation of SOC and CO_3-C stock and their inverse relationship with soil depth can help land resource managers in their efforts to restore the productivity of BCS (Bhattacharyya et al., 2001).

Tolanur and Badanur (2003) studied the effect of inorganic fertilizers coupled with organic manure and green manure on organic carbon, available N, P and K in an Inceptisol. The pearlmillet and pigeonpea cropping system significantly improved the organic carbon content and available N, P and K status of soil. The highest grain yield of pearlmillet was obtained with organic source as nutrient to meet 50 per cent N in conjunction with 50 per cent recommended dose of fertilizer (RDF) over control. Nitrogen applied in two splits recorded the highest grain yield (1767 kg ha^{-1}) followed by FYM to meet 50 per cent N with 50 per cent RDF (1744 kg ha^{-1}). Similarly grain yield of pigeonpea recorded the highest grain yield (801 kg ha^{-1}) with 50 per cent N through subabul with 50 per cent RDF. The organic carbon content, available N, P and K were significantly influenced by the use of 50 per cent N through organic manure in conjunction with 50 per cent RDF.

Earlier Doraisami and Perumal (2001) conducted an experiment to study the effect of inorganic nitrogen. A field experiment was conducted to study the effect of inorganic N coupled with composted coir-pith and biofertilizers on available N fraction in a mixed black soil (Inceptisol). The intercropping of sorghum + cowpea significantly improved the N status and organic carbon content in the soil and N uptake by sorghum. While sole sorghum accounted for higher grain yield, the intercrop encountered yield reduction to the tune of 6.6 per cent. The N level of 90 kg ha^{-1} registered higher yield and 120 kg ha^{-1} recorded higher uptake supplementation of organic sources of N enhanced the soil available N, organic carbon, inorganic N fraction and N uptake over fertilizer N alone. The available N, and inorganic fraction showed significant positive correlation with N uptake.

Venugopalan et al. (2004) reported effect of organic and conventional cotton production systems on soil properties. Results indicate that soil under both the systems were non-saline, non-sodic but calcareous (1.1 – 12.5% $CaCO_3$). However, the mean organic carbon in the surface soils under organic system (0.7%) was higher than the conventionally cultivated soils (0.54%). Moreover, 70% of these soils had over 0.6% organic carbon (0.61 – 1.70%). Despite tropical climate, the build up in organic C is attributed to the switch over to organic production system. Further in these soils, the dissolution of $CaCO_3$ helped in maintaining the soil pH below 8.1, thus preventing natural degradation. The soils under organic system had higher zinc content (0.90 mg/kg) as against 0.67 mg/kg in the conventional system. The semi-arid climate of this region induces the formation of $CaCO_3$. Continuous organic cultivation also enriched the organic carbon of sub-surface horizons. The study demonstrated a favourable effect of organic production system on those soil properties that improve nutrient and water transmission besides preventing natural degradation and sustaining cotton production even under subtropical pedo-climatic conditions.

Chapter III

MATERIALS AND METHODS

In this chapter, the sampling sites and the analytical methods of soils for different physical, chemical and mineralogical properties have been discussed. This region consists of eleven districts.

3.1 Study Area

The Vidarbha region is situated in the eastern part of Maharashtra. This region consists of eleven districts. It is located between 18°45' and 21°45'N latitudes and 76°0' and 81°0'E longitudes. It occupies a total geographical area of about 97 lakh hectares accounting for 31.6% of the state.

Physiography and Relief

A major part of the region occupied by plateau and alluvial plains while the rest of the area is mostly rocky, hilly and rugged. The elevation of the region ranges between 150 to 1050 m above MSL. The higher landform mainly occupies the northern and eastern parts while the plains with elevation less than 300 m occupy the south-eastern, central and western parts. The Satpuras form a chain of the ranges in the north and the north-western borders and mark the highest points with peaks attaining the heights of 1066 m at Govilgarh and Narnala. The region is mainly dominated by flat topped tablelands, mesas and buttes with steep and furrowed scarp faces, rocky and stony pediments in the western part. The eastern part is mainly dominated by longitudinal ridges, isolated hillocks, broad alluvial plains and flood plains.

Climate

The climate is tropical monsoon type. The annual rainfall varies from 750 to 1600 mm distributed over 60 to 70 days. From middle of June to end of August is the period of heavy rainfall. September rains are occasional. Few showers associated with cyclonic storm are also received during January and February. The mean annual air temperature varies from 25 to 27°C. High temperatures of 45°C or more are witnessed during May while low temperature of 8 to 10°C are recorded in the months of December and January. The rainfall in the area ranges between 750 and 1600 mm. Low rainfall zone with rainfall between 750 and 900 mm located in the western and south western parts constitutes the semi-arid part. While the central part with rainfall between 1000 and 1200 mm is dry subhumid. The eastern, south eastern and the northern tip of the Amravati districts with high rainfall between 1200 and 1600 mm forms the subhumid to humid parts. For the present study the eleven sites represent 4 distinct climatic zones such as sub-humid (moist), sub-humid (dry), semi-arid (moist) and semi-arid (dry).

3.2 Benchmark soils of the Vidarbha region

Murthy et al. (1981) reported three benchmark soils in Maharashtra, out of these two benchmark soils are reported from the Vidarbha region. Lal (1994) reported seventeen soil series in Maharashtra, out of these three soil series are reported from Vidarbha. Challa et al. (1999) reported one hundred fifty soil series in Maharashtra, out of these forty four soil series represent Vidarbha.

Keeping in view of dominant soils in this region (Challa et al., 1999), eleven benchmark spots were chosen from Vidarbha region of Maharashtra. This is shown in Table 3.1. Datasets of all the eleven soils have been shown in the Appendix. The location of eleven BM spots is shown in figure 3.1

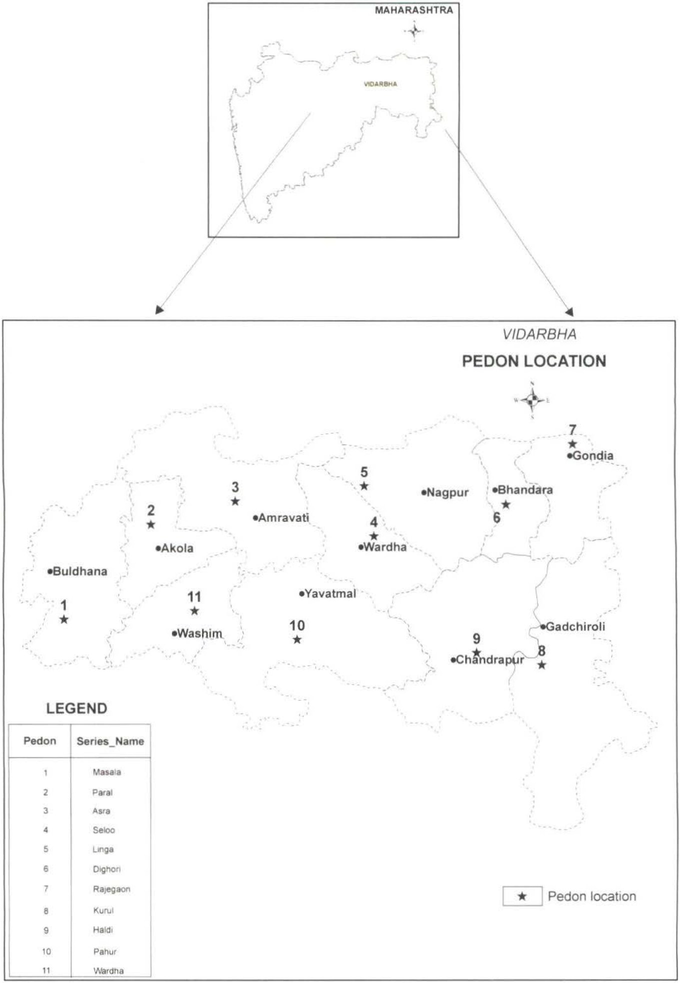


Fig. 3.1. Study area showing pedon location

Table 3.1. Study area and benchmark sites in Wardha and Nagpur districts

BM sites	Districts	Series Name	Soil Classification (family)*	Cropping System	Bioclimatic Regions**
1	Buldhana	Masala/ Dhanora	Fine, smectitic, hyperthermic Vertic Haplustepts	Cotton-Sorghum	SA(m)
2.	Akola	Paral	Very fine, smectitic, hyperthermic Sodic Haplusterts	Cotton+Pigeonpea-Sorghum	SA(d)
3.	Amravti	Asra	Very fine, smectitic, hyperthermic Typic Haplusterts	Soybean+Pigeonpea	SH(d)
4	Wardha	Brahmni/ Seloo	Very fine, smectitic, hyperthermic Typic Haplusterts	Banana, cotton, jowar, vegetables, gram, chili	SH(m)
5	Nagpur	Linga	Very fine, smectitic, hyperthermic Typic Haplusterts	Citrus	SH(m)
6	Bhandara	Dhighori	Fine, smectitic, hyperthermic Chromic Haplusterts	Paddy-Chick pea	SH(m)
7	Gondia	Rajegaon	Fine, smectitic, hyperthermic Vertic Haplustalfs	Paddy-Mustard	SH(m)
8	Gadchiroli	Kurul	Fine, smectitic, hyperthermic Ustic Endoaquerts	Paddy-Mung/Gram	SH(m)
9	Chandrapur	Haldi	Fine, smectitic, hyperthermic Vertic Haplustalfs	Degraded Forest	SH(m)
10	Yavatmal	Pahur	Very fine, smectitic, hyperthermic Sodic Haplusterts	Cotton+Pigeonpea-Sorghum-Gram (2 years)	SH(m)
11	Washim	Hisai/ Wardha	Fine, smectitic, hyperthermic Chromic Haplusterts	Cotton/Jowar/Soybean-wheat/gram	SH(d)

* Soil Survey Staff (2003).
** SH(m) – sub-humid (moist) (rainfall >1100 mm)
SH(d) – sub-humid (dry) (rainfall 1100-1000 mm)
SA(m) – Semi-arid (moist) (rainfall 1000-850 mm)
SA(d) – Semi-arid (dry) (rainfall 850-550 mm)

The benchmark profile sites described above were selected for study after thorough traversing of area where black soils (Vertisols) are present. Profiles were dug at selected site and detailed morphological examination was carried out as per procedure laid down in Soil Survey Manual (Soil Survey Staff, 1995). Soil samples were collected for the estimation of bulk density in the core.

3.2.1 Collection and Processing of Soil Samples

Horizonwise soil samples were collected for each benchmark site. The soil samples were then dried. They were ground and passed through 2 mm sieve. The screened samples were well mixed, labeled and stored for subsequent use.

3.3 Analysis of Soil Samples

Brief description of the standard procedure followed for various physical and chemical characteristics of the soil samples are given here. Moisture percentage of the processed sample was determined by heating 105°C to at constant weight to express soil data on oven dry basis.

3.3.1 Physical Properties

Particle-Size Distribution

Particle size distribution was determined as per the international pipette method. The known amount of air-dried soil sample was treated with 1N NaOAc buffer (pH 5.0) to remove $CaCO_3$. After oxidizing organic matter with 30% H_2O_2 the samples were given citrate-bicarbonate-dithionite (CBD) treatment for removal of free iron and aluminium oxides (Mehra and Jackson, 1960). Ninety five percent ethanol washing was given for removing excess salts. Dispersion and particle size fractionation were accomplished by standard procedure (Jackson, 1956). Percentage of different soil separates was calculated on the basis of above determination.

Bulk Density

The bulk density was determined by field moist method using core samples by known volume, to collect the soil core, from moist soil. It was calculated by dividing the oven dry weight of soil core by the volume of the core (Richards, 1954).

Water Retention

The moisture retention and release behaviour within the available range of 33 kPa to 1500 kPa were measured on <2 mm soil sample using pressure plate membrane apparatus as per method outlined by Richards (1954).

Available Water Holding Capacity

Available water holding capacity (AWC) was determined by using the formula suggested by Gardner et al. (1984) and later modified by Coughlam et al. (1986).

$$AWC\ (\%) = \frac{W_{max} - W_{dry}}{Dw} \times BD$$

Where,

W_{max} = Gravimetric water content (gg^{-1}) at the upper soil water storage limit (0.33 bar)

W_{dry} = Gravimetric water content after the plant water extraction i.e. lower soil water storage limit (15 bar)

BD = Bulk density of Wmax (0.33 bar) ($gm\ cm^{-3}$)

DW = Density of water ($\simeq$ 1 $gm\ cm^{-3}$)

Coefficient of Linear Extensibility (COLE)

The determination of COLE was done as per the method of Schaffer and Singer (1976). The COLE has been defined as the ratio of the difference between the moist length and dry length of clod to its dry length.

It is expressed as

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

Where,

Lm = Length of moist clod

Ld = Length of dry clod

3.3.2 Chemical Properties

Soil Reaction

pH in soil suspension (1:2.5 soil : water) was measured by a glass electrode pH meter after equilibrating the soil with water for 30 minutes with occasional stirring (Jackson, 1973).

Electrical Conductivity

The clear supernatant extract obtained from the suspension used for pH (soil : water, 1:2.5) was utilized for EC measurement by conductivity bridge (Richards, 1954).

Calcium Carbonate

For the determination of calcium carbonate, the soils were first treated with a known volume of 0.5 N excess hydrochloric acid solution to neutralize all carbonates and the excess hydrochloric acid was back titrated with standard NaOH solution using phenolphthalein as an indicator (Piper, 1950).

Cation Exchange Capacity

The fine earth samples (soils) were saturated with 1 N sodium acetate (pH 8.2). After removal of excess sodium acetate washing with alcohol, the absorbed Na^+ was extracted by washing with 1 N ammonium acetate (pH 7.0) and the leachate was made up to a known volume. The Na^+ ions present in the leachate were determined with a flame emission spectrophotometer (Richards, 1954) to determine cation exchange capacity of soils.

Extractable Bases

For determination of extractable bases such as Na^+ and K^+ ions, the soil samples were pre-washed with ethanol and there after saturated with NH_4OAc (pH 7.0) and measured on atomic absorption spectrophotometer.

Due to presence of $CaCO_3$, Ca^{2+} and Mg^{2+} ions were determined by saturating soil samples with 1 N NaCl solution (Piper, 1950) and then titrating the leachate with standard EDTA solution as per the method of Richards (1954) using Erichrome Black T and Murexide indicator.

3.3.3 Mineralogical Analysis by X-Ray Diffractometer

The total clay fractions (<2 μm) of the selected pedons (the surface horizons) were analysed for mineralogy by X-ray diffraction techniques. About 2% of clay fractions were taken and saturated separately with Ca and K ions. Parallel oriented aggregate specimen of clay slides (4.5 x 2.5 cm) taking 1 ml suspension in each case. The slides were dried at room temperature and then subjected to X-ray diffraction analysis (Jackson, 1979) using a Philips diffractometer with Ni-filtered Cu-Kα radiation at a scanning speed of $2^{\circ}2\theta$/min.

Identification of each crystalline mineral species present in the samples is the purpose of the qualitative interpretation of diffraction pattern (Jackson, 1979). The identification of different minerals was accomplished by finding out the d-spacing values corresponding to the degrees (2θ) as given in ASTM "X-ray powder data file" published by American Society of Testing Materials, Philadelphia. The base diffraction spacing varies according to the nature of cation with which the saturation is accomplished and the type of minerals present were identified in the samples. Different thermal pre-treatments, as required, were given to distinguish and confirm the type of minerals present. As a routine method the following six treatments were followed.

1) Ca : Ca saturation
2) Ca-EG : Ca-saturated ethylene glycolated
3) K25°C : K-saturated at room temperature 25°C
4) K110°C : K-saturated and heated at 110°C
5) K330°C : K-saturated and heated at 330°C
6) K550°C : K-saturated and heated at 550°C

The semi-qualitative analysis of minerals present were carried out following standard method.

3.4 Oxidizable soil organic carbon and its pool

The oxidizable soil organic carbon (SOC) was determined by wet oxidation (Walkley and Black, 1934). This was approximated into different pools by the modified Walkley and Black method as described by Chan et al. (2001) using 5, 10 and 20 ml of concentrated (36.0N) H_2SO_4 that resulted in three acid-aqueous solution ratios of 0.5:1, 1:1 and 2:1 (corresponding to 12, 18 and 24N of H_2SO_4, respectively). The amount of C, thus determined allowed the apportioning of total SOC into the following four different pools according to their decreasing order of oxidizability.

Pool I : (C_{VL} very labile) : Organic C oxidizable by 12N H_2SO_4

Pool II : (C_L labile) : The difference in C oxidizable by 18.0N and that by 12.0N H_2SO_4

Pool III (C_{LL} less labile) : The difference in C_{tot} oxidizable by 24.0N and that by 18.0N H_2SO_4

Pool IV : (C_{NL} non labile) : The difference between C and oxidizable by 24.0N H_2SO_4

The pool I and II together represent the active pool [active pool = Σ (pool I + Pool II)] while pool III and pool IV together constitute the passive pool [Passive pool = Σ (pool III + Pool IV)] of organic C in soils (Chan et al., 2001).

Lability Index of SOC

A lability index for SOC was computed by first expressing the amount of each of the three labile pools namely C_{LL}, C_L and C_{VL} or a fraction of the amount of C and then multiplying the fraction with their respective weightages of 3, 2 and 1 given on the basis of ease of their oxidation and finally adding and averaging them (Majumder et al., 2008; Mandal et al. 2008).

Accordingly

$$\text{Lability Index} = \frac{C_{VL}}{C_{tot}} \times 3 + \frac{C_L}{C_{tot}} \times 2 + \frac{C_{LL}}{C_{tot}} \times 1$$

The values thus obtained are compared for assessing the relative performance of different treatments in maintaining labile soil organic C at different depths.

Chapter IV

RESULTS AND DISCUSSION

This chapter deals with results obtained through the field and laboratory study. The morphological properties are discussed in all the horizons of eleven representative benchmark spot of study area. However, for physical, chemical and mineralogical properties only surface soils are analysed. Linking of chemical properties with SOC and its fractionation, soils from all the horizons were anlysed.

4.1 Morphological properties of soil
4.2 Physical properties of soil
4.3 Mineralogy of total clay fractions
4.4 Chemical properties of soil
4.5 Oxidizable organic carbon (OOC) and its fractionation
4.6 Distribution of active and passive pool of organic carbon
4.7 Effect of landuse on different pools of organic carbon
4.8 Lability Index for soil organic carbon
4.9 Relation between Active and Passive pool of SOC with selected soil parameters
4.10 Discussion

4.1 Morphological Properties of Soils

Table 4.1 shows the morphological properties of surface horizons of soils for 11 benchmark spots.

Table 4.1. Morphological properties of soils

Hori-zon	Depth (cm)	Bound-ary [1]		Matrix colour (M) [2]	Texture [3]	Coarse fragments (%)	Structure [4]			Consistence [5]			Roots [7]		Effervescence	Other features	Cracks
		D	T				S	G	Ty	D	M	W	S	Q			
Pedon 1: Buldhana district : Masala Series																	
Ap	0-9	c	s	7.5YR 2.5/2	C	2	m	2	sbk	sh	vfr	sp	vf	c	e		
Bw	9-28	g	s	7.5YR 2.5/2	C	2	m	--	--	--	fr	sp	vf	c	e		2-5 cm
Bw1	28-45	c	i	7.5YR 3/2	C	5	m	2	sbk	--	fr	vs	vf	c	es		
BCk	45-61	g	i	7.5YR 5/2	C	20	m	1	gr	--	vfr	ps	vf	f	ev		
Crk	61-91	Partially weathered basalt with lime													ev		
Pedon 2 : Akola District – Paral Series																	
Ap	0-9	c	s	7.5YR 3/2	c	5-8	m	2	sbk	--	fr	sp	vf,f,m,c	c,f	es		
Bw1	9-35	g	s	7.5YR 2.5/2	c	5-8	m	3	sbk	--	fr	sp	vf,f,m	c,f	es	Pressure faces	4 cm
Bss1	35-69	g	s	7.5YR 2.5/2	c	5-8	m	3	abk	--	fi	svp	vf,f,m	c,f	es	Slickensides	
Bss2	69-105	g	w	7.5YR 2.5/2	c	5-8	c	3	abk	--	fi	vsvp	vf,f	c	es	Slickensides	1 cm
Bss3	105-132	g	w	7.5YR 2.5/2	c	5-8	c	3	abk	--	fi	vsvp	vf,f	c	es	Slickensides	
Bss4	132-150	--	--	7.5YR 2.5/2	c	8-10	c	3	abk	--	fi	vsvp	vf,f	f	es	Slickensides	0.5 cm
Pedon 3 : Amravati District – Asra Series																	
Ap	0-14	--	--	10YR 2/2	c	1-3	m	3	sbk	--	fr	sp	vf,f	c,f	es		
Bw1	14-35	c	s	10YR 2/2	c	1-3	m	2	sbk	--	fr	sp	vf,f	c,f	es		1-2 cm
Bss1	35-69	g	s	10YR 2/2	c	1-3	m	3	abk	--	fi	sp	vf	c	es	Pressure faces	1 cm
Bss2	69-107	g	w	10YR 2/2	c	<1	m	3	abk	--	sfi	vsvp	vf	f	es	Slickensides	0.5 cm
Bss3	107-150	g	w	10YR 2/2	c	<1	m	3	abk	--	sfi	vsvp	vf	f	es	Slickensides	0.7 cm
Pedon 4 : Wardha District – Brahmni Series																	
Ap	0-13			10YR 3/2	c	5-10	m	2	sbk	sh	vfr	sp	vfm	fe	e	--	
Bw1	13-32			10YR 3/2	c	<5	m	2	sbk	sh	vfr	sp	vfm	fe	e	--	
Bw2	32-59	c	s	10YR 3/2	c	<5	m	2	abk	sh	f	vsps	f	c	e	Pressure faces	

Hori-zon	Depth (cm)	Bound-ary [1]		Matrix colour (M) [2]	Tex ture [3]	Coarse fragme nts (%)	Structure [4]			Consistence [5]			Roots [7]		Effer vesc ence	Other features	Cracks
		D	T				S	G	Ty	D	M	W	S	Q			
Bss1	59-81	c	s	10YR 3/2	c	<5	m	2	abk	sh	f	vsps	f	f	e	ss	
Bss2	81-115	g	s	10YR 3/2	c	<5	m	2	abk	sh	f	vsps	f	f	e	ss	
BCk	115-145			10YR 3/2	c	25-30	m	2	abk	h	fr	vsps	f	f	e	--	
Pedon 5 : Nagpur District – Linga Series																	
Ap	0-16	c	s	10YR 3.5/2	c	3-5	m	2	sbk	sh	fr	sp	vf,f,m	m,f	e	--	0.5 cm
Bw1	16-44	g	s	--	c	3-5	m	3	sbk	--	fr	sp	vf,f,m	c,f	e	Pressure faces	0.5 cm
Bw2	44-69	g	s	--	c	2-3	m	3	sbk-abk	--	fr	sp	vf,f	c	e	Slickensides (weak)	
Bss1	69-102	g	s	--	c	2-3	m	3	abk	--	fr	vsvp	vf,f	f	e	Slickensides (weak)	
Bss2	102-128	g	s	--	c	2-5	m	3	abk	--	fr	vsvp	vf	f	es	Slickensides	
Bss3	128-150	c	s	--	c	5-8	c	3	abk	--	fr	vsvp	--	--	es	Slickensides	
Pedon 6 : Bhandara District – Dighori Series																	
Ap	0-13	c	s	10YR 4/2	c	5	m	2	sbk	vh	fi	sp	vf,f	m,c	nil/e	--	3-5 cm
Bw1	13-27	c	s	10YR 4/3	c	5	m	2	sbk	h	fr	sp	vf,f	m,f	nil/e	--	
Bw2	27-53	g	s	10YR 4/3	c	5	m	3	sk	vh	fr	sp	vf,f	m,f	e	--	
Bss1	53-76	g	s	10YR 4/3.5	c	2	m	2	abk	vh	fr	sp	vf	c	e	--	
Bss2	76-105	g	s	10YR 4/4	c	2	m	2	abk		fr	sp	vf	f	e	--	
Bss3	105-160			10YR 4/6	c	2	m	3	abk		fr	sp	vf	f		--	
Pedon 7 : Gondia District – Rajegaon Series																	
Ap	0-10	c	s	7.5YR 3/3	c	2	m	2	sbk		Fr	p	vf,f	m	Nil	--	1-2 cm
Bt1	10-25	c	s	7.5YR 4/6	c	1	m	3	sbk		fr	p	vf,f	m,c	Nil	--	
Bt2	25-55	g	s	10YR 4/3	sc	1	m	2	sbk		fr	p	vf	f	Nil	--	
Bt3	55-74	c	s	10YR 4/3	sc	1	m	2	sbk		fr	p	vf	f	Nil	--	
Bt4	74-107	c	s	10YR 4/3	c	2	m	3	sbk		fr/fi	p	vf	f	e	--	
Bw/Bt5	107-150+			10YR 4/3	c	3	m	2	sbk		fr/fi	p	vf	f	e	--	
Pedon 8 : Gadchiroli District – Kurul Series																	
Ap	0-12			10YR 3/2	c	2	f	1	sbk	s	vfr	sp	vf,f	m	e	--	
Bw1	12-28	c	s	10YR 3/2	c	3	m	2	sbk		fr	sp	vf,f	m	e	--	

Hori-zon	Depth (cm)	Bound-ary [1]		Matrix colour (M) [2]	Texture [3]	Coarse fragments (%)	Structure [4]			Consistence [5]			Roots [7]		Effervescence	Other features	Cracks
		D	T				S	G	Ty	D	M	W	S	Q			
Bw2	28-50	c	s	10YR 4/3	c	3	m	2	sbk		vfr	sp	vf,f	c	e	--	
Bw3	50-76	g	s	10YR 3.5/2	c	3	m	1	sbk		vfr	sp	vf,f	c	e	--	
Bss1	76-101	c	s	10YR 3.5/2	c	2	m	2	sbk/abk		fr	sp	vf	f	e	--	
Bss2	101-126	g	s	10YR 3.5/2	c	2			sbk/abk		fr	sp	vf	f	e	--	
Bw Bss3	126-150			10YR 3.5/2	c	2			sbk/abk		vfr		vf	f	e	--	
Pedon 9 : Chandrapur District – Haldi Series																	
Ap	0-14	c	s	10YR 3/2	c	<1-2	m	1	sbk	h	s	ps	vf,f	m,f	--	--	
Bw	14-46	c	w	10YR 3/4	c	--	m	3	abk	h	s	ps	f,m	m,f	--	--	
Bsst	46-82	g	w	10YR 3/3	c	--	c	3	abk	h	fr	sp	v,m	f,f	es	--	
Bsst	82-114	g	s	10YR 3/3	c	--	c	3	abk	h	vfri	sp	f,m	f,f	es	--	
Bsst	114-135			10YR 3/4	c	--	c	5	abk	h	vfi	sp	f,m	f,f	e	--	
Pedon 10 : Yavatmal District – Pahur Series																	
Ap	0-19	c	s	10YR 3/2	c	2-3	m	2	sbk	h	fr	sp	vf,f	fe	es	--	10
Bw	19-40	g	s	10YR 3/2	c	2-3	m	2	sbk		fr	vsvp	f,m	d	es	Pressure faces	5
Bss1	40-78	g	s	10YR 3/2	c	2-3	m	3	absk/abk		fi	vsvp	f,m	d	e	Slickensides	5
Bss2	78-122	g	s	10YR 3/1.5	c	2-3	m/c	3	abk		vfi	vsvp	v,m	f	e	Slickensides	5
Bss3	122-150	g	s	10YR 3/1.5	c	3-5	m/c	3	abk		vfi	vsvp	v,m	f	e	Slickensides	2
Pedon 11 : Washim District – Wardha Series																	
Ap	0-10	c	s	10YR 4/3.5	c	3	m	1	bk	sh	vfr	sp	vf,f	m,c	es		3-5 cm
Bw1	10-31	c	s	10YR 4/2	c	5	m	2	sbk		fr	sp	vf,f	c,f	es		
Bw2	31-53	g	s	10Yr 4/2.5	c	5	m	2	sbk		fr	sp	vf,f	c,f	es		
Bss1	53-81	g	s	10YR 4/2.5	c	2	m	2	abk	fr	sfi	sp	vf	f	e		
Bss2	81-114	g	s	10YR 4/2.5	c	2	m	3	abk	fr	sfi	vsvp	vf	f	e		
Bss3	114-150+			10YR 4/3	c	3	m	3	abk	fr	sfi	vsvp	vf	f	e		

[1] D = distinctness, T = Topography, CS =clear smooth, gs = gradual smooth; [2] M = moist; [3] C = clay; [4] S = size; G = Grade; Ty = Type; m2sbk = medium moderate subangular blocky; m2abk = medium moderate angular blocky; [5] D = dry; M = moist; W = wet; Sh = Slightly hard; h = hard; vfr = very friable; fi = firm; [6] S = size; Q = Quantity; VFM = many very fine; F = few; FC = fine common; MF = many few; [7] e = slight effervescence

4.1.1 Colour

The moist colour of Masala soils is in hue of 7.5YR, value 2.5 to 5 and chroma 2. The soil colour is 7.5YR 2.5/2 (very dark brown) in the surface and 7.5YR 5/2 (brown) in sub-surface.

The moist colour of Paral soils is in the hue of 7.5YR value 2.5 to 3 and chroma 2. The soil colour is 7.5YR 2.5/2 (very dark brown) in the sub-surface.

The moist colour of Asra soils is in hue of 10YR, value 2 and chroma 2. The soil colour is 10YR 2/2 (very dark brown) in the sub-surface.

The moist colour of Brahmni soils is in hue of 10YR, value 3 and chroma 2. The soil colour is 10YR 3/2 (very dark grayish brown) in the surface and sub-surface.

The moist colour of Linga soils is in hue of 10YR, value 3.5 and chroma 2. The soil colour is 10YR 3.5/2 (dark grayish brown to very dark grayish brown) in surface.

The moist colour of Dighori soils is in hue of 10YR, value 4 and chroma 2 to 6. The soil colour is 10YR 4/2 (dark grayish brown) in the surface and 10YR 4/6 (dark yellowish brown) in the surface.

The moist colour of Rajegaon soils is in hue of 7.5 to 10YR, value 3 to 4 and chroma 2 to 6. The soil colour is 7.5YR 3/3 (dark brown) in the surface and 10YR 4/3 (brown in sub-surface).

The moist colour of Kurul soils is in hue of 10YR, value 3 to 4 and chroma 2 to 3. The soil colour is 10YR 3/2 (dark brown) in surface and 10YR 3.5/2 (dark brown to brown) in the sub-surface.

The moist colour of Haldi soils is in hue of 10YR, value 3 to 4, and chroma 2 to 4. The soil colour is 10YR 3/2 (very dark grayish brown) in surface and 10YR 3/4 (dark yellowish brown) in the sub-surface.

The moist colour of Pahur soils is in hue of 10YR, value 3 and chroma 1.5 to 2. The soil colour is 10YR 3/2 (very dark grayish brown) in surface and 10YR 3/5 (very dark gray to very dark grayish brown) in sub-surface.

The moist colour of Wardha soils is in the hue of 10YR, value 4 and chroma 2 to 3.5. The soil colour is 10YR 4/3.5 (brown to dark grayish brown) in sufface and 10 YR 4/3 (brown) in sub-surface (Table 4.1).

4.1.2 Texture

The texture of all the eleven soils is clayey. The Rajegaon soils (Pedon 7) however, indicate sandy clay texture in the surface (Table 4.1).

4.1.3 Coarse Fragments

The content of coarse fragment in surface horizon of Masala, Asra, Rajegaon, Kurul, Wardha and Pahur soils is 1-3 percent, in Dighori soils it is 8.5 percent and in Paral and Linga soils it is 5-10 percent. The content of coarse fragment in Asra, Dighori, Rajegaon, Kurul is 1-3 percent, in Masala it is 3-5 percent and in Paral and Linga soils it is 10 percent in sub-surface horizon (Table 4.1).

4.1.4 Structure

The surface horizon of all soils have medium weak to moderate sub-angular blocky structure. The sub-surface horizon of all soils have medium, coarse to moderate to strong angular blocky structure (Table 4.1).

4.1.5 Consistence

The soils of Haldi, Dighori, Rajegaon and Kurul soils have hard to very hard, friable to firm (moist) and plastic to slightly plastic consistence. The other soils are slightly hard from friable and have slightly plastic to very plastic consistence (Table 4.1).

4.1.6 Roots

Many fine and medium size roots are observed in the surface layer. The number of roots decreased with depth. Below 100 cm depth there are only few and fine roots (Table 4.1).

4.1.7 Effervescence

Strong effervescence is observed in Paral, Asra and Wardha soils. In Masala, Brahmni, Linga and Pahur soils slight effervescence is observed. In Dighori and Rajegaon soils effervescence are not observed (Table 4.1).

4.1.8 Other Features

A) Slickensides

The slickensides are common in Paral, Asra, Brahmni, Linga and Pahur soil series. It is not observed in Dighori, Rajegaon, Wardha and Masala soils. The slickenside are formed at a depth of 45 to 55 cm from surface and extend upto 150 cm (Table 4.1).

B) Cracks

In Paral, Dighori, Pahur and Wardha soils 3-5 cm wide cracks are observed. In Masala soils 2-5 cm wide cracks are observed in surface horizon (Table 4.1).

4.2 Physical Properties

4.2.1 Particle size distribution

The sand, silt and clay contents of Dighori, Rajegaon, Kurul and Haldi soils range from 22 to 46 percent, 27 to 37 percent, 37 to 57 percent, respectively. In other soils sand content is very less (2.8 to 0.2 percent). Clay content is high (55 to 78 percent) and the silt content ranges from 38 to 45 percent (Table 4.2).

4.2.2 Bulk Density

The bulk density of eastern districts of Vidarbha i.e. Bhandara, Gondia, Gadchiroli and Chandrapur varies from 1.4 to 1.6. In other soils of Vidarbha (Yavatmal, Buldhana, Amravati and Nagpur) it has similar range. It is comparatively higher in Wardha district (1.73) (Table 4.2).

4.2.3 Available Water Capacity

The Dhanora soils retained water at field capacity (33 kPa) was 18 percent and the water retained at wilting point was 16 percent. The available water holding capacity of soil was 26 percent (Table 4.2). The Bhandara, Gondia, Gadchiroli and Chandrapur soils retained water in the range of 12 to 23 percent at field capacity (33 kPa) and 6 to 12 percent at wilting point. The available water holding capacity of the soils ranged from 9 to 17 percent. The available water holding capacity of Hisai and Brahmni soils were found to range from 25 to 27 percent.

4.3. Mineralogy of Total Clay Fractions

The total clay fractions (<2 μm) indicate the presence of smectite as dominant mineral (Fig. 4.1 to 4.6). The d spacing of minerals is shown as angstrom). The CaEG samples indicate the presence of 8.54° peak which is due to 002 reflection of smectite. On K saturation this peak (14A°) broadens and appears as hump with corresponding reinforcement of 10A° peak. The tailing of 10A° peak at low angle indicate chloritisation of smectite in clay fractions.

Table 4.2. Physical properties of soils

Horizon	Depth (cm)	Particle size distribution			Bulk density Mg dm^{-3}	Water Retention		COLE	AWC (%)	HC cm/hr
		Sand (%)	Silt (%)	Total Clay (%)		33 kPa (%)	1500 kPa (%)			
Pedon 1: Buldhana District – Masala Series										
Ap	0-9	0.5	45.5	58.8	1.6	18.72	16.33	0.22	26.1	--
Pedon 2: Akola District – Paral Series										
Ap	0-9	2.5	42.2	55.3	0.2	--	--	0.2	--	1.7
Pedon 3 : Amravati District – Asra Series										
Ap	0-14	2.8	36.1	61.1	--	--	--	0.2	--	1.1
Pedon 4 : Wardha District – Brahmni Series										
Ap	0-13	1.0	34.0	65.0	1.73	45.0	30.00	--	25.9	--
Pedon 5 : Nagpur District – Linga Series										
Ap	0-16	1.2	32.3	65.5	1.4	--	--	0.2	--	2.3
Pedon 6 : Bhandara District – Dighori Series										
Ap	0-13	22.2	37.0	57.8	1.7	22.72	12.07	0.15	17.0	--
Pedon 7 : Gondia District – Rayegaon Series										
Ap	0-10	34.9	89.1	37.8	1.5	19.40	10.28	0.08	12.9	--
Pedon 8 : Gadchiroli District – Kurul Series										
Ap	0-12	30.9	31.7	46.9	1.5	23.39	11.18	0.15	17.0	--
Pedon 9 : Chandrapur District – Haldi Series										
Ap	0-14	46.1	27.0	41.0	1.6	12.43	6.68	0.13	9.2	--
Pedon 10 : Yavatmal District – Pahur Series										
Ap	0-19	3.2	41.2	55.6	1.4	46.3	26.90	0.2	--	1.0
Pedon 11 : Washim District – Wardha Series										
Ap	0-10	0.5	45.5	54.9	1.5	41.35	23.27	0.22	27.1	--

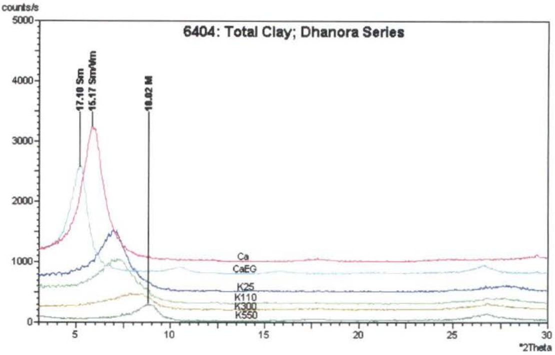


Fig. 4.1 Representative X-ray diffractograms of clay fractions (2-0.5 μm) of Dhanora series (Pedon-1), horizon Ap

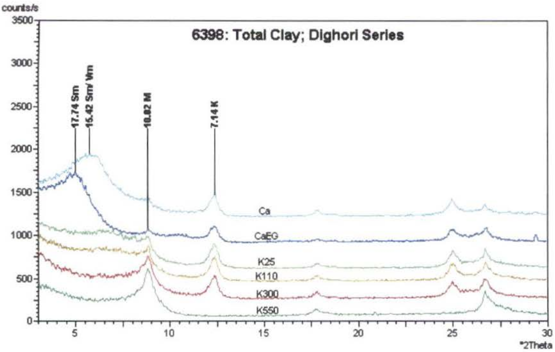


Fig. 4.2 Representating X-ray diffractograms of clay fractions (2-0.5 μm) of Dighori series (Pedon 6) horizon, Ap

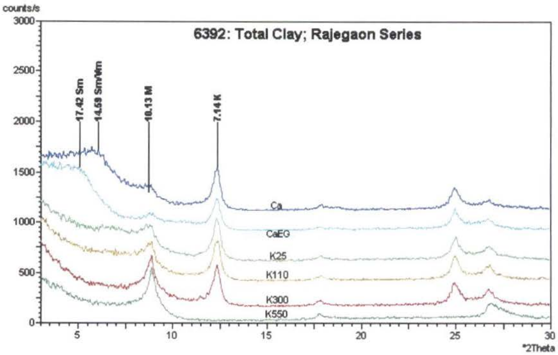


Fig. 4.3 Representating X-ray diffractograms of clay fractions (2-0.5 μm) of Rajegaon series (Pedon 7) horizon, Ap

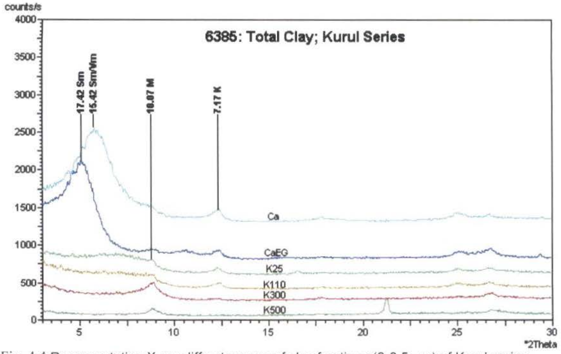


Fig. 4.4 Representating X-ray diffractograms of clay fractions (2-0.5 μm) of Kurul series (Pedon 8) horizon, Ap

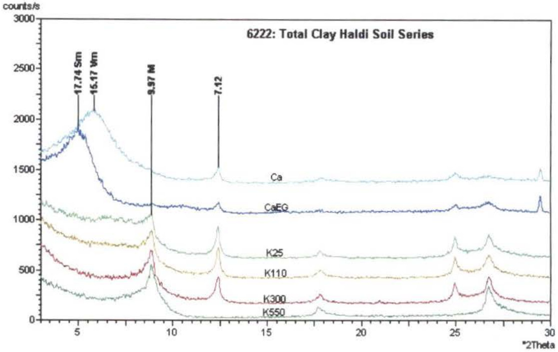


Fig. 4.5 Representating X-ray diffractograms of clay fractions (2-0.5μm) of Haldi series (Pedon 9) horizon, A

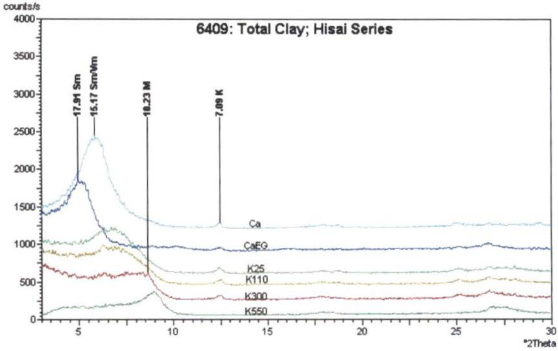


Fig. 4.6 Representating X-ray diffractograms of clay fractions (2-0.5 μm) of Hisai/Wardha series (Pedon 11) horizon, Ap

The peak at 7.2 and 3.5A° indicate the presence of kaolin, a slight shift and tailing of the peak on glycolation and gradual reinforcement of 1.0 nm peak with a corresponding decrease in intensity of 7.2A° peak indicate that the kaolins are to some extent interstratified with smectite. The peak at 10A° treatment indicates the presence of mica (Table 4.2).

4.4 Chemical Properties of Soil

4.4.1 Soil Reaction

Soil reaction as indicated by soil pH was determined in water. The pH values of Pedons 2, 3, 4, 5, 10 and 11 ranges from 7.8 to 8.9. In Pedon 1, 6 and 8 the pH values range from 6.50 to 7.75. In Pedon 7 it is only 5.64 (Table 4.3). In general, the pH of paddy growing soils of Bhandara, Gondia and Gadchiroli is less than other soils.

4.4.2 Electrical Conductivity

The electrical conductivity of Paral, Asra, Brahmni, Linga, Rajegaon, Kurul and Hisai soils in 0.1 to 0.2 dS m^{-1}. In Masala and Pahur soils it is 0.38 and 0.4 dS m^{-1} respectively. In Dighori soils EC is 0.8 dS m^{-1} (Table 4.3). The data show that these soils are not saline.

4.4.3 Calcium Carbonate

The calcium carbonate content varies in these soils. The $CaCO_3$ content ranges from 6.9 to 9.7 percent in Paral, Asra, Linga, Pahur and Hisai soils. In Paral, Brahmni, Dighori, Rajegaon Kerul soils, $CaCO_3$ content ranges from 1.7 to 3.3 percent. In Masala soils at the depth of 61 cm calcic horizon observed (Table 4.3).

4.4.4 Cation Exchange Capacity (CEC)

The cation exchange capacity of soils of Bhandara, Gondia, Gadchiroli and Chandrapur ranges from 13 to 32. In soils of Yavatmal, Washim and Akola

Table 4.3. Chemical properties of soils

Horizon	Depth (cm)	pH (1:2.5) water	EC (dS m^{-1})	SOC (%)	$CaCO_3$ (%)	Exchangable Cations cmol(p$^+$)kg^{-1}					BS (%)	CEC cmol(p$^+$)kg^{-1}	ESP (%)
						Ca^{++}	Mg^{++}	Na^+	K^+	Sum			
Pedon 1: Buldhana District – Masala Series													
Ap	0-9	8.30	0.36	0.5	10.8	54.48	10.08	2.26	1.3	65.15	100	67.83	
Pedon 2: Akola District – Paral Series													
Ap	0-9	8.0	0.18	0.7	9.7	36.3	7.6	0.7	1.2	45.8	84	54.4	1
Pedon 3 : Amravati District – Asra Series													
Ap	0-14	7.8	0.10	0.7	8.1	40.1	12.2	0.4	1.1	53.8	88	60.9	0.6
Pedon 4 : Wardha District – Brahmni Series													
Ap	0-13	8.9	0.19	0.9	3.3	53.4	7.6	0.2	1.5	62.7	90	69.6	0.2
Pedon 5 : Nagpur District – Linga Series													
Ap	0-16	7.9	0.16	0.98	6.9	40.0	11.8	0.6	1.3	253.7	82	65.2	0.9
Pedon 6 : Bhandara District – Dighori Series													
Ap	0-13	6.50	0.16	1.07	1.75	23.4	11.16	0.08	0.5	35.10	109	32.0	0.26
Pedon 7 : Gondia District – Rayegaon Series													
Ap	0-10	25.64	0.10	0.93	0.86	70.92	3.96	0.04	0.3	12.186	90	13.48	0.297
Pedon 8 : Gadchiroli District – Kurul Series													
Ap	0-12	7.75	0.84	1.24	2.01	16.54	8.46	0.09	0.4	25.45	88	28.87	0.31
Pedon 9 : Chandrapur District – Haldi Series													
Ap	0-14	6.23	0.038	0.25	--	13.97	5.04	0.05	0.2	19.25	82	23.478	0.21
Pedon 10 : Yavatmal District – Pahur Series													
Ap	0-19	8,3	0.23	0.90	8.2	42.4	13.9	0.8	1.0	58.1	104	55.5	1.37
Pedon 11 : Washim District – Wardha Series													
Ap	0-10	7.03	0.38	0.33	3.0	36.42	9.36	0.59	1.3	47.71	91	52.17	1.146

this value ranges from 52.17 to 55.5. The soils of Buldhana, Wardha and Nagpur CEC ranges from 62 to 69. Assuming that only clays contribute towards CEC. The clay CEC values indicate dominant of smectite (Smith, 1986; Bhattacharyya et al., 1997; Shirsath et al., 2000). The X-ray diffraction analysis of clay surfaces confirm the dominance of smectites as has been discussed later (Table 4.3).

4.4.5 Exchangeable Bases

In general the content of extractable bases decreases in the order calcium > magnesium > potassium > sodium. In soils of Bhandara, Gondia, Gadchiroli and Chandrapur the calcium content ranges from 7.9 to 23.4. In other soils this percentages varies from 36 to 53. The distribution of magnesium ion ranges from 3.9 to 11.8 m different soils of Vidarbha region (Table 4.3).

4.5 Oxidizable Organic Carbon (OOC) and its Fractionation

Soil organic carbon (SOC) determined by Walkley Black method using 36 N H_2SO_4 represents the SOC pool. As mentioned earlier this fraction was sub-fractionated into four different pools namely very labile (pool I : C_{VL}), labile (pool II : C_L), less labile (pool III : C_{LL}) and non-labile (pool IV : C_{NL}) (Table 4.4).

It has been reported that the most important factor which controls SOC level is climate which indirectly influences other SOC controlling factors namely hydrology and vegetation (Jenny, 1941). It is in view of these the data set generated on SOC and its different fractions are classified into four bioclimatic divisions viz. sub-humid moist (MAR >1100 mm), sub-humid dry (MAR 1100-1000 mm), semi-arid moist (1000-850 mm), semi-arid dry (850-550 mm). Grouping of soils according to bioclimatic class (Bhattacharjee, 1982) shows seven soils (Kurul, Dighori, Rajegaon, Haldi, Linga, Brahmni and Pahur) falls in sub-humid moist (SHm) and two (Asra and Hisai) ins sub-humid dry (SHd) and one each (Hisai and Paral) in semi-arid moist (SAm) and semi-arid dry (SAd), respectively.

The general trend of SOC content decreases with depth with some exception in the soils of sub-humid moist bioclimatic system. It is interesting to observe that very labile carbon (fraction 1 : C_{VL}) is not present in Kurul, Dighori, Rajegaon, Haldi and Brahmni soils (Table 4.4). In contrast Pahur soils contain 14 to 40 percent of total SOC as very labile (Fraction 1 : C_{VL}) form of carbon. Besides, Linga soils under horticultural system registered 0.12 to 0.31 percent of very labile C which constitute 30 to 35% of total SOC. The trend of very labile carbon with depth is also shown in figure 4.7. In contrast to very labile carbon (fraction 1), all the soils show labile carbon (C_L, fraction 2), less labile carbon (C_{LL}, fraction 3) and non-labile carbon (C_{NL}, fraction 4) although the amount vary from soils to soils (Table 4.4). It is observed that the soils of Kurul, Dighori, Rajegaon, Haldi and Brahmni which do not contain very labile carbon show quite high amount of labile carbon ranging between 30 to 44 percent of total SOC in the surface layer. It is also observed that Linga and Pahur soils which showed nearly 30 to 40 percent of very labile carbon registered labile carbon (C_L, fraction 2), to the tune of only 2 to 8 percent. It might indicate a dynamic equilibrium between C_{VL} and C_L which together form the active pool (discussed subsequently) of SOC. In general labile carbon (C_L, fraction 2) ranges between 2 to 23 percent of total SOC in the soils under sub-humid moist bio-climatic system (Table 4.4). The non-labile carbon (C_{NL} fraction 4) forms the largest contribution in the total SOC and these values range from 43 to 92 percent of total SOC (Table 4.4). In general C_{NL} increases with depth with Dighori soils as exception (Table 4.4). The C_L values in Rajegaon, Haldi and Brahmni soils show decreasing trend with depth, while this trend is found opposite in Pahur and Dighori soils. Total SOC of other three soils there is no definite trend C_L with depth (Table 4.4).

In the sub-humid dry bioclimatic system the total SOC varies from 0.15 to 0.35 percent in Hisai soils and 0.57 to 0.77 in Asra soils. Hisai soils do not have C_{VL}, whereas Asra soils contain C_{VL} which ranges from 12 to 24 percent.

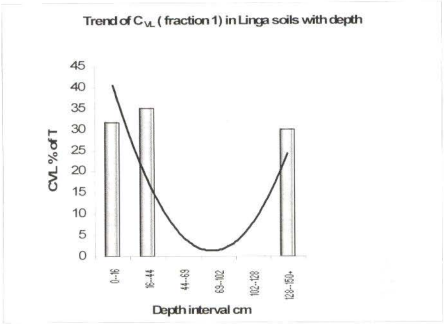


Fig. 4.7. Trend of C_{VL} (fraction 1) in Linga soils with depth.

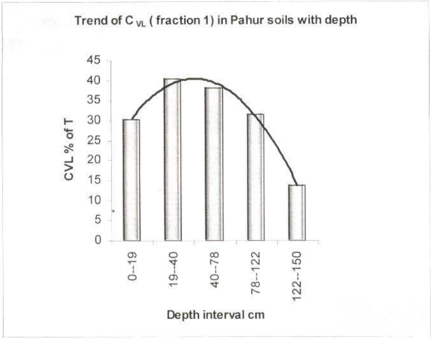


Fig. 4.8. Trend of C_{VL} (fraction 1) in Pahur soils with depth.

Table 4.4. Sub-fractionation of organic carbon (%) from soils under different bioclimatic regions using modified Walkley-Black method with varying concentration of sulphuric acid.

Depth of soil	C_{VL} (fraction 1) %		C_L (fraction 2) %		C_{LL} (fraction 3) %		C_{NL} (fraction 4) %		Total SOC %
	12N	%SOC	18 N-12 N	%SOC	24N -18N	%SOC	36 N-24 N	%SOC	
Sub-Humid Moist(>1100mm)									
Kurul (Gadchiroli; MAR 1551 mm)									
0-12	0.00	0	0.62	35	0.23	13	0.90	51	1.75
12-28	0.00	0	0.21	40	0.02	3	0.31	57	0.54
28-50	0.00	0	0.11	36	0.02	7	0.18	58	0.32
50-76	0.00	0	0.04	18	0.03	12	0.15	70	0.21
76-101	0.00	0	0.01	6	0.00	2	0.15	92	0.16
101-126	0.00	0	0.02	14	0.00	2	0.13	84	0.16
126-150	0.00	0	0.03	46	0.01	14	0.03	40	0.06
Dighori (Bhandara; MAR 1388 mm)									
0--13	0.00	0	0.42	38	0.08	7	0.59	55	1.08
13--27	0.00	0	0.13	32	0.05	12	0.22	56	0.40
27--53	0.00	0	0.09	31	0.01	3	0.20	66	0.30
53--76	0.00	0	0.05	21	0.03	12	0.16	67	0.24
76--105	0.00	0	0.09	33	0.06	23	0.11	44	0.26
105--160	0.00	0	0.11	41	0.03	11	0.13	49	0.27
Rajegaon (Gondia; MAR 1363 mm)									
0--10	0.00	0	0.38	41	0.10	11	0.45	48	0.93
10--25	0.00	0	0.13	44	0.04	12	0.13	43	0.29
25--55	0.00	0	0.10	48	0.01	3	0.10	49	0.20
55--74	0.00	0	0.03	30	0.02	17	0.05	54	0.10
74--107	0.00	0	0.05	34	0.02	16	0.07	50	0.14
107--150+	0.00	0	0.04	36	0.01	11	0.06	53	0.11
Haldi (Chandrapur; MAR 1312 mm)									
0-14	0.00	0	0.08	30	0.06	21	0.13	48	0.26
14-46	0.00	0	0.17	31	0.11	20	0.26	49	0.54
46-82	0.00	0	0.06	30	0.02	10	0.12	60	0.20
82-114	0.00	0	0.05	26	0.02	13	0.11	61	0.18
114-135	0.00	0	0.03	15	0.01	7	0.14	78	0.18
Linga (Nagpur; MAR 1242 mm)									
0--16	0.31	32	0.07	7	0.05	5	0.56	56	0.99
16--44	0.22	35	0.01	1	0.13	20	0.28	44	0.63
44--69	0.00	0	0.16	34	0.04	8	0.29	59	0.49
69--102	0.00	0	0.17	34	0.04	8	0.29	58	0.50
102--128	0.00	0	0.16	36	0.01	2	0.27	62	0.44
128--150+	0.12	30	0.01	3	0.02	5	0.25	62	0.40
Brahmni (Wardha; MAR 1134 mm)									
0--13	0.00	0	0.33	35	0.15	16	0.45	49	0.93
13--32	0.00	0	0.18	30	0.02	3	0.39	67	0.58
32--59	0.00	0	0.08	23	0.01	2	0.25	75	0.33

Depth of soil	C_{VL} (fraction 1) %		C_L (fraction 2) %		C_{LL} (fraction 3) %		C_{NL} (fraction 4) %		Total SOC %
	12N	%SOC	18 N-12 N	%SOC	24N -18N	%SOC	36 N-24 N	%SOC	
59--81	0.00	0	0.11	34	0.02	8	0.18	58	0.31
81--115	0.00	0	0.06	24	0.03	13	0.17	63	0.26
115--145	0.00	0	0.01	7	0.01	4	0.14	89	0.16
Pahur (Yavatmal; MAR 1133 mm)									
0--19	0.28	30	0.07	8	0.11	12	0.45	49	0.91
19--40	0.26	40	0.01	1	0.04	5	0.35	53	0.66
40--78	0.24	38	0.01	2	0.04	6	0.34	54	0.63
78--122	0.15	32	0.05	11	0.02	4	0.25	54	0.47
122--150	0.09	14	0.13	19	0.02	3	0.45	64	0.69
Sub-humid Dry(1100-1000mm)									
Hisai (Washim; MAR 926 mm)									
0--10	0.00	0	0.11	34	0.01	4	0.21	62	0.33
10--31	0.00	0	0.11	42	0.03	11	0.12	48	0.26
31--53	0.00	0	0.06	37	0.01	5	0.10	58	0.16
53--81	0.00	0	0.03	21	0.01	5	0.11	74	0.15
81--114	0.00	0	0.09	44	0.01	4	0.11	52	0.21
114--150	0.00	0	0.09	43	0.02	8	0.10	49	0.20
Asra (Amravati; MAR 976 mm)									
0--14	0.17	22	0.07	9	0.08	10	0.46	59	0.77
14--35	0.11	17	0.07	11	0.10	15	0.37	56	0.66
35--69	0.11	19	0.02	4	0.14	25	0.30	52	0.57
69--107	0.09	12	0.18	24	0.05	7	0.41	57	0.73
107--150	0.15	24	0.07	11	0.06	10	0.35	55	0.63
Semi-arid moist(1000-850mm)									
Dhanora (Buldhana; MAR 901 mm)									
0--9	0.00	0	0.14	28	0.10	20	0.26	52	0.50
9--28	0.00	0	0.08	22	0.09	24	0.20	53	0.38
28--45	0.00	0	0.08	24	0.09	28	0.16	48	0.33
45--61	0.00	0	0.06	55	0.00	3	0.05	42	0.12
61--91	0.00	0	0.03	65	0.01	19	0.01	16	0.05
Semi-arid dry (850-550mm)									
Paral (Akola; MAR 687 mm)									
0--9	0.10	14	0.01	2	0.19	27	0.40	57	0.70
9--35	0.06	10	0.02	4	0.16	30	0.30	56	0.54
35--69	0.02	3	0.02	4	0.19	35	0.31	57	0.54
69--105	0.05	8	0.06	10	0.14	23	0.36	59	0.61
105--132	0.04	6	0.05	7	0.15	23	0.41	63	0.66
132--150	0.02	3	0.13	20	0.13	21	0.34	55	0.62

As discussed earlier C_L is found to be abundant in soils like Hisai which do not contain any C_{VL}. Similarly for Asra soils C_{VL} is found to be less than Hisar soils (Table 4.4). Figure 4.9 indicates the trend of very labile carbon in Asra soils. In the semi-arid moist bioclimatic system Hisai soils do not show very labile carbon (C_{VL}, fraction 1). The labile carbon (C_L) ranges from 20 to 26.5 percent, less labile carbon (C_{LL}) 3 to 28 percent and non-labile carbon (C_{NL}) 16 to 53 percent of total SOC (Table 4.4).

Paral soils in the semi-arid bioclimatic regions registered 3 to 4 percent of total SOC as very labile carbon C_{VL}. The labile carbon C_L, less labile carbon C_{LL} and non-labile carbon C_{NL} ranges from 2 to 20, 21 to 35 and 55 to 60 percent of total SOC, respectively (Table 4.4). Figure 4.10 indicates the depth distribution of very labile carbon for Paral soils which shows a decreasing trend.

4.6 Distribution of Active and Passive Pool of Organic Carbon

As has been mentioned earlier C_{vl} and C_L together represent the active pool while C_{LL} and C_{NL} together comprises passive pool of organic carbon in soil (Chan et al., 2001; Mandal et al., 2008). For all the soils passive pool has always remained dominant over the active pool. The eight soils studied in the sub-humid moist bioclimatic system show a range of active pool between 6 to 48 percent while that of the passive pool between 52 to 94 percent (Table 4.5). The two soils studied from sub-humid dry bioclimatic system indicate the active pool and passive pool to range between 21 to 44 percent and 58 to 79 percent respectively. The active pool values of carbon gradually decreased in drier tracts of semi-arid moist and semi-arid dry bioclimatic region with a corresponding increase in values of passive pool carbon.

Table 4.6 shows the relative proportion of active and passive pool carbon at three different depth interval such as 0-50, 50-100 and 100-150 cm.

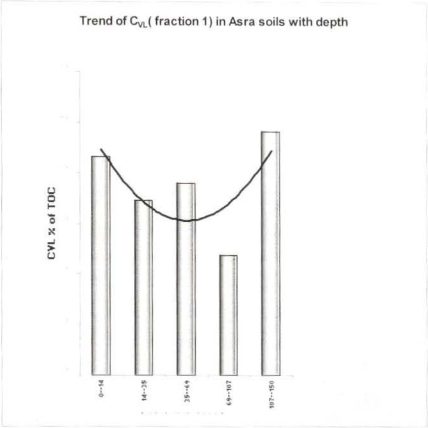


Fig. 4.9. Trend of C_{VL} (fraction 1) in Asra soils with depth.

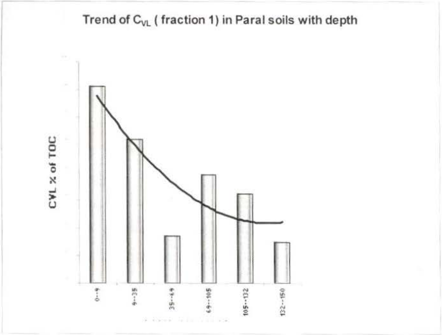


Fig. 4.10. Trend of C_{VL} (fraction 1) in Paral soils with depth.

Table 4.5. Percentage of active and passive pool according to different bioclimatic regions in Vidarbha

Depth of soil	Active Pool (%)	% of total SOC	Passive Pool (%)	% of total SOC
Sub-Humid Moist (>1100mm)				
Kurul (Gadchiroli; MAR 1551 mm)				
0-12	0.620	35	1.130	65
12-28	0.214	40	0.327	60
28-50	0.113	36	0.205	64
50-76	0.039	18	0.175	82
76-101	0.010	6	0.151	94
101-126	0.023	14	0.138	86
126-150	0.029	46	0.035	54
Dighori (Bhandara; MAR 1388 mm)				
0--13	0.416	38	0.664	62
13--27	0.126	32	0.270	68
27--53	0.091	31	0.205	69
53--76	0.051	21	0.192	79
76--105	0.086	33	0.174	67
105--160	0.111	41	0.162	59
Rajegaon (Gondia; MAR 1363 mm)				
0--10	0.384	41	0.551	59
10--25	0.128	44	0.161	56
25--55	0.098	48	0.105	52
55--74	0.029	30	0.069	70
74--107	0.050	34	0.095	66
107--150+	0.040	36	0.072	64
Haldi (Chandrapur; MAR 1312 mm)				
0-14	0.079	30	0.181	70
14-46	0.166	31	0.371	69
46-82	0.059	30	0.139	70
82-114	0.047	26	0.135	74
114-135	0.027	15	0.149	85
Linga (Nagpur; MAR 1242 mm)				
0--16	0.386	39	0.604	61
16--44	0.225	36	0.402	64
44--69	0.165	34	0.327	66
69--102	0.170	34	0.334	66
102--128	0.158	36	0.278	64
128--150+	0.132	33	0.269	67
Brahmni (Wardha; MAR 1134 mm)				
0--13	0.326	35	0.603	65
13--32	0.177	30	0.408	70
32--59	0.077	23	0.255	77
59--81	0.108	34	0.206	66
81--115	0.063	24	0.199	76

Depth of soil	Active Pool (%)	% of total SOC	Passive Pool (%)	% of total SOC
115--145	0.010	7	0.147	93
Pahur (Yavatmal; MAR 1133 mm)				
0--19	0.349	38	0.561	62
19--40	0.270	41	0.386	59
40--78	0.253	40	0.372	60
78--122	0.200	42	0.273	58
122--150	0.225	32	0.469	68
Sub-humid Dry (1100-1000mm)				
Hisai (Washim; MAR 926 mm)				
0--10	0.114	34	0.220	66
10--31	0.110	42	0.153	58
31--53	0.060	37	0.104	63
53--81	0.032	21	0.116	79
81--114	0.093	44	0.120	56
114--150	0.086	43	0.115	57
Asra (Amravati; MAR 976 mm)				
0--14	0.239	31	0.534	69
14--35	0.187	28	0.477	72
35--69	0.133	23	0.436	77
69--107	0.263	36	0.463	64
107--150	0.225	36	0.409	64
Semi-arid moist(1000-850mm)				
Dhanora (Buldhana; MAR 901 mm)				
0--9	0.139	28	0.364	72
9--28	0.085	22	0.295	78
28--45	0.082	24	0.252	76
45--61	0.064	55	0.053	45
61--91	0.034	65	0.018	35
Semi-arid dry(850-550mm)				
Paral (Akola; 687 mm)				
0--9	0.115	16	0.589	84
9--35	0.077	14	0.465	86
35--69	0.039	7	0.500	93
69--105	0.111	18	0.500	82
105--132	0.091	14	0.569	86
132--150	0.144	23	0.476	77

Table 4.6. Weighted mean values of active and passive pool (%) of soil organic carbon

Soil Series	Soil Depth (cm)	Active pool (% of total SOC)	Passive pool (% of total SOC)	Active:Passive pool ratio
Hisai	0-50	25	75	0.341
	50-100	61	39	1.558
	100-150	65	35	1.845
Paral	0-50	12	88	0.139
	50-100	14	86	0.168
	100-150	18	82	0.213
Asra	0-50	28	72	0.392
	50-100	32	68	0.472
	100-150	36	64	0.554
Brahmni	0-50	22	78	0.283
	50-100	29	71	0.403
	100-150	14	86	0.160
Linga	0-50	37	63	0.589
	50-100	43	57	0.741
	100-150	36	64	0.568
Digori	0-50	35	65	0.540
	50-100	28	72	0.380
	100-150	40	60	0.666
Rajegaon	0-50	44	56	0.777
	50-100	35	65	0.543
	100-150	31	69	0.452
Kurul	0-50	36	64	0.573
	50-100	13	87	0.154
	100-150	35	65	0.531
Haldi	0-50	31	69	0.445
	50-100	28	72	0.397
	100-150	18	82	0.223
Pahur	0-50	40	60	0.659
	50-100	41	59	0.700
	100-150	36	64	0.558
Hisai	0-50	38	62	0.624
	50-100	33	67	0.487
	100-150	43	57	0.755

The active pool in 0-50, 50-100 and 100-150 cm depth decreases in Dighori, Rajegaon, Haldi and Pahur soils with concomitant increase in passive pool in those three soil depth intervals. In case of Brahmni, Linga and Kurul soils the distribution pattern is erratic, as is evident from active : passive pool carbon ratio values also (Table 4.6).

For sub-humid dry, semi-arid moist and semi-arid dry bioclimatic system the general tendency of active and passive pools of carbon indicates an increasing and decreasing tendency, respectively down the depth.

Figures 4.11, 4.12 and 4.13 show active and passive pools of soil organic carbon as related to soil depth.

4.7 Effect of Landuse on Different Pools of Organic Carbon

Out of eleven soils studied in different bioclimatic regions in Vidarbha, eight soils are used for agriculture, two for horticulture and one for forestry (Table 4.7). Out of eight soils under agriculture four are used mainly for cotton (Pahur, Hisai, Hisai and Paral), three for paddy (Kurul, Dighori and Rajegaon) and one for soybean (Asra). Within horticultural land use, one soil is used for citrus (Linga) and other one for banana (Brahmni). In the first 50 cm depth of soil, nearly 12 to 44 percent of total soil organic carbon is found to be in active pool for all the soils. When the data on active and passive pools of carbon were arranged in order of decreasing rainfall, a few interesting observations were made. Active pool of carbon gradually decreases with decrease in rainfall in those soils which are used for cotton. This leads to a corresponding increase in level of passive pool (Fig. 4.14). Similar observations were not, however, made when data were compared for the soils used for paddy. Periodic inundation of soils with water might stabilize active pool of SOC irrespective of amount of rainfall (Fig 4.15). The soils under citrus were found to store more active pool of carbon in surface than banana (Fig. 4.16).

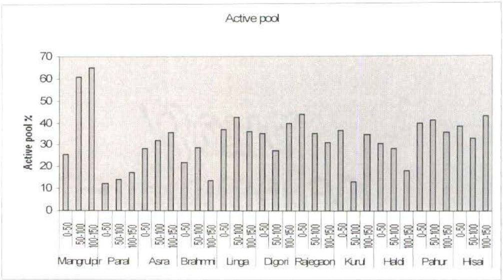


Fig. 4.11. Weighted mean of active pool of soil organic carbon for 0-50, 50-100 and 100-150 cm depth.

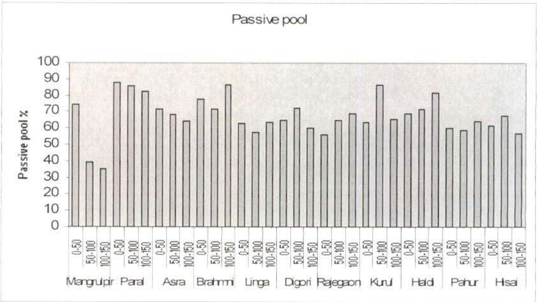


Fig. 4.12. Weighted mean of passive pool of soil organic carbon for 0-50, 50-100 and 100-150 cm depth.

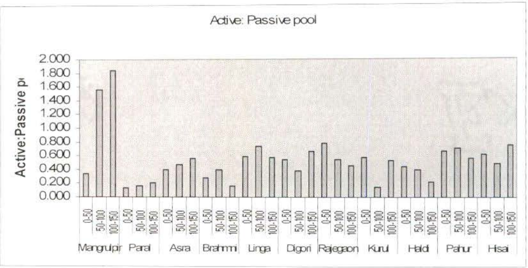


Fig. 4.13. Ratio of active : passive pool of soil organic carbon for 0-50, 50-100 and 100-150 cm depth.

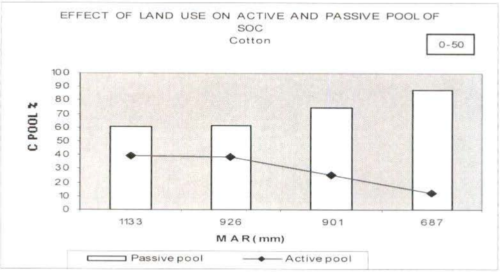


Fig. 4.14. Effect of land use on active and passive pool of SOC in soils used for cotton cultivation (arranged in decreasing order of rainfall).

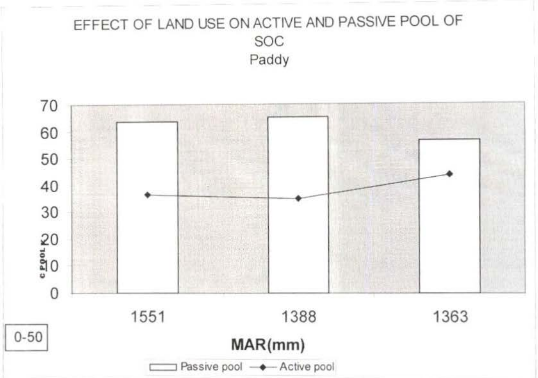


Fig. 4.15. Effect of land use on active and passive pool of SOC in soils used for paddy cultivation (arranged in decreasing order of rainfall).

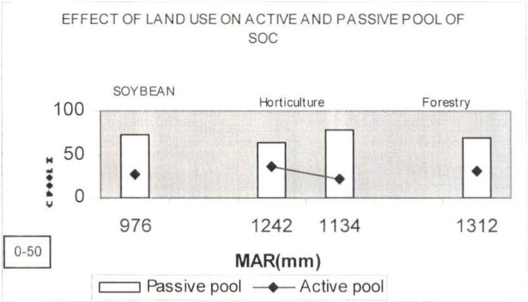


Fig. 4.16. Effect of land use on active and passive pool of SOC in soils used for soybean cultivation, horticulture and forestry.

Table 4.7. Active and passive pool of soil organic carbon in different land use system

Sl No	District	Soil Series	MAR (mm)	Active pool*	Passive pool*
Agriculture (Cotton)					
1	Yavatmal	Pahur	1133	40	60
2	Washim	Hisai	926	38	62
3	Buldhana	Dhanora	901	25	75
4	Akola	Paral	687	12	88
Agriculture (Paddy)					
5	Gadchirolui	Kurul	1551	36	64
6	Bhandara	Digori	1388	35	65
7	Gondia	Rajegaon	1363	44	56
Agriculture (Soybean)					
8	Amravati	Asra	976	28	72
Horticulture					
9	Nagpur	Linga	1242	37	63
10	Wardha	Brahmni	1134	22	78
Forestry					
11	Chandrapur	Haldi	1312	31	69

* values are for 0-50 cm of soil depth and expressed as percent of total soil organic carbon.

4.8 Lability Index for Soil Organic Carbon

4.8.1 Lability Index for SOC in different Bioclimatic Systems

As mentioned earlier estimation of lability Index (LI) involves assigning different weightage to C_{VL}, C_L and C_{LL}. This indicates that higher LI will indicate higher amount of C_{VL}. Since again C_{VL} and C_L together forms the active pool of SOC, therefore, higher lability index will reflect more active pool of SOC.

Linga and Pahur soils registered very high LI as compared to other soil in the same bioclimatic region. This is because Linga and Pahur soils, representing sub-humid bioclimate contain sizeable amount of C_{VL} which has contributed heavily towards high LI. C_{VL} is completely absent in other five soils of this bioclimate. Similar observations were made when LI values are compared with soils under sub-humid dry and semi-arid moist bioclimatic system. Interestingly, Paral soils which contain C_{VL}, does not show high LI. On the contrary, Hisai soil in spite of containing no C_{VL} registered higher LI (Table 4.8). The reason is, in absence of C_{VL} (Hisai) and/or low amount of C_{VL} (Paral) the LI is governed by C_L; and C_L is present in sizeable amount in these two soils. Tables 4.8, 4.9 and 4.10 show lability indices for soil organic carbon for different depth intervals.

When LI values were arranged in different depth intervals, it was observed that for few soils like Kurul and Dighori LI values increased with depth. However, soils like Linga, Brahmni and Pahur, LI values decrease with increasing depth (Fig. 4.17). On an average LI values increased with increasing soil depth in Asra and Hisai soils under sub-humid dry and Hisai under semi-arid moist bioclimatic region (Fig. 4.18, 4.19). Interestingly, for Paral soils which represent semi-arid dry bioclimatic regions, LI values do not change over depth (Fig. 4.20).

4.8.2 Lability Index for SOC in different land use systems

In general the LI values were found to be high in cotton (Pahur), paddy (Rajegaon), soybean (Asra) and citrus (Linga). The other soils under cotton (Hisai and Paral), paddy (Dighori) and banana (Brahmni) show relatively

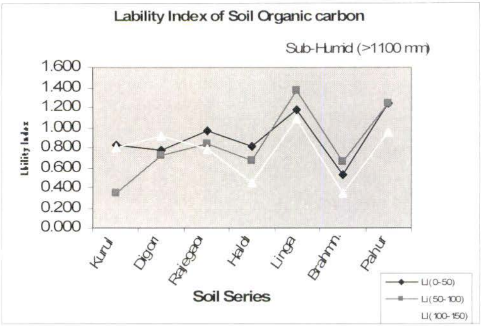


Fig. 4.17. Lability index for soil organic carbon (sub-humid moist >1100 mm).

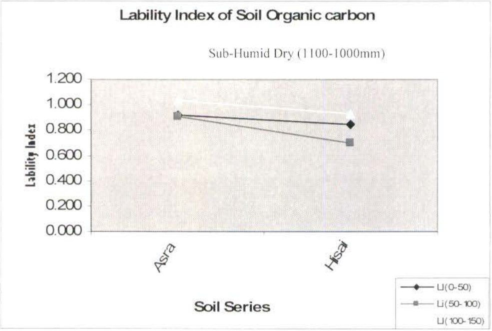


Fig. 4.18. Lability index for soil organic carbon (sub-humid dry 1100-1000).

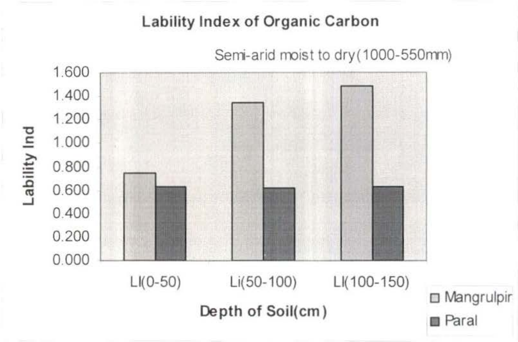


Fig. 4.19. Lability index for soil organic carbon (semi-arid moist to dry 1000-500 mm).

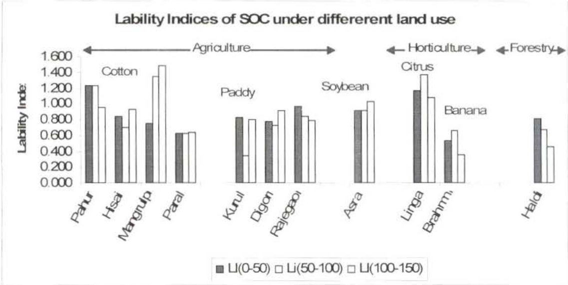


Fig. 4.20. Depth distribution of lability indices for soil organic carbon under different land use system.

Table 4.8. Lability indices for soil organic carbon in different bioclimatic systems (0-50 cm)

District	Soil Series	C_{VL}	C_L	C_{LL}	C_{NL}	Total SOC	LI
Sub-Humid moist(>1100 mm)							
Gadchirolui	Kurul	0.000	0.267	0.072	0.394	0.733	0.826
Bhandara	Digori	0.000	0.185	0.037	0.306	0.528	0.771
Gondia	Rajegaon	0.000	0.164	0.034	0.177	0.375	0.966
Chandrapur	Haldi	0.000	0.133	0.085	0.214	0.432	0.812
Nagpur	Linga	0.223	0.046	0.090	0.368	0.727	1.172
Wardha	Brahmni	0.000	0.114	0.048	0.355	0.517	0.535
Yavatmal	Pahur	0.264	0.033	0.065	0.385	0.746	1.236
Sub-Humid dry (1100-1000 mm)							
Amravati	Asra	0.127	0.058	0.107	0.366	0.657	0.919
Washim	Hisai	0.000	0.092	0.017	0.130	0.240	0.841
Semi-arid moist (1000-850mm)							
Buldhana	Dhanora	0.000	0.091	0.085	0.183	0.360	0.746
Semi-arid dry (850-550mm)							
Akola	Paral	0.053	0.020	0.175	0.349	0.596	0.626

Table 4.9. Lability indices for soil organic carbon in different bioclimatic systems (50-100 cm)

District	Soil Series	C_{VL}	C_{L}	C_{LL}	C_{NL}	Total SOC	Li
Sub-Humid moist (>1100mm)							
Gadchirolui	Kurul	0.000	0.025	0.015	0.149	0.188	0.344
Bhandara	Digori	0.000	0.070	0.043	0.141	0.254	0.721
Gondia	Rajegaon	0.000	0.047	0.019	0.068	0.133	0.844
Chandrapur	Haldi	0.000	0.055	0.021	0.117	0.192	0.676
Nagpur	Linga	0.255	0.031	0.096	0.291	0.673	1.373
Wardha	Brahmni	0.000	0.085	0.024	0.188	0.297	0.656
Yavatmal	Pahur	0.200	0.030	0.029	0.299	0.558	1.233
Sub-Humid dry (1100-1000 mm)							
Amravati	Asra	0.095	0.119	0.085	0.368	0.666	0.910
Washim	Hisai	0.000	0.057	0.008	0.109	0.173	0.699
Semi-arid moist (1000-850mm)							
Buldhana	Dhanora	0.000	0.040	0.008	0.017	0.066	1.346
Semi-arid dry (850-550mm)							
Akola	Paral	0.037	0.047	0.160	0.340	0.584	0.624

Table 4.10. Lability indices in soil organic carbon in different bioclimatic systems (100-150 cm)

District	Soil Series	C_{VL}	C_L	C_{LL}	C_{NL}	Total SOC	LI (100-150)
Sub-Humid moist (>1100mm)							
Gadchirolui	Kurul	0.000	0.014	0.004	0.022	0.041	0.801
Bhandara	Digori	0.000	0.109	0.032	0.131	0.272	0.917
Gondia	Rajegaon	0.000	0.041	0.022	0.070	0.132	0.786
Chandrapur	Haldi	0.000	0.032	0.015	0.130	0.178	0.451
Nagpur	Linga	0.127	0.075	0.072	0.283	0.558	1.081
Wardha	Brahmni	0.000	0.026	0.015	0.148	0.189	0.355
Yavatmal	Pahur	0.119	0.095	0.021	0.362	0.597	0.951
Sub-Humid dry (1100-1000 mm)							
Amravati	Asra	0.143	0.087	0.061	0.356	0.648	1.029
Washim	Hisai	0.000	0.088	0.014	0.102	0.204	0.931
Semi-arid moist (1000-850mm)							
Buldhana	Dhanora	0.000	0.034	0.010	0.009	0.052	1.485
Semi-arid dry (850-550mm)							
Akola	Paral	0.034	0.078	0.145	0.383	0.641	0.631

less lability index in first 50 cm soil depth (Table 4.11). Depth distribution of lability indices show irregular pattern. In the soils used for cotton (Pahur, Hisar, Hisai and Paral) LI values are found to decrease, increase and remain similar, respectively. Overall tendency of LI under forestry and horticulture show a decreasing tendency with depth. For the soils used for paddy, the depth distribution of LI is not uniform. For Asra soils used for soybean, the LI values increased with depth.

4.9 Relation between Active and Passive Pool of SOC with selected Soil Parameters

A few soil parameters were selected to find out correlation with active and passive pool of SOC. Earlier detailed study was carried out showing correlation between total soil organic carbon and morphological, physical, mineralogical and chemical properties (Bhattacharyya et al., 2007a, b, c).

There are no reports on correlation of active and passive pool of carbon to the different parameters. An effort has been made in the present study to find out relation between a selected parameters on soil physical, chemical and mineralogical properties with active and passive pools of SOC.

The datasets developed on the soil parameters for the first horizon were compared with active and passive pool of SOC. All the datasets used for this particular study were arranged (weighted mean) for first 30 cm depth of soil.

4.9.1 Influence of Bulk Density on Active and Passive Pool of Soil Organic Carbon

The data indicate that active pool of carbon is negatively correlated with bulk density (Fig. 4.21), but with the passive pool of SOC this relation is positive (Fig. 4.25). It has been observed that SOC varies depending on rainfall and atmospheric temperature (Jenny and Raychaudhury, 1960; Bhattacharyya et al., 2000). Since SOC influences bulk density therefore bulk density is supposed

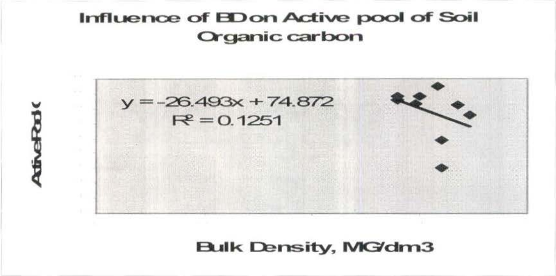


Fig. 4.21. Influence of bulk density on active pool of soil organic carbon.

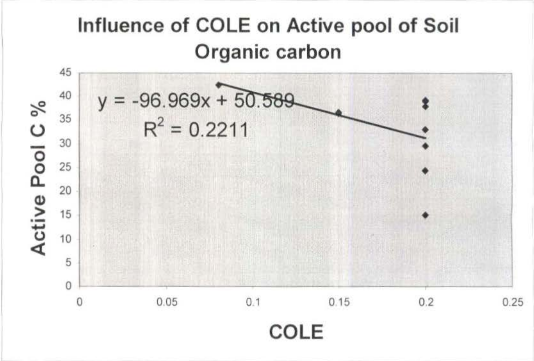


Fig. 4.22. Influence of COLE on active pool of soil organic carbon.

Table 4.11. Depth distribution of lability index for soil organic carbon under different land use system

District	Soil Series	MAR mm	Land Use	Lability Index (LI)		
				LI(0-50)	Li(50-100)	LI(100-150)
			Cotton			
Yavatmal	Pahur	1133		1.236	1.233	0.951
Washim	Hisai	926		0.841	0.699	0.931
Buldhana	Dhanora	901		0.746	1.346	1.485
Akola	Paral	687		0.626	0.624	0.631
			Paddy			
Gadchirolui	Kurul	1551		0.826	0.344	0.801
Bhandara	Digori	1388		0.771	0.721	0.917
Gondia	Rajegaon	1363		0.966	0.844	0.786
			Soybean			
Amravati	Asra	976		0.919	0.910	1.029
			Horticulture			
Nagpur	Linga	1242		1.172	1.373	1.081
Wardha	Brahmni	1134		0.535	0.656	0.355
			Forestry			
Chandrapur	Haldi	1312		0.812	0.676	0.451

to change in different bioclimatic regions. In general, bulk density of soil is found to decrease with increase in rainfall. This observation finds support due to fact that in drier tract the bulk density value increased. Study also indicates that the SOC value gradually decreased with decreasing rainfall. It is interesting to note that with the increase in rainfall the active pool of SOC increases, therefore, earlier observation on a negative correlation between total SOC and bulk density also holds goods for active pool of SOC (Bhattacharyya et al., 2007b). The relation between passive pool of SOC and bulk density is in sharp contrast with the observation made between bulk density and active pool of SOC with the decrease in rainfall effecting increasing bulk density and increase in passive pool of SOC is observed. This indicates that with the decrease in rainfall, recalcitrant pool of SOC will gradually increases.

4.9.2 Relation with COLE

The data indicate the negative correlation with active pools of SOC and COLE, and it is positively correlated with passive pool of SOC (Fig. 4.22 and Fig. 4.26). The percentage of passive pool increased with increase in value of COLE.

4.9.3 Influence of CEC on active and passive pool of soil organic carbon

The data indicate that active pool of SOC is negatively correlated with CEC. The active pool of SOC decreased with increase in CEC, whereas passive pool of SOC is positively correlated with CEC. The passive pool of SOC increased with increase in CEC (Fig. 4.23 and Fig. 4.27).

4.9.4 Influence of soil inorganic carbon on active and passive pool of soil organic carbon

Soil inorganic carbon increased with decrease in rainfall. The data indicate the negative correlation between active pool of SOC and SIC. With increased in SIC, active pool of SOC decreased (Fig. 4.24 and Fig. 4.28).

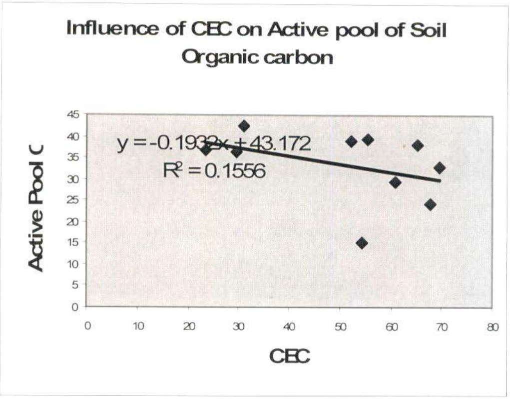


Fig. 4.23. Influence of CEC on active pool of soil organic carbon.

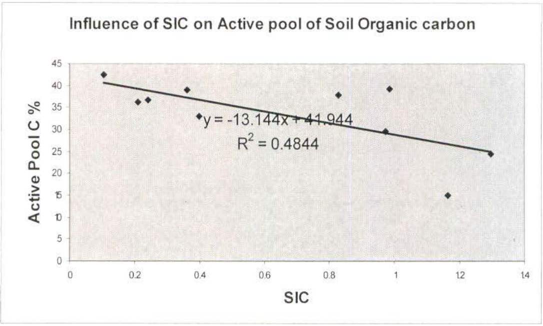


Fig. 4.24. Influence of SIC on active pool of soil organic carbon.

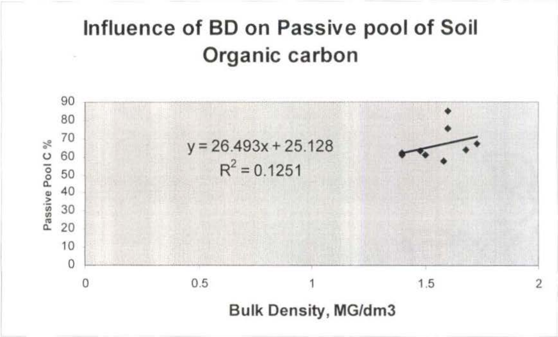


Fig. 4.25. Influence of bulk density on passive pool of soil organic carbon.

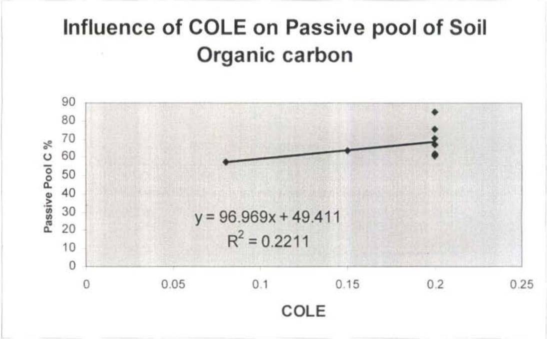


Fig. 4.26. Influence of COLE on passive pool of soil organic carbon.

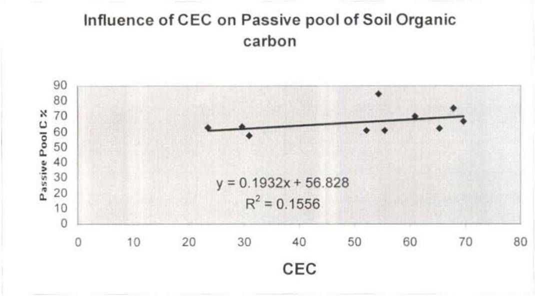


Fig. 4.27. Influence of CEC on passive pool of organic carbon.

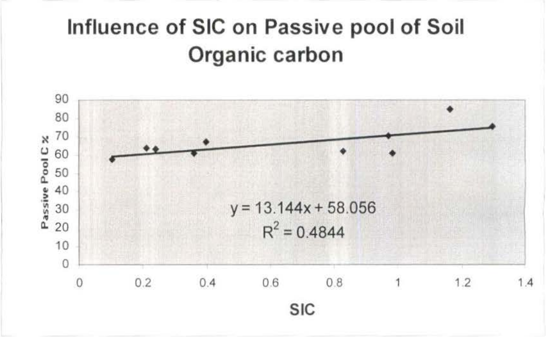


Fig. 4.28. Influence of SIC on passive pool of soil organic carbon.

Higher COLE indicates more smectites in the soils. In fact COLE values are one of the important diagnostic criteria for shrink-swell soils (Soil Survey Staff, 1999). Higher COLE might influence more SOC content. And since, in the present study, SOC has been subfractionated into active and passive pool of carbon, it may be prudent to understand that higher smectite (and have more COLE) may not have more influence on active pool of carbon. In fact most of the carbon stored as passive pool may be governed by higher smectite (indicating high COLE). The present study supports this contention.

4.9.5 X-ray diffraction analysis for selected soils

The X-ray diffraction analysis was carried out for selected soils to find out the minerals present in the clay fractions. The quantified values of smectite for these selected soils were correlated with the active and passive pool of SOC. The study indicates that the active pool of SOC is positively and passive pool of SOC is negatively correlated with the smectite content in total clay fraction of these soils. (Fig. 4.29 and 4.30).

It has been earlier indicated that Vertisols and their integrades dominated by smectite minerals provide good sub-strate for increasing soil organic carbon stock (Bhattacharyya et al., 2000; 2005; 2006). After fractionating SOC it appears that perhaps higher content of smectite increased recalcitrant pool of SOC which constitute most of the passive pool of SOC.

4.10 Discussion

4.10.1 Distribution of total SOC

Significantly higher SOC were found in the soils under paddy cultivation (Table 4.4). The mechanisms involved in preferential accumulation of organic carbon in wet land soil under paddy have been ascribed mainly to anaerobiosis and the associated chemical and biochemical changes that take place in submerged soils. Decomposition of added organic matter in well aerated soil is relatively fast, complete and efficient in soils under aerobic condition where oxygen is the electron acceptor. However, decomposition of organic matter in absence of oxygen in submerged or anaerobic soils is comparatively slow, incomplete and inefficient. In addition, in submerged soils the formation of recalcitrant pool complexes with organic matter (the recalcitrant pool ranges from 44 to 92 percent in the paddy soils of Kurul, Dighori and Rajegaon soils, Table 4.4) and renders them less available for microbial attack. Biological nitrogen fixation coupled with overall higher primary productivity of wetlands and decreased humification of organic matter lead to net accumulation of organic matter in wet land soils after paddy cultivation in eastern Vidarbha (Table 4.4, Sahrawat et al., 2005). The other soils which contain sizeable amount of organic carbon in the surface soils are Linga and Brahmni these soils are used for horticulture (Linga for citrus and Brahmni for banana). It is interesting to note that out of the four soils (Pahur, Hisai, Dhanora and Paral) used for growing cotton show 0.9 percent of SOC. These (Table 4.4) sites (Pahur, Haldi, Dhanora, Paral) are used for growing cotton with pigeonpea. Introduction of legume in the crop rotation has been found to be beneficial in increasing total SOC (Naitam and Bhattacharyya, 2003; Bhattacharyya et al., 2007).

4.10.2 LI of SOC in different soils

Table 4.12 indicate lability index of SOC of representative soils of Vidarbha in order of decreasing rainfall. Lability index has a decreasing trend with decreasing rainfall. When the lability index values are averaged according to dominant cropping pattern in the study area (Table 4.13), it is observed that for paddy soils LI values range from 0.808 to 0.950 %. Highest LI values in Pahur soils under cotton might be due to pigeonpea intercropping with cotton. When effect of FYM was taken into account to find relation with LI, it is found that paddy soils (Gadchiroli, Bhandara and Gondia) receive approximately 6 tonnes FYM per year and thus maintained LI values between 0.808 to 0.957 in the first 30 cm depth of soils (Table 4.13). Very high amount of FYM (@30 tonnes/ha for Washim soil and 20 tonnes/ha for Wardha soils) do not appreciably affect LI values. On the

Table 4.12. Lability index of SOC and climate and soil management practices

Arranged in order of decreasing rainfall

District	Soil Series	MAR, mm	MAT°C	Fertilizer dose (kg/ha)			FYM,t/ha	LI(0-30)
				N	P	K		
Sub-Humid Moist(>1100mm)								
Gadchiroli	Kurul	1551	26	103[1]	18	10	4	0.836
Bhandara	Digori	1388	27	69[2]	48	--	6	0.808
Gondia	Rajegaon	1363	28	23[3]	16	--	6	0.957
Chandrapur	Haldi	1312	28	[4]	--	--	--	0.817
Nagpur	Linga	1242	25	[5]	--	--	--	1.188
Wardha	Brahmni	1134	28	[6]	48	--	20	0.761
Yavatmal	Pahur	1133	28	40[7]	20	20	2	1.220
Sub-humid Dry(1100-1000mm)								
Amravati	Asra	976	27	120[8]	120	--	30	0.912
Washim	Hisai	926	29	46[9]	46	25	30	0.858
Semi-arid moist(1000-850mm)								
Buldhana	Dhanora	901	27	45[10]	45	25	3	0.718
Semi-arid dry(850-550mm)								
Akola	Paral	687	26	60[11]	40	---	--	0.705

[1] 1 bag of Urea,18:18:10,and 1 trolly FYM /acre
[2] 1 bag SSP and 1 bag urea,1 trolly FYM/acre
[3] 1 bag SSP and 1 bag urea,1 trolly FYM/acre
[4] The site was sloping and is in degraded forest. The upper part of this site was dominated by red soil with thick vegetation of different forest species. This particular site represents black soils and is without any forest species management is nil (Bhattacharyya et al., 2004)
[5] This site was old experimental area for citrus cultivation. This site was abandoned and therefore natural vegetation consist of thick population of native grasses. This may be the reason for high SOC *in the soil.*
[6] High level management ,FYM Monocrotophos 4-5 tonn .Apply 3 bags of SSP ,2 Bg of DAP(1 bag=50kg) and 4 to 5 trolly of FYM/acre(Thakur, 2007)
[7] Conventional farming with cotton and pigeonpea intercropping, Fertlizer and FYM are also applied (Venugopalan et al,2004)
[8] 15--20 cartloads FYM,120 N,120 P_2O_5: Land use in Cotton +Green Gram+Pigeon pea(Bhattacharyya et al,2004)
[9] DAP,25 kg/acre, SSP 50 kg/acre, 18:18:10 mix fertilizer and 5-6 trolly FYM
[10] 18:18:10 and15:15:10 mix fertilizer,2-3 tonnes cowdung
[11] 40-60 N/ha and 30-40 kg P_2O_5/ha with no amendment(Bhattacharyya et al,2004)

Table 4.13. Lability index of SOC and climate and soil management practices

Arranged in order of dominant cropping pattern

District	Soil Series According to Land Use		MAT°C	Fertilizer dose (kg/acre)			FYM,t/ha	LI(0-30)
	0			N	P	K		
	Cotton							
Yavatmal	Pahur	1133	28	40[1]	20	20	2	1.220
Washim	Hisai	926	29	46[2]	46	25	30	0.858
Buldhana	Dhanora	901	27	45[3]	45	25	3	0.718
Akola	Paral	687	26	60[4]	40	---	--	0.705
	Paddy							
Gadchiroli	Kurul	1551	26	103[5]	18	10	4	0.836
Bhandara	Digori	1388	27	69[6]	48	--	6	0.808
Gondia	Rajegaon	1363	28	23[7]	16	--	6	0.957
	Soybean							
Amravati	Asra	976	27	120[8]	120	--	--	0.912
	Horticulture						--	
Nagpur	Linga	1242	25	[9]	--	--	--	1.188
Wardha	Brahmni	1134	28	[10]	48	--	20	0.761
	Forestry							
Chandrapur	Haldi	1312	28	[11]	--	--	--	0.817

[1] Conventional farming with cotton and pigeonpea intercropping, Fertilizer and FYM also apply (Venugopalan et al, 2004)

[2] DAP,25kg/acre, SSP50kg/acre, 18:18:10 mix fertilizer and 5-6 trolly FYM

[3] 1 bag SSP and 1 bag urea,1 trolly FYM/acre

[4] 40-60 N/ha and 30-40 kg P_2O_5/ha with no amendment(Bhattacharyya et al,2004)

[5] 1 bag of Urea,18:18:10,and 1 trolly FYM /acre

[6] 1 bag SSP and 1 bag urea,1 trolly FYM/acre

[7] 1 bag SSP and 1 bag urea,1 trolly FYM/acre

[8] 15--20 cartloads FYM 120 N,120 P_2O_5: Land use Cotton +Green Gram+Pigeonpea (Bhattacharyya et al,2004)

[9] This site was old experimental area for citrus cultivation. This site was abundant and therefore natural vegetation consists of thick population of native grasses. This may be the reason for high SOC in the soil.

[10] High level management ,FYM Monocrotophos 4-5 tonnes. Apply 3 bags of SSP, 2 Bg of DAP (1 bag=50kg) and 4 to 5 trolly of FYM/acre (Thakur, 2007)

[11] The site was sloping in degraded forest. The upper part of this site was dominated by red soil with thick vegetation of different forest species. This particular site represent black soils and is without any forest species .management is nil (Bhattacharyya et al., 2004)

contrary, grass vegetation (Linga soils under horticulture) and legume as an intercrop (Pahur soils under cotton legume) produce very high lability index of SOC (Table 4.13).

As indicated earlier that the Lability index of SOC is calculated by the following formula :

$$\text{Lability Index} = \frac{C_{VL}}{C_{tot}} \times 3 + \frac{C_{L}}{C_{tot}} \times 2 + \frac{C_{LL}}{C_{tot}} \times 1 \quad \ldots\ldots \text{(a)}$$

The formula indicates that ideally for a soil containing one percent of native SOC, if the entire amount is very labile (C_{VL}) then the LI value should be 3.0. On the contrary, for some soils assuming 100% SOC in non-labile from (C_{NL}), should produce LI value of zero. Keeping in view of the theoretical value of LI between 0 to 3.0, the LI values between 0.8 to 1.2 obtained for the soils under study, appear good so far as lability of SOC is concerned. However, a closer scrutiny of equation (a) suggests that different degrees of weightage assigned in three different forms of carbon viz. C_{VL}, C_L and C_{LL}. These weightages of 3, 2 and 1 have been given on the basis of the ease of the oxidation of C_{LL}, C_L and C_{VL}, respectively. Ease of oxidation indirectly controls the ease of availability of respective fractions SOC for plant availability. From this point of view, C_{VL} and C_L are considered as the active pool of SOC. Detailed analysis of the relative share of C_{VL} and C_L (which form the active pool of SOC) indicates that for paddy soils the entire active pool of SOC is constituted by C_L only (Fig. 4.32); for cotton growing soils (Pahur and Paral) 85 to 78 percent SOC is contributed towards active pool of soil organic carbon (Fig. 4.31), while for Hisai and Dhanora soils C_{VL} does not contribute any carbon for active pool of SOC at all. Out of 11 soils studied only four soils contribute 66 to 87 percent of C_{VL} in the active pool of SOC. The relative proportion of C_{LL} and C_{VL} are shown in figure 4.33. The active

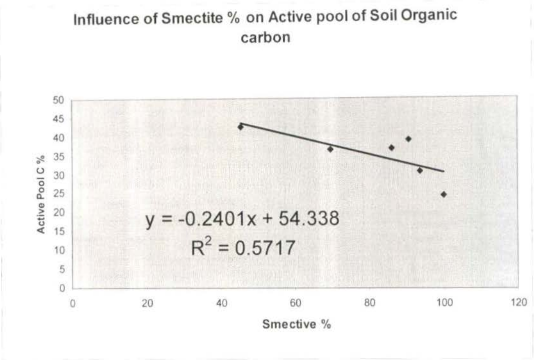


Fig. 4.29. Influence of smectite content on active pool of soil organic carbon.

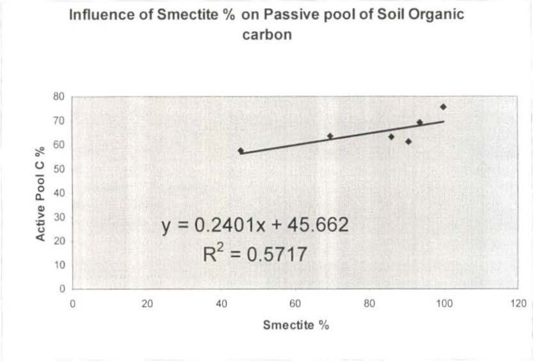


Fig. 4.30. Influence of smectite content on passive pool of soil organic carbon

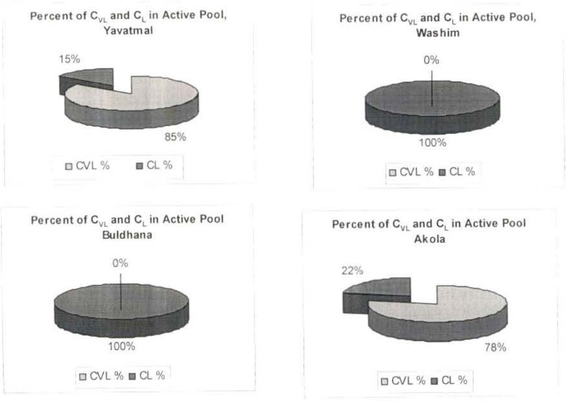


Fig. 4.31. Percentage of C_{VL} and C_L under cotton growing area.

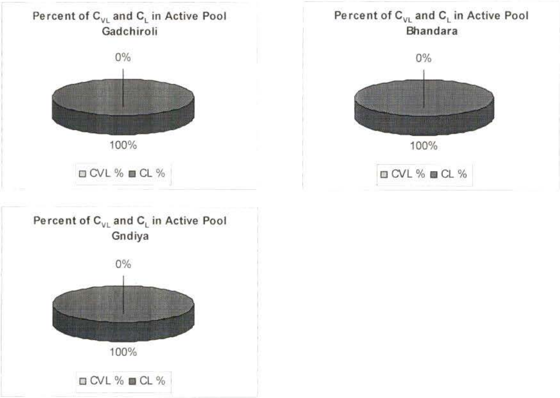


Fig. 4.32. Percentage of C_{VL} and C_L under paddy growing area.

and passive pools of SOC and the four sub-fractions (C_{VL}, C_L, C_{LL} and C_{NL}) have been shown in Table 4.4.

It is interesting to note that more than 80 per cent of passive pool of SOC in non-labile or C_{NL} while Hisai, Paral and Haldi soils are exceptions (Fig. 4.34). It has been reported that addition of FYM might increase the C_{VL} form of SOC. However, no such definite trend was observed from the present study. It is interesting to note that wherever C_{VL} form of SOC value was found, it has always been 66 to 87 percent of active pool. Otherwise the C_{VL} contribution has remained nil. In recent studies (Mandal et al., 2008; Majumder et al., 2008) surface soil sample of IGP representing humid bioclimatic system have been found to contain all the forms of SOC (C_{VL}, C_L, C_{LL}, C_{NL}). Earlier Chan et al. (2001) reported nearly 40 percent, 30 percent, 10 percent and 20 percent of C_{VL}, C_L, C_{LL}, C_{NL} of SOC in soils from pastures from UK. It therefore appears that the soils of cooler climate such as UK (Chan et al., 2000) and humid climate such as soils of IGP always posses all the four sub-fractions of SOC. Such rule may not be applicable for all the soils of Vidarbha which represent relatively dry and very hot climate (summer temperature as high as 45°C for 2-3 months). It has been mentioned earlier that C_{VL} represents most readily oxidazable portion of SOC, which is very fast oxidized to carbon dioxide from the soils of most part of Vidarbha. It seems higher atmospheric temperature oxidizes the very labile portion of SOC (C_{VL}) in not of the Vidarbha soils, although the total SOC may appear relatively higher. Total SOC stocks value may thus not be able to portray the actual availability of the organic carbon for plant growth. The total SOC stock may not therefore be the criterion for soil health and quality.

On the basis of dominant soils representing each of the eleven districts of Vidarbha an effort has been made to generate a few thematic maps on C_{VL}, C_L, C_{LL}, C_{NL}, active pool of SOC and passive pool of SOC (Fig. 4.35 to 4.40).

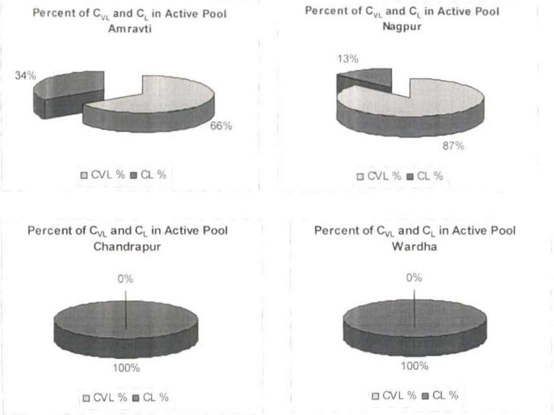


Fig. 4.33. Percentage of C_{VL} and C_L under different land use.

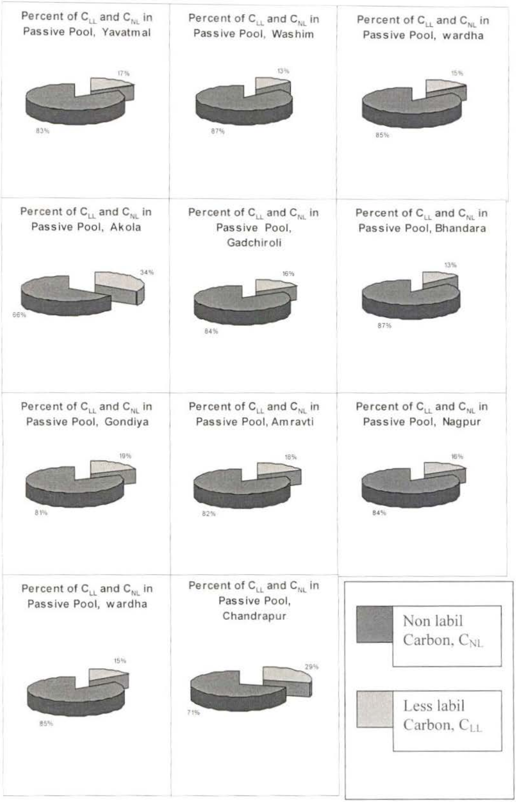


Fig. 4.34. Contribution of less labile carbon (C_{LL}) and low labile carbon (C_{NL}) in the overall passive pool of soil organic carbon under different land use.

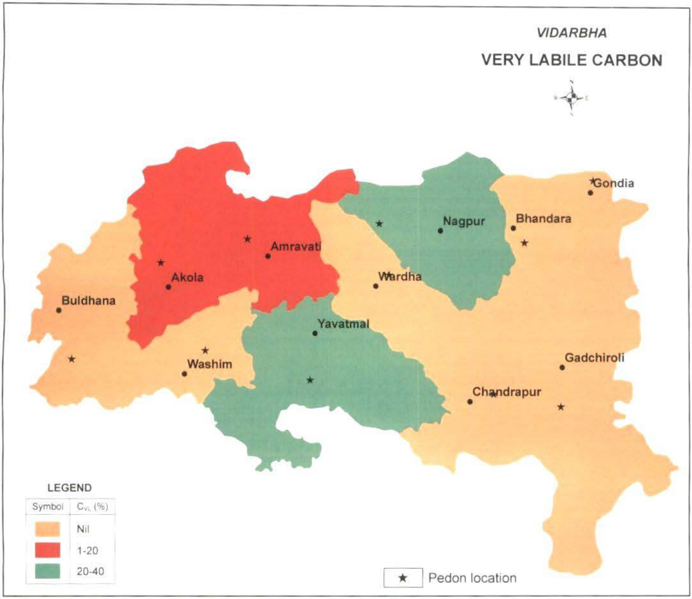


Fig. 4.34. Distribution of very labile form of SOC in soils of vidarbha region

Fig. 4.35 shows the distribution of very labile form of organic carbon, where most of the areas does not show very labile carbon (Fig. 4.35). Figure 4.36 shows the distribution of labile form of SOC in Vidarbha. The central part of Vidarbha shows <20 percent C_L while eastern and western part indicate >20 percent C_L in the north east part of Vidarbha C_L has been found to pretty high (>40 percent). Accept few areas in west and south east of Vidarbha. The distribution of less labile carbon is low (<15 percent) (Fig. 4.37). The distribution of non-labile portion of organic matter shows that south east and western part of Vidarbha contain 50 to 55 percent C_{NL}. Sizeable area in southern and north east part show <15 percent C_{NL}. The north west part and some part in east Vidarbha show very high content of C_{NL} (Fig. 4.38), when active pool of SOC was mapped it was found that western part contain relatively low amount of active pool of SOC which could be due to relatively high temperature and low annual rainfall(Fig. 4.39). The other part of Vidarbha show 30 to 40 percent active pool of SOC (Fig. 4.40). The distribution of passive pool of SOC show pretty high (<70 percent) amount of passive pool in the western part of Vidarbha. Rest of Vidarbha contains 60-70 percent passive pool. The far east of Vidarbha indicate relatively low amount of passive pool.

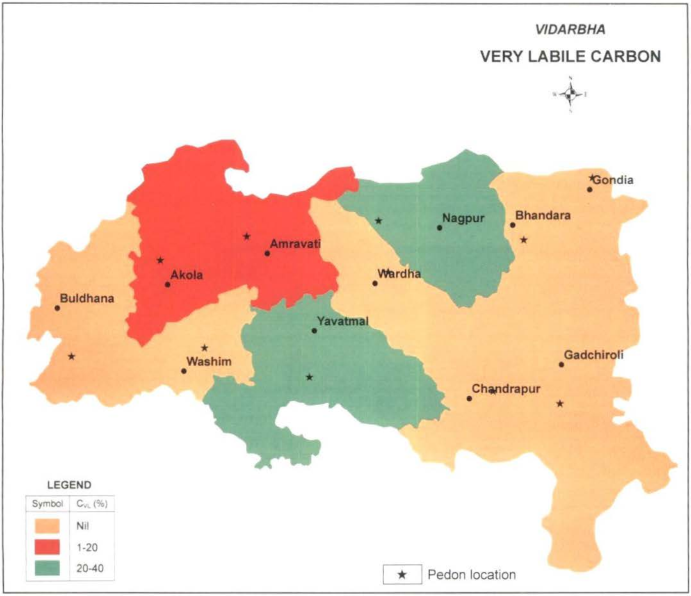


Fig. 4.34. Distribution of very labile form of SOC in soils of vidarbha region

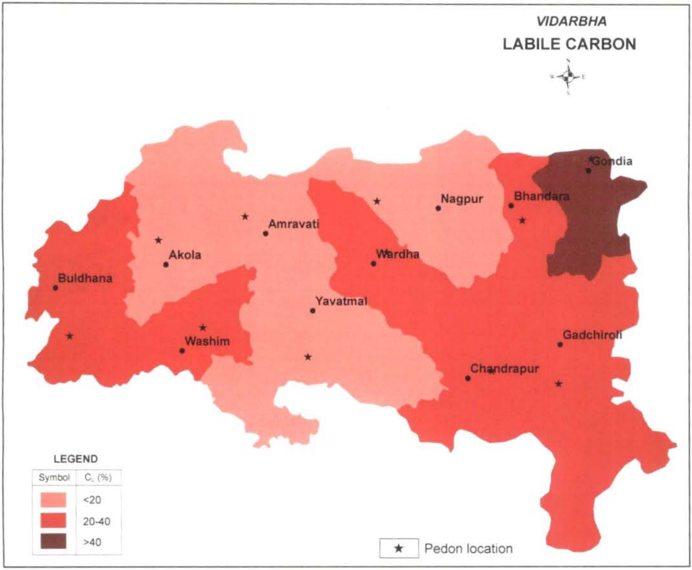


Fig. 4.35. Percentage of labile form of SOC in soils of vidarbha region

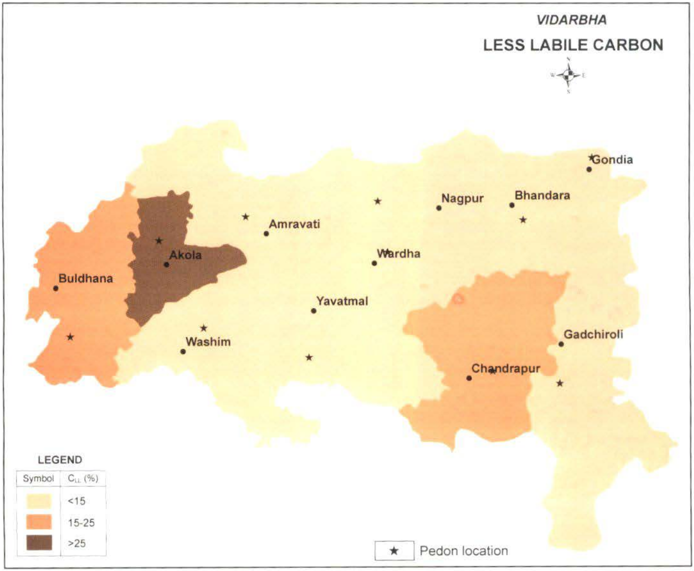


Fig. 4.36. Distribution of less labile form of SOC in soils of vidarbha region

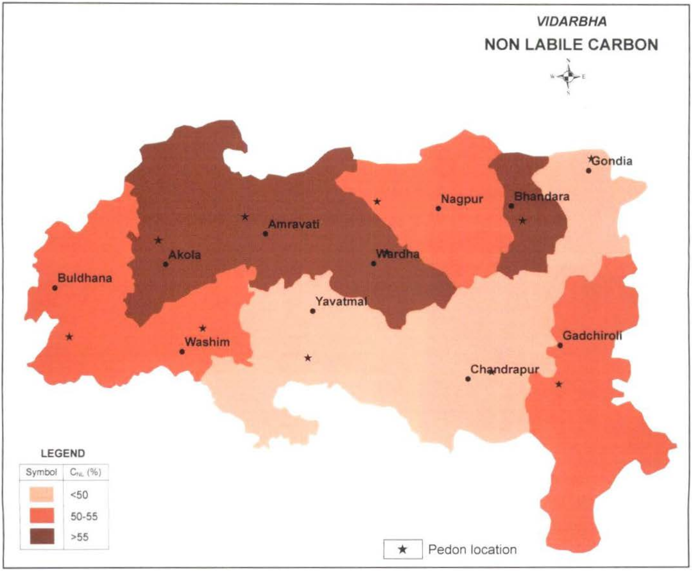


Fig. 4.37. Distribution of non labile form of SOC in soils of vidarbha region

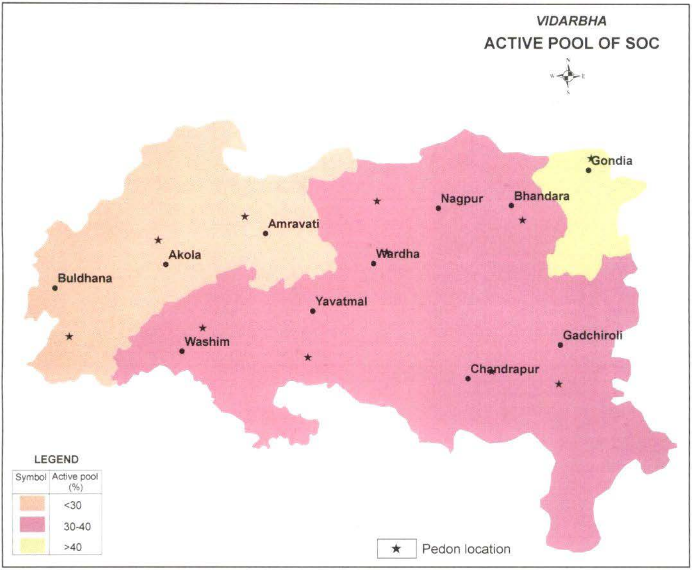


Fig. 4.38. Distribution of Active pool form of SOC in soils of vidarbha region

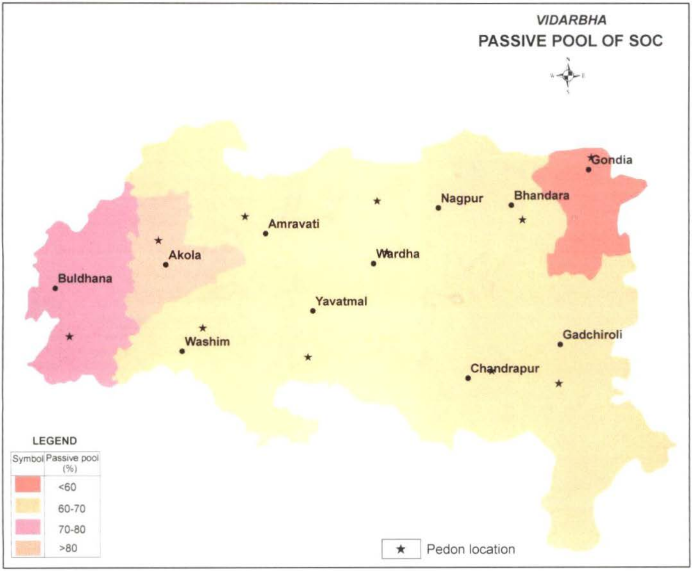


Fig. 4.39. Distribution of Passive pool form of SOC in soils of vidarbha region

Chapter V

SUMMARY AND CONCLUSION

The study on sub-fractionation of oxidizable organic carbon the selected soils of Vidarbha region, Maharashtra were taken up with two objectives, viz. (i) to sub-fractionate oxidizable organic carbon in a few selected soils, and (ii) to find out the effect of land use and different soil parameters on the quality of sub-fractions of total soil organic carbon.

Keeping in view of dominant soils in this region eleven benchmark spots were chosen from the Vidarbha region of Maharashtra. Grouping of soils according to bioclimatic zone shows seven soils (Kurul, Dighori, Rajegaon, Haldi, Linga, Brahmni and Pahur) to fall in the sub-humid moist (SHM) zone, two (Asra and Hisai) in sub-humid dry (SHD) and one each (Dhanora and Paral) in semi-arid moist and semi-arid dry zones, respectively. The distribution of soils according to dominant crops shows four soils (Pahur, Hisai, Dhanora and Paral) under cotton, three soils (Kurul, Dighori and Rajegaon) under paddy and one each (Asra) under soybean. Three other soils are selected from horticulture (Linga, Citrus and Brahmni, Banana).

The summary of the results and the conclusions drawn are enumerated below.

- Out of eleven soils, eight soil series belonging to Vertisols order. The soils from Rajegaon ahd Haldi are grouped under Alfisols with vertic subgroup while three from Masala are Inceptisols with vertic intergrades.

- All the soils strudied in the different system are calcareous in nature except Rajegaon and Haldi soils. Slickensides are common in Paral, Asra, Brahmni, Linga and Pahur soils. It is not observed in Dighori, Rajegaon and Masala soils. The bulk density of all soils ranges from 1.4 to 1.6 except Brahmni which shows a value of 1.73.
- The soils are mildly alkaline to moderately alkaline. However, the soils of Gadchiroli, Bhandara and Buldhana are slightly acidic to neutral. The electrical conductivity varies from 0.1 to 0.2 dS m^{-1} in Masala and Pahur soils it is 0.38 to 0.4 dS m^{-1}.
- The general trend of SOC content decreases with depth with some exceptions. Very labile carbon (C_{VL}) is present only in Pahur, Asra, Paral and Linga soils. It is observed that the soils of Kurul, Dighori, Rajegaon, Haldi and Brahmni which do not contain very labile carbon (CVL) show quite high amount of labile carbon (CL) ranging between 30 to 44 percent of total SOC in the surface layers.
- Very labile carbon (C_{VL}) and labile carbon (C_L) together represents the active pool of soil organic carbon while less labile carbon (C_{LL}) and non-labile carbon (C_{NL}) together comprises passive pool of organic carbon in soil. The active pool of SOC, calculated in 0-50, 50-100 and 100-150 cm soil depth, decreases in Dighori, Rajegaon, Haldi and Pahur soils with concomitant increase in passive pools in those three soil depth intervals. In case of Brahmni, Linga and Kurul soils the distribution pattern is erratic, as is evident from active : passive pool carbon ratio values also.
- The percentage of active pool under horticulture ranges from 12 to 44 percent of total soil organic carbon. Active pool of carbon gradually decreases with decrease in rainfall in those soils which are used for cotton. This leads to corresponding increase in level of passive pool. Similar observations were not, however, made when data were compared for the soils used for paddy.

- Linga and Pahur soils registered very high lability index (LI) as compared to other soils in some bioclimatic region. On an average LI values increased with increase in soil depth in Asra, Hisai and Dhanora.
- LI values were found to be high in cotton (Pahur), paddy (Rajegaon), soybean (Asra) and citrus (Linga). The other soils under cotton (Dhanora and Paral), paddy (Dighori) and banana (Brahmni) show relatively less lability index (LI) in first 50 cm soil depth.
- The study on relation between a few selected parameters on physical, chemical and mineralogical properties of soils with active and passive pool of SOC shows the negative correlation with BD, COLE, CEC and SIC with active pool and a positive correlation with passive pool of SOC.
- On the basis of dominant soils representing each of the eleven districts of Vidarbha an effort has been made to generate a few thematic maps on very labile carbon (C_{VL}), labile carbon (C_L), less labile carbon (C_{LL}) and non-labile carbon (C_{NL}), active pool of SOC and passive pool of SOC.

It is reported that C_{VL} represents the most readily oxidizable portion of SOC, which is very fast oxidized to CO_2 from the soils of most part of Vidarbha. It seems that high atmospheric temperature oxidizes C_{VL} in most of the Vidarbha soils. It happens inspite of relatively high values of SOC. Total SOC stock value may not thus be able to portray the actual availability of the organic carbon for plant growth. And thus the total SOC stock may not be the criterion for soil health and quality. On the contrary the ratio of active and passive pool of SOC could be a better tool to judge the soil quality.

Conclusions

It is observed that very labile fraction of carbon (C_{VL}) is not found in seven selected soils district of the Vidarbha region. It might be because of high atmospheric temperature and relatively less rainfall in the study area.

Active pool of SOC decreases with decrease in rainfall in those soils which are used for cotton cultivation. This leads to corresponding increase in level of passive pool; this shows the importance of rainfall to conserve the active pool of total SOC.

The paddy soils representating sub-humid moist bioclimateshows uniform distribution of active pools, passive pools, and Lability Index of Carbon.

There is a negative correlation of BD, COLE, CEC, and SIC with active pool and positive correlation with passive pool of SOC.

Chapter VI

IMPLICATIONS

The present study indicates that the sub-fractions of soil organic carbon(SOC), especially very labile pool of carbon (C_{VL}) should be given more importance rather than the total SOC content. Nearly 70 percent of the soil studied show absence of C_{VL}. In case C_{VL} is absent in soil, the labile pool of carbon (C_L) may be considered as the other important sub-fractions of SOC.

The study was conducted using only a few selected soils. Judging by the vast areas of Vidarbha, this study reflects information on sub-fractions of SOC which is only indicative in nature.

In future a project may be initiated to find out the relative proportion of labile pool of carbon in soils. Such project will require more number soils and more time to perform field as well as laboratory work. The present study will serve as a base for such future research work on soil carbon .

CHAPTER VII

LITERATURE CITED

Ajtay, G.L., P. Ketnr, P. Duvigneaud, 1979. Terrestrial primary production and photomass. In : Bolin, B., Degnes, E.T., Kempe, S., Ketner, P. (Eds.). The Global carbon cycle. John Wiley, Chichester, pp.129-181.

Allison, L.E. 1935. Organic soil carbon by reduction of chromic acid. Soil Science, 40, 311.

Barrios, E., R.J., Busch, J.I. Sprent, 1996. Organic matter in the soil particle size and endsity fraction from maize and legume cropping system. Soil Biology and Biochemistry 28, 185-193.

Batjes, N.H. 1996. Total carbon and nitrogen in the soil of world. European Journal of Soil Science, 47, 151-163.

Bhattacharjee, J.C., K.P.C. Rana, A.R. Kalbande, C.S. Shivaprasad, G.S. Vaidya and M.Y. Gajbe, 1976. Report on detailed soil survey of the operational research project, Wardha Tehsil, district Wardha, Maharashtra, National Bureau of Soil Survey and Land Use Planning (ICAR), New Delhi, Report No. 377.

Bhattacharyya, T., D.K. Pal and S.B. Deshpande, 1997. On kaolinite and mixed mineralogy classes of shrink-swell soils. Australian Journal of Soil Research 35, 1245-1252.

Bhattacharyya, T., D.K. Pal, M. Easter, N.H. Batjes, E. Milne, K.S. Gajbhiye, P. Chandran, S.K. Ray, C. Mandal, K. Paustian, S. Williams, K. Killian, K. Coleman, P. Falloon, D. Powlson, 2007e. Modelled soil organic carbon stocks and changes in the Indo-Gangetic Plains, India from 1980 to 2030; Agriculture, Ecosystem and Environment, 122, 84-94.

Bhattacharyya, T., D.K. Pal, M. Easter, S. Williams, K. Paustian, E. Milne, P. Chandran, S.K. Ray, C. Mandal, K. Coleman, P. Falloon, D. Powlson, K.S. Gajbhiye, 2007d. Evaluating the Century C model using long-term fertilizer trials in the Indo-Gangetic Plains, India; Agriculture, Ecosystem and Environment, 122, 73-83.

Bhattacharyya, T., D.K. Pal, M. Velayutham, P. Chandran, C. Mandal, 2000. Total carbon stock in Indian soils : priorities and management. In : Special publication of the international seminar on Land Resource Management for Food, Employment and Environment Security (ICLRM), Soil Conservation Society of India, New Delhi, pp.1-46.

Bhattacharyya, T., D.K. Pal, M. Velayutham, P. Chandran, P. and C. Mandal, 2001. Soil organic and inorganic carbon stocks in the management of Black Cotton Soils of Maharashtra, Clay Research, 20, 11-20.

Bhattacharyya, T., P. Chandran, S.K. Ray, (Mrs) C. Mandal, D.K. Pal, M.V. Venugopalan, S.L. Durge, P. Srivastava, P.N. Dubey, G.K. Kamble and R.P. Sharma, 2004. Physical and chemical properties of red and black soils of selected Benchmark spots on semi-arid tropics, India, working report of "Identifying System for Carbon Sequestration and Increased Productivity in Semi-Arid Tropical Environment (RNPS-25), NATP, ICAR, pp.246.

Bhattacharyya, T., P. Chandran, S.K. Ray, D.K. Pal, M.V. Venugopalan, C. Mandal, S.P. Wani, M.C. Manna and V. Ramesh, 2007a. Carbon sequestration in red and black soils I. Influence of morphological properties Agropedology 17, 1-15.

Bhattacharyya, T., P. Chandran, S.K. Ray, D.K. Pal, M.V. Venugopalan, C. Mandal, S.P. Wani, M.C. Manna and V. Ramesh, 2007b. Carbon sequestration in red and black soils II. Influence of physical and chemical properties Agropedology 17, 16-25.

Bhattacharyya, T., P. Chandran, S.K. Ray, D.K. Pal, M.V. Venugopalan, C. Mandal, S.P. Wani, M.C. Manna and V. Ramesh, 2007c. Carbon sequestration in red and black soils III. Identifying system through carbon stock and bulk density of soil. Agropedology 17, 26-34.

Bhattacharjee,J.C., C. Roychoudhary,, R.J. Landy, and S. Pandey, 1982. Bioclimatic Analysis of India. NBSSLUP Bull. 7, Nagpur, India,21p+map

Black, C.A. 1965. Methods of Soil analysis, part 1 and 2. Agronomy Series No. 9, Am. Soc. Agron. Inc. Pub. Madison, Wisconsin, USA.

Blair, G.J., R.D.B. Lefroy, and L. Lisle, 1995. Soil carbon fractions based on their degree of oxidation and the development of a carbon management index for agricultural systems. Australian Journal of Agricultural Research, 46, 1459-1466.

Bruce, J.P., M. Frome, E. Haites, H. Jozen, R. Lal, K. Paustian, 1999. Carbon sequestration in soils. Journal of Soil and Water Conservation 54, 382-389.

Cambardella, C.A. and E.T. Elliott, 1992. Particulate soil organic matter changes across grassland cultivation sequence. Soil Science Society of America Journal, 56, 777-783.

Carolon, R. 1948. Modification of Graham's method for determining soil organic matter by colorimetric analysis. Soil Science, 66, 241-247.

Challa, O., K.S. Gajbhiye and M. Velayutham, 1999. Soil Series of Maharashtra, NBSS Publ. 79.

Chan, K.Y. 1997. Consequences of changes in particulate organic carbon in Vertisol undr pasture and cropping. Soil Science Society of America Journal, 61, 1376-1382.

Chan, K.Y., A. Bowman, and A. Oates, 2001. Oxidizable organic carbon fractions and soil quality changes in an Oxic Paleustult under different pasture leys. Soil Science, 166, 61-67.

Chhabra, A., S. Patria, V.K. Dadhawal, 2003. Soil organic carbon pool in Indian forests. Forest Ecology and Management, 173, 187-199.

Collins, H.P., E.T. Elliott, K. Paustian, L.G. Bundy, W.A. Dick, D.R. Huggins, A.J.M., Smecker, E.A. Paul, 2000. Soil organic pools and fluxes in long term corn belt agroecosystem. Soil Biology and Biochemistry 32, 157-168.

Coughlam, K.J., Mc Garry, G.D. Smith, 1986. The physical and mechanical characteristics of Vertisols. In : First regional seminar on management of Vertisols and semi-arid conditions, IBSRAM Proc. No. 6, Nairobi, Kenya 89-106.

Dadhwal, V.K., S.R. Nayak, 1993. A preliminary estimate of biogeochemical cycle of carbon for India. Soil Culture, 59, 9-13.

Dakora, F.D., D.A. Philips, 2002. Root exudates as mediators of mineral acquisition in low nutrient environment Plant and Soil 248, 35-47.

Datta, N.P., M.S. Khera, and T.R. Saini, 1962. A rapid colorimetric procedure for the determination of the organic carbon I soils. Journal of the Indian Society of Soil Science, 10, 67-74.

Degtjarett, W.T. 1930. Method for determining soil organic matter. Soil Science, 29, 239.

Dinakaran, J. and N.S.R. Krishnayya, 2008. Variation in type of vegetal cover and heteroreneity of soil organic carbon in affecting sink capacity of tropical soil, Current Science, 94-9 pp.1144-1150.

Duraisami, V.P., Rani Perumal, 2001. Changes in organic carbon, available Nitrogen and inorganic N fractions under integrated nitrogen management of sorghum in a mixed black soil. Journal of Indian Society of Soil Science, 49, 435-439.

Duxbury, J.M., S.V. Nkambule, 1994. Assessment and significance of biological active soil organic nitrogen. In : Doran, J.W., Coleman, D.C., Bezdick, D.F. Stewart, B.A. (eds.) Dening Soil Quality for sustainable Environment SSA Special Publ. No. 35, SSSA Madison, WI pp.125-146.

Eillert, B.H., E.G. Gregorien, 1945 Management-induced changes in the actively cycling changes of soil organic matter. In ; Mcfee, W.W. Kelley J.(eds.) Carbon form and functions in forest soils. SSSA Madison, WI, pp.119-138.

Eswaran, H., E. van den Berg, P. Reich, 1993. Organic crbon in soil of the world. Soil Science Society of America Journal, 57, 192-194.

Gardner, E.A., R.I. Shaw, G.D. Smith and K.J. Coughlan, 1984. Plant available water capacity – concept, measurement, prediction. In J.W. McGarity, E.H. Hoult and H.B. Co (eds.). Properties and Utilization of cracking clay soils. Univ. of New England, Armidale, 164-175.

Gaudinski, J.B., S.E. Trumbose, E.Davidson, S. Zheng, 2000. Soil carbon cycling in a temperate forest : radiocarbon estimaties of residence times, sequestration rates and portioning of fluxes,. Bioecochemistry 51, 33-69.

Graham, E.R. 1948. Determination of soil organic matter means of photo-electrimeter. Soil Science 65, 181-183.

Gupta, R.K., D.L.N. Rao, 1994. Potential of wastelands for sequestering carbon by reforestation. Current Science, 66, 378-380.

Hesse, P.R., 1971. A textbook of soil chemical analysis. William Clowes and Sans Limited, London, p.520.

Jacinthe, P.A., R. Lal, M.J. Kimble, 2001. Organic carbon storage and dynamics in cropland and terrestrial; deposits as influenced by sub-surface tile drainage. Soil Science 166, 322-335.

Jackson, M.L., 1956. Soil Chemical Analysis – Advanced course (second Printing, 1965), Published by author, Dept. of Soil Sci., University of Wisconsin, Madison, Wisconsin.

Jackson, M.L., 1958. Soil Chemical Analysis. Prentice Hall, Englewood Cliffs, NJ, USA.

Jackson, M.L., 1973. Soil Chemical Analysis, Prentice Hall, New Delhi, India.

Jackson, M.L., 1979. Soil Chemical Analysis, Advanced Course, published by the author, Unviersity of Wisconsin, Madison, USA.

Jenny, H., 1941. Factors of soil formation. McGraw Hill Book, Co., New York.

Jenny, H., S.P. Raychaudhuri, 1960. Effect of climate and cultivation on Nitrogen and Organic Matter Reserves in Indian soils. ICAR, New Delhi, India, 126pp.

Jones, D.L., 1998. Organic acids in the rhzospher – a critical review. Plant and Soil 205, 25-44.

Lal, R., 2004b. Soil carbon sequestration impact on global climate change and food security. Science 304, 1623-1627.

Lal, R., J.M. Kimble, R.F. Fallett, B.A. Stewart (eds.), 1998a. Management of carbon sequestration in soil. CRC Press, Boca Raton, NY, pp.457.

Leggett, H., Zakiya Kelting, L. Daniel, 2006. Fertilization effects on carbon pools in Loblolly Pine Plantations on two upland sites. Soil Science Society of America Journal 70, 279-286.

Majumdar Bidisha, Biswapati Mandal, P.K. Bandyop-adhyay, J. Choudhary, 2006a. Soil organic carbon pools and productivity relationship for 34 years old rice. Wheat-Jute agroecosystem, Biogeochemistry.

Majumdar, Bidisha, Biswapati Mandal, P.K. Bandyopadhyay, A. Gangopadhyay, P.K. Mani, A.L. Kadu, 2006b. Carbon pool and crop productivity in a 19 years old rice-wheat agrecosystem. Soil Biology and Biochemistry.

Majumdar, Bidisha, Biswapati Mandal, P.K. Bandyopadhyay, A. Gangopadhyay, P.K. Mani, A.L. Kundu, D. Majumdar, 2008. Organic amendments influence soil organic carbon pools and crop productivity in nineteen year old rice-wheat agroecosystem. Soil Science Society of Am. J. 72, 1-11.

Mandal, Biswapati, Bidisha Majumdar, T.K. Adhya, P.K. Bandopadhyay, A. Gangopadhyaym, Dibyendu Sarkar, M.C. Kundu, Shreyasi Gupta, Choudhury, G.C. Harra, S. Kudus, R.N. Samantray and A.K. Mishra, 2008. Potential of double cropped rice ecology of conserve organic carbon under sub-tropical climate. Global Change Biology 14, 1-13.

Manna, M.C., A. Swarup, R.H. Wanjari, Y.V. Singh, P.K. Ghosh, K.N. Singh, A.K.Tripathi, and M.N. Saha, 2005. Soil organic matter in a West Bengal Inceptisol after 30 years of multiple cropping and fertilization. Soil Science Society of Am. J. 70, 121-129.

Markert, S., 1962. Albrecht-thaer Arch., **6**:523.

Mehara, O.P., M.L. Jackson, 1960. Iron oxide removal from soil and clay by a dithionite citrate system buffered with sodium bicarbonate. In : Clays and Clay Minerals. Proc. 7^{th} Conf. Natl. Acad. Sci. Natl. Res. Council Publ. pp.317-327.

Metson, A.J., 1961. Methods of Chemical Analysis for soil survey samples, Soil Bureau Bulletin 12, Dpt. Scientific & Industrial Research, New Zealand.

Murthy, R.S., L.R. Hirekerur, S.B. Deshpande, B.V. Venkata Rao, 1981. Benchmark soils of India. National Bureau of Soil Survey and Land Use Planning, pp.242-56.

Naitam, R., T. Bhattacharyya, 2004. Quasi-equilibrium of organic carbon in shrink-swell soils of the sub-humid tropics in India under forest, horticulture and agriculture system. Australian Journal of Soil Research 42, 181-188.

Nelson, D.W. L.E. Sommers, 1982. Total carbon, oranic carbon and organic matter. In Methods of Soil Analysis, Part 2, 2^{nd} Ed. Chemical and Microbiological properties. A.L. Page (ed.) ASA, Madison,WI, pp.539-579.

Pal, D.K., G.S. Dasog, S. Vadivelu, R.L. Ahuja, T. Bhattacharyya, 2000. Secondary calcium carbonate in soils of arid and semi-arid regions of India. In : Global Climate Change and Pedogenic Caronates (Eds. Lal, R., et al.), Lewis Publishers, Florida, USA, pp.149-195.

Pal, D.K., T. Bhattacharyya, S.K. Ray, P. Chandran, P. Srivastava, S.L. Durge, S.R. Bhuse, 2006. Significance of soil modifiers (Ca-zolites and gypsum) in naturally degraded Vertisols of the Peninsular India in redefining the sodic soils. Geoderma, 136, 210-228.

Peech, M., L.A. Dean, J. Reed, 1947. Methods of soil analysis for soil fertility investigations. U.S. Dep. Agric. Cic. 757.

Piper, C.S., 1950. Soil and Plant Analysis (Reprint of Original, 1942 edn. Published by Interscience Published Inc., NY). The University of Adelaide, Australia, 368pp.

Purvis, E.R., G.E. Higson, 1939. Ind. Eng. Chem. A.E. 11:19.

Quinn, J.G., M. Salomon, 1964. Chloride interference in the dichromate oxidation of soil hydrolysates, Soil Science, 87, 22.

Richard, L.A. (eds.), 1954. Diagnosis and improvement of saline and alkali soils, USDA Agric. Handbook 60, U.S. Govt. Printing Office, Washington, D.C. 160pp.

Schafer, W.M., M.J. Singer, 1976. A new method for measuring shrink-swell potential using soil paste. Soil Science Society of America Journal 40, 805-806.

Schallenberger, C.J., 1945. Determination of soil organic matter. Soil Science, 59, 53-56.

Schelesinger, W.H., 1983. The world carbon pool in soil organic carbon dioxide. In : Woodwell, G.M. (Ed.). The Role of Terrestrial vegetation in the global carbon cycle : Measurement by Remote Sensing. SCOPE Wiley, New York, pp.111-127

Schollenberger, 1931. Determination of organic matter. Soil Science, 31,483-496.

Schollenbergr, C.J., 1927. A rapid approximate method for determining soil organic matter. Soil Science, 24, 65-68.

Sherrod, L.A., G.A. Peterson, D.G. Wotfall and L.P. Aheya, 2005. Soil organic carbon pools after 12 years in no-till dryland agroecosystem. Soil Science Society of American Journal 67, 1533-1543.

Shirsath, S.K., T. Bhattacharyya, D.K. Pal, 2000. Minimum threshold value of smectite for vertic properties Australian Journal of Soil Research 38, 189-201.

Six, J., E.T. Elliott, K. Paustian, 2000. Soil microaggregate turnover a microaggregate formation : a mechanism for C sequestration under no tillage agriculture. Soil Biology and Biochemistry 32, 2099-2103.

Smith, G.D., 1986. The Guy Smith Interviews : Can Soil Scientist make useful contribution ? Soil Use and Management 15, 71-75.

Smith, H.W., M.D. Weldon, 1941. A comparison of some methods for the determination of soil organic matter. Soil Science Society of America Proceeding, 5, 177-182.

Sohan Lal, S.B. Deshpande, J. Sehgal (Eds.), 1994. Soil Series of India, Soil Bulletin 40, National Bureau of Soil Survey and Land Use Planning, Nagpur, India, pp.279-333.

Soil survey Division Staff, 1995. Soil Survey Manual. USDA Handbook 18, U.S. Government Printing Office, Washington, DC.

Soil Survey Staff, 1999. Soil Taxonomy : A basic system of soil classification for making and interpreting soil surveys, 2nd edn. Agriculture and Handbook No. 436, SCS-USDA US Govt. Printing Office, Washington, D.C.

Soil Survey Staff, 2003. Keys to Soil Taxonomy. 9th Edition. United States Department of Agriculture, Natural Resources Conservation Services, Washington, D.C.

Sombroek, W.G., F.O. Nachtergach, A. Habel, 1993. Amounts, dynamics and sequestration of carbon in tropical and subtropical soils. Ambio 22, 417-427.

Srivastava, P., T. Bhattacharyya, D.K. Pal, 2002. Significance of the formation of calcium carbonate minerals in the pedogenesis and management of cracking clay soil (Vertisols) of India. Clays and Clay Minerals 50, 111-126.

Tahkur, P., 2006 (Unpubl.) Relation between carbon content, exchangeable cation and shrink-swell behaviour of selected black soils, Dr. PDKV, Akola.

Tinsley, J., 1950. The determination of organic carbon in soils by dichromate mixtures. Trans. 4th International Congress of Soil Science, 7, 161-164.

Tiurin, I.V., 1931. A new modification of the volumetric method of determining soil organic matter by means of chromic acid. Pedology 26, 36-47.

Tolanur, S.I., V.P. Badanur, 2003. Changes in organic carbon available N, P and K under integrated use of organic manure, Green manure and fertilizer on sustaining productivity of pearlmillet-pigeonpea system and fertility of an Inceptisol. Journal of the Indian Society of Soil Science 51(1), 37-41.

Venugopalan, M.V., P. Chandran, D.K. Pal, O. Challa and S.L. Durge, 2004. Effect of organic and conventional cotton production systems on soil properties : A case study in Yavatmal district, Maharashtra. International symposium on "strategies for sustainable cotton production – A global vision 2". Crop Production 23-25.

Walkley, A., 1935. An examination of methods for determination of organic carbon and nitrogen in soil. Journal of Agricultural Sciences, 25, 598.

Walkley, A., 1947. A critical examination of rapid method of determining organic carbon in soils. Soil Science, 63, 251-26.

Walkley, A., I.A. Black, 1934. An examination of the Degterett method for determining soil organic matter and proposal modification of the chromic acid titration method. Soil Science, 37, 29-38.

Weil, R.R., K.R. Islam, M.A. Stine, J.B. Grewer, S.F. Somson Irebig, 2003. Estimating active carbon for soil quality assessment : a simplified method for laboratory and field use. American Journal of Alternate Agriculture, 18, 3-17.

Woomer, P.L., A. Martin, A. Albercht, D.V.S. Resck, H.W. Scharpenseel, 1994. The importance and management of soil organic matter in the tropics. In Woomer, P.L., Swift, M.J. (eds.), The Biological Management of Tropical Soil Fertility. John Wiley & Sons, Chichester, U.K., pp.47-80.

Zou, X.M., H.H. Ruan, Y.Fu, X.O. Yang, L.Q. Shah, 2005. Estimating soil labile organic carbon and potential turnover rates using a sequentian fersgation-incubation procedure. SoilBiology and Biochemistry 37, 1023-1928.

VITA

1. Name of student : Shrikant P. Chivhane
2. Date of Birth : 07.06.1985
3. Name of the College : Post graduate institute, Dr. P.D.K.V., Akola.
4. Residential address along with Phone no : Gurudev Ward, Ghati,A/p ; Ghatanji, Tq; Ghatanji Dist.:Yavatmal, M.S.
   : Mobile no. 9421774131

5. Academic qualifications

Sr.No.	Name of Degrees awarded	Year in which obtained	Division / Class	Name of awarding university	Subjects
1	SSC	2000	II	Amravti University	English, Hindi, Marathi, Maths, General Science, Social Science
2	HSSC	2002	II	Amravti University	Physics, Chemistry, Biology, Mathematics, English
3	B. Sc. (Agri.)	2006	II	Dr.PDKV, University	Agriculture.

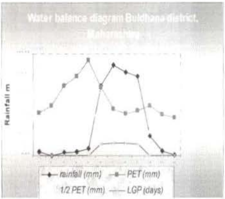
6. Research papers published : Nil
7. Field of interest (in which you desire to work) : Research and development

Place : Akola

Date : 1/7/2008

Signature of Student

BM SPOT – 1 : DHANORA (MASALA)
AGRICULTURE` (Cotton + Sorghum)



Classification	:	Fine, smectitic, hyperthermic Vertic Haplusterts
Location	:	500 m South from Dhanora village, Nandura, Buldhana, M.S. Lat. 20°53'15.2"N Long. 76°17'25.8"E
Physiographic position	:	Lower Maharashtra, Deccan Plateau
Topography and slope	:	Very gently sloping; 1-3% (50-150 m)
Vegetation	:	Ber, Acacia, Neem
Land Use	:	Cotton, Sorghum, Jowar, Makka, Soybean, Tur
Parent material	:	Alluvium
Sampled by	:	T. Bhattacharyya, S.K. Ray, S.L. Durge and Shrikant Chivhane
Date of collection	:	13/03/08

Ap	0-9 cm	Very dark brown colour (7.5YR 2.5/2M) clay; medium to moderate sub-angular blocky structure; slightly hard, friable to very friable, slightly plastic, consistence; very fine to fine roots and nodules are common; clear and smooth boundary.
Bw	9-28 cm	Very dark brown colour (7.5YR 2,5/2M) clay; massive structure; friable, sticky, plastic, consistence, very fine to fine roots are common, very fine nodules of calcium are common, slightly effervescence, gradual and smooth boundary.
Bw1	28-45 cm	Dark brown (7.5YR 3/2M) clay; medium moderate sub-angular structure; friable, very sticky, very plastic consistence; very fine to fine roots are common; fine, many pores, strong effervescence, clear irregular boundary.
BCk	45-61 cm	Brown (7.5YR 5/2) clay; medium weak subangular blocky structure; very friable, sticky, slightly plastic, consistence, very fine roots are few, fine nodules of calcium are many, very strong effervescence, gradual irregular boundary.
Crk	61-91 cm	Partially weathered basalt with lime.

Morphological properties of soils

Horizon	Depth (cm)	Boundary[1]		Matrix colour (M)[2]	Texture[3]	Coarse fragments (%)	Structure[4]		
		D	T				S	G	Ty
Ap	0-9	c	s	7.5YR 2.5/2	C	2	m	2	sbk
Bw	9-28	g	s	7.5YR 2.5/2	C	2	m	--	--
Bw1	28-45	c	i	7.5YR 3/2	C	5	m	2	sbk
BCk	45-61	g	i	7.5YR 5/2	C	20	m	1	gr

Depth (cm)	Consistence[5]			Roots[7]		Effervescence	Other features	Cracks
	D	M	W	S	Q			
0-9	sh	vfr	sp	vf	c	e		
9-28	--	fr	sp	vf	c	e		2-5 cm
28-45	--	fr	vs	vf	c	es		
45-61	--	vfr	ps	vf	f	ev		

Physical properties of soils

Horizon	Depth (cm)	Particle size distribution		
		Sand (%)	Silt (%)	Total Clay (%)
Ap	0-9	0.5	45.5	58.8

Depth (cm)	Bulk density Mg dm^{-3}	Water Retention		COLE	AWC (%)
		33 kPa (%)	1500 kPa (%)		
0-9	1.6	18.72	16.33	0.22	26.12

Chemical properties of soils

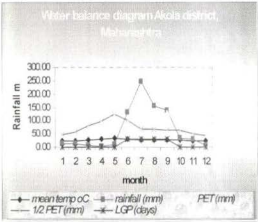
Horizon	Depth (cm)	pH (1:2.5) water	EC (dS m^{-1})	SOC (%)	$CaCO_3$ (%)	SIC
Ap	0-9	7.03	0.38	0.50	3.0	0.36
Bw	9-28	7.83	0.20	0.38	0.6	0.072
Bw1	28-45	7.81	0.23	0.33	5.1	0.61
BCk	45-61	8.02	0.21	0.11	22.8	2.73
CrK	61-91	8.06	0.18	0.05	12.3	1.47

Landscape of Masala soil series

Profile showing different features of Masala soil series

Wide cracks in Masala soils

BM Spot 2 : PARAL – Agriculture (LM) (Cotton+Pigeonpea/Sorghum)



Classification	:	Very fine, smectitic, hyperthermic, Sodic Haplusterts
Location	:	Vill. Parala (Paral), Akot, Akola, M.S. Lat. 20°57'04"N, Long. 76°57'05"E
Physiographic position	:	Lower Maharashtra Deccan Plateau
Topography and slope	:	Nearly level to very gently sloping, 0-1% (50-150 m)
Vegetation	:	Acacia, neem, ber, karanj
Land Use	:	Cotton+Pigeonpea, Sorghum
Parent material	:	Basaltic Alluvium
Sampled by	:	D.K. Pal, P. Chandran, S.K. Ray, M.V. Venugopalan, S.L. Durge, S.R. Bhuse
Date of collection	:	19-01-2001

Ap	0-9 cm	Dark brown (7.5YR 3/2M) clay; moderate medium subangular blocky structure; friable, sticky and plastic; common very fine and fine, few medium and coarse roots; common very fine and fine lime nodules; many very fine and fine pores; moderately alkaline (pH 8.0); strongly effervescent;clear smooth boundary.
Bw1	9-35 cm	Very dark brown (7.5YR 2.5/2M) clay; moderate medium subangular blocky structure in pressure faces on ped surfaces; friable, sticky and plastic; common very fine and fine, few medium roots; common very fine and fine lime nodules; moderately alkaline (pH 8.2); strongly effervescent; gradual smooth boundary.
Bss1	35-69 cm	Very dark brown (7.5YR 2.5/2M) clay; strong medium angular blocky structure with weakly developed wedge shaped aggregates and slickensides that breaks into small angular peds; slightly firm, sticky and plastic; common very fine and fine, few medium roots; common very fine and fine lime nodules; moderately alkaline (pH 8.4); strongly effervescent; gradual

		smooth boundary.
Bss2	69-105 cm	Very dark brown (7.5YR 2.5/2M) clay; strong coarse angular blocky and columnar structure with well developed wedge shaped aggregates and slickensides that breaks into small angular peds; firm, very sticky and very plastic; common very fine and fine roots; common very fine and fine lime nodules; moderately alkaline (pH 8.4); strongly effervescent; gradual wavy boundary.
Bss3	105-132 cm	Very dark brown (7.5YR 2.5/2M) clay; strong, coarse angular blocky and columnar structure with well developed wedge shaped aggregates and slickensides that breaks into small angular peds; firm, very sticky and very plastic; common very fine and fine roots; common very fine and fine lime nodules; strongly alkaline (pH 8.5); strongly effervescent; gradual wavy boundary.
Bss4	132-150+ cm	Very dark brown (7.5YR 2.5/2M) clay; strong, coarse angular blocky and columnar structure with well developed wedge shaped aggregates and slickensides that breaks into small angular peds; firm, sticky and plastic; few very fine and fine roots; many very fine and fine lime nodules; strongly alkaline (pH 8.5); strongly effervescent.

Morphological Properties of Soil

Horizon	Depth (cm)	Boundary		Matrix Colour		Texture	Coarse Fragments (%) (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap	0-9	c	s	-	7.5YR3/2	c	5-8	m	2	sbk
Bw1	9-35	g	s	-	7.5YR2.5/2	c	5-8	m	3	sbk
Bss1	35-69	g	s	-	7.5YR2.5/2	c	5-8	m	3	abk
Bss2	69-105	g	w	-	7.5YR2.5/2	c	5-8	c	3	abk
Bss3	105-132	g	w	-	7.5YR2.5/2	c	5-8	c	3	abk
Bss4	132-150	-	-	-	7.5YR2.5/2	c	8-10	c	3	abk

Depth (cm)	Consistence			Porosity		Nodules(conca		Roots		Effervescence	Other Features	Cracks
	Dry	Moist	Wet	S	Q	Size	Quanti	Size	Quantity	dil HCl		
0-9	-	fr	sp	v f,f	m	vf,f	c	vf,f; m, c	c; f	es	-	6 cm
9-35	-	fr	sp	-	-	vf,f	c	vf,f; m	c; f	es	Pressure faces	4 cm
35-69	-	fi	svp	-	-	vf,f	c	vf,f; m	c; f	es	Slickensides (Weak)	
69-105	-	fi	vsvp	-	-	vf,f	c	vf,f	c	es	Slickensides	1 cm
105-132	-	fi	vsvp	-	-	vf,f	c	vf,f	c	es	Slickensides	
132-150	-	fi	vsvp	-	-	vf,f	m	vf ,f	f	es	Slickensides	0.5 cm

**Cracks <1 cm wide up to 35 cm and <0.5 cm wide up to 50 cm.*
***Matrix effervescence*

Physical Properties of Soil

Horizon	Depth (cm)	Size class and particle diameter (mm)			BD (Mgm^{-3})	COLE
		Total				
		Sand (2-0.05)	Silt (0.05-0.002)	Clay (<0.002)		
		←----------(% of <2 mm) ---------------→				
Ap	0-9	2.5	42.2	55.3	-	0.2
Bw1	9-35	0.9	40.2	58.9	1.6	0.2
Bss1	35-69	2.6	40.5	56.9	1.5	0.2
Bss2	69-105	1.6	35.7	62.6	-	0.2
Bss3	105-132	1.0	37.3	61.8	1.5	0.2
Bss4	132-150	0.5	43.1	56.3	1.5	0.2

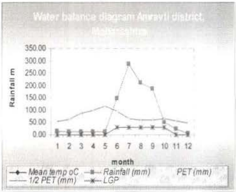
Chemical Properties of Soil

Depth (cm)	pH (1:2) H_2O	EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)
0-9	8.0	0.18	0.7	9.7
9-35	8.2	0.21	0.6	10.0
35-69	8.4	0.30	0.6	10.2
69-105	8.4	0.39	0.6	10.4
105-132	8.5	0.25	0.6	10.2
132-150	8.5	0.62	0.5	11.8

Depth (cm)	Extractable bases				CEC	BS (%)	ESP
	Ca	Mg	Na	K			
	← ----------[cmol(p+)kg^{-1}]----------→						
0-9	36.3	7.6	0.7	1.2	54.4	84	1
9-35	32.2	9.2	2.3	0.9	56.5	79	4
35-69	28.5	11.0	3.9	0.9	47.8	92	8
69-105	28.2	13.9	7.4	0.9	51.8	97	14
105-132	23.7	14.6	8.8	0.9	52.5	91	17
132-150	18.9	14.5	9.1	0.8	43.3	100	21

* *Percent of water dispersible clay size carbonate*

BM Spot 3 : ASRA – Agriculture (FM) (Soybean+Pigeonpea)



Classification	:	Very fine, smectitic, hyperthermic, Typic Haplusterts
Location	:	Vill. Asra, Bhatukli, Amravati, M.S. Lat. 20°52'41"N, Long. 77°29'16"E
Physiographic position	:	Lower Maharashtra, Deccan Plateau
Topography and slope	:	Very gently sloping to slightly undulating, 1-3% (50-150 m)
Vegetation	:	Acacia, Neem, Pipal, Grass, Shrubs
Land Use	:	Soybean + Pigeonpea
Parent material	:	Basaltic alluvium
Sampled by	:	P. Chandran, S.K. Ray, S.L. Durge, S.R. Bhuse
Date of collection	:	16-01-2001

Ap	0-14 cm	Very dark brown (10YR 2/2M) clay; moderate medium subangular blocky structure; friable, sticky and plastic; common very fine, few fine roots; many very fine, few fine lime nodules;many very fine and fine pores; mildly alkaline (pH 7.8); strongly effervescent; clear smooth boundary.
Bw1	14-35 cm	Very dark brown (10YR 2/2M) clay; strong medium subangular blocky structure with pressure faces on ped surfaces; friable, very sticky and very plastic; common very fine, few fine roots; many very fine, few fine lime nodules; many very fine and fine pores; moderately alkaline (pH 7.9); strongly effervescent; clear smooth boundary.
Bss1	35- 69 cm	Very dark brown (10YR 2/2M) clay; strong medium angular blocky structure (weak) with not so well developed wedge shaped aggregates and slickensides that breaks into small angular peds; slightly firm, very sticky and very plastic; common very fine roots; many very fine, few fine lime nodules; mildly alkaline (pH 7.8); strongly effervescent; gradual smooth boundary.

Bss2	69-107 cm	Very dark brown (10YR 2/2M) clay; strong medium angular blocky structure with well developed wedge shaped aggregates and slickensides that breaks into small angular peds; slightly firm, very sticky and very plastic; few very fine roots; common very fine, few fine lime nodules; moderately alkaline (pH 7.9); strongly effervescent; gradual smooth boundary.
Bss3	107-150+ cm	Very dark brown (10YR 2/2M) clay; strong medium angular blocky structure with well developed wedge shaped aggregates and slickensides that breaks into small angular peds; slightly firm, very sticky and very plastic; few very fine roots; common very fine, few fine lime nodules; moderately alkaline (pH 8.1); strongly effervescent; gradual smooth boundary.

Morphological Properties of Soil

Horizon	Depth (cm)	Boundary		Matrix Colour		Texture	Coarse Fragments (%) (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap	0-14	-	-	-	10YR2/2	c	1-3	m	3	sbk
Bw1	14-35	c	s	-	10YR2/2	c	1-3	m	2	sbk
Bss1	35-69	g	s	-	10YR2/2	c	1-3	m	3	abk(w)*
Bss2	69-107	g	w	-	10YR2/2	c	<1	m	3	abk
Bss3	107-150	g	w	-	10YR2/2	c	<1	m	3	abk

Depth (cm)	Consistence			Porosity		Nodules(conca)		Roots		Effervescence	Other Features	Cracks
	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity	dil HCl		
0-14	-	fr	sp	vf, f	m	vf; f	m; f	vf; f	c; f	es	-	1-2 cm
14-35	-	fr	sp	-	-	vf; f	m; f	vf; f	c; f	es	Pressure faces	1 cm
35-69	-	fi	sp	-	-	vf; f	m; f	vf	c	es	Slickensides (Weak)	0.5 cm
69-107	-	sfi	vsvp	-	-	vf; f	c; f	vf	f	es	Slickensides	0.7 cm
107-150	-	sfi	vsvp	-	-	vf; f	c; f	vf	f	es	Slickensides	

**Cracks: 1-2 cm wide up to 18 cm and 0.5 cm up to 107 cm.*
***Matrix effervescence was also observed.*

Physical Properties of Soil

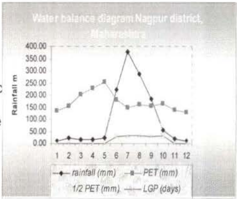
Laboratory No	Horizon	Depth (cm)	Size class and particle diameter (mm)			BD (Mgm^{-3})	COLE
			Total				
			Sand (2-0.05)	Silt (0.05-0.002)	Clay (<0.002)		
			←-----------------(% of <2 mm) ------------------→				
3120	Ap	0-14	2.8	36.1	61.1	-	0.2
3121	Bw1	14-35	2.7	34.6	62.7	1.5	0.2
3122	Bss1	35-69	2.7	34.8	62.5	1.5	0.2
3123	Bss2	69-107	2.6	36.1	61.3	1.6	0.2
3124	Bss3	107-150	2.1	35.8	62.1	1.6	0.2

Chemical Properties of Soil

Depth (cm)	pH (1:2) H_2O	EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)
0-14	7.8	0.10	0.8	8.1
14-35	7.9	0.15	0.7	9.4
35-69	7.8	0.14	0.6	9.6
69-107	7.9	0.32	0.6	9.7
107-150	8.1	0.23	0.5	10.6

Depth (cm)	Extractable bases				CEC	BS (%)	ESP
	Ca	Mg	Na	K			
	------------------[$cmol(p+)kg^{-1}$]------------------						
0-14	40.1	12.2	0.4	1.1	60.9	88	0.6
14-35	39.0	14.9	0.6	0.8	56.5	97	1.0
35-69	38.0	16.9	0.8	0.8	59.8	94	1.3
69-107	37.8	19.0	1.7	0.8	63.0	94	2.8
107-150	36.2	22.2	2.6	0.8	61.9	100	4.2

BM Spot 4 : LINGA – Horticulture
Citrus



Classification	:	Very fine, smectitic, hyperthermic Typic Haplusterts
Location	:	½ km west of Res. Farm Bldg c Reg. Fruit Res. Stn., Wandli, Katol, Nagpur, M.S. This is the original site of Linga series Lat. 21° 15'18"N; Long. 78° 36'40"E
Physiographic position	:	Lower Maharashtra Deccan Plateau
Topography and slope	:	Plain to very gently sloping; 1-3% (50-150 m)
Vegetation	:	*Acacia*, neem, palas, ber, karanji, parthenium; kans, dub
Land Use	:	citrus (horticultural system)
Parent material	:	Basalt; Basaltic alluvium
Sampled by	:	P. Chandran, S.K. Ray, S.L. Durge
Date of collection	:	07-11-2000

Ap	0-16 cm	Dark grayish brown to very dark grayish brown (10YR 3.5/2D) very dark grayish brown (10YR 3/2M) clay; medium, moderate subangular blocky structure; slightly hard, friable, sticky and plastic; many very fine and fine, few medium roots; many very fine and fine lime nodules; many very fine and fine pores; moderately alkaline (pH 7.9); slightly effervescent; clear smooth boundary.
Bw1	16-44 cm	Very dark grayish brown (10YR 3/2M) clay; medium strong subangular blocky structure with pressure faces; friable, sticky and plastic; common very fine and fine, few medium roots; many very fine and fine, few medium lime nodules; many very fine, common few pores; moderately alkaline (pH 8.0); nil to slightly effervescent; gradual smooth boundary.
Bw2	44-69 cm	Very dark grayish brown to very dark gray (10YR 3/1.5 M) clay; medium strong subangular to angular blocky structure with well

		developed pressure faces; friable, sticky and plastic; common very fine and fine roots; many very fine and fine, few medium lime nodules; mildly alkaline (pH 7.8); nil to slightly effervescent; gradual smooth boundary.
Bss1	69-102 cm	Very dark grayish brown to very dark gray (10YR 3/1.5 M) clay; medium, strong, subangular blocky to medium strong angular blocky structure with weak development of slickensides; friable, very sticky and very plastic; few, very fine and fine roots; common very fine and fine few medium line nodules; moderately alkaline (pH 7.9); nil to slightly effervescent; gradual smooth boundary.
Bss2	102-128 cm	Very dark grayish brown to dark brown (10YR 3/2.5M) clay; medium strong angular blocky structure with well developed slickensides and wedge shaped aggregates which breaks into small angular blocks; friable, very sticky and very plastic; few, very fine roots; common very fine and fine, few medium lime nodules; moderately alkaline (pH 8.0); gradual smooth boundary.
Bss3	128-150+ cm	Brown (10YR 4/3M) clay; coarse, strong angular blocky structure with well developed slickensides and wedge shaped aggregate which breaks into small angular blocks; friable, very sticky and very plastic; common very fine and fine, few medium and coarse lime nodules moderately alkaline (pH 7.9); clear smooth boundary.

Morphological Properties of Soil

Horizon	Depth (cm)	Boundary		Matrix Colour		Texture	Coarse Fragments (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap	0-16	c	s	10YR3.5/2	10YR3/2	c	3--5	m	2	sbk
Bw1	16-44	g	s	-	10YR3/1.5	c	3--5	m	3	sbk
Bw2	44-69	g	s	-	10YR3/1.5	c	2--3	m	3	sbk-abk
Bss1	69-102	g	s	-	10YR3/1.5	c	2--3	m	3	abk(w)**
Bss2	102-128	g	s	-	10YR3.5/2.5	c	2--5	m	3	abk
Bss3	128-150	c	s	-	10YR4/3	c	5--8	c	3	abk

Depth (cm)	Consistence			Porosity		Nodules(conca)		Roots		Effervescence*	Other Features	Cracks
	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity	dil HCl		
0-16	sh	fr	sp	vf, f	m	vf,f	m	vf,f, m	m, f	e	-	0.5 cm
16-44	-	fr	sp	vf, f	m, c	vf,f; m	m; f	vf,f, m	c, f	e	Pressure faces	0.5 cm
44-69	-	fr	sp	-	-	vf,f, m	m; f	vf,f	c	e	Slickensides (weak)	
69-102	-	fr	vsvp	-	-	vf,f; m	f; c	vf,f	f	e	Slickensides (weak)	
102-128	-	fr	vsvp	-	-	vf, f,c	m, f	vf	f	es	Slickensides	
128-150	-	fr	vsvp	-	-	vf,f; m,c	c; f	-		es	Slickensides	

** Matrix effervescence was also observed.*
Cracks ~ 0.5 mm wide upto 35 cm depth

Physical Properties of Soil

Horizon	Depth (cm)	Size class and particle diameter (mm)			BD (Mgm^{-3})	COLE
		Total				
		Sand (2-0.05)	Silt (0.05-0.002)	Clay (<0.002)		
		←----------------(% of <2 mm) ------------------→				
Ap	0-16	1.2	33.3	65.5	-	0.2
Bw1	16-44	0.7	32.5	66.8	1.4	0.2
Bw2	44-69	0.7	32.4	66.9	1.4	0.2
Bss1	69-102	0.6	28.4	71.0	1.5	0.2
Bss2	102-128	0.5	28.4	71.1	1.5	0.3
Bss3	128-150+	0.5	29.2	70.3	1.4	0.3

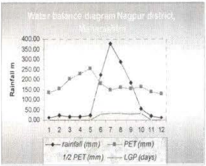
Chemical Properties of Soil

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)
	H_2O	1*N* KCl			
0-16	7.9	6.6	0.16	1.0	6.9
16-44	8.0	6.4	0.15	0.7	7.6
44-69	7.8	6.6	0.14	0.6	7.2
69-102	7.9	6.4	0.16	0.5	9.0
102-128	8.0	4.5	0.17	0.5	9.2
128-150+	7.9	6.4	0.25	0.4	9.4

Depth (cm)	Extractable bases				CEC	BS (%)	ESP
	Ca	Mg	Na	K			
	---------------------------------[cmol(p+)kg^{-1}]---------------------------						
0-16	40.0	11.8	0.6	1.3	65.2	82	0.9
16-44	43.6	10.9	0.5	0.7	64.1	87	0.8
44-69	41.3	10.2	0.6	0.7	63.0	84	0.9
69-102	40.2	13.1	0.7	0.7	63.0	87	1.1
102-128	37.8	14.4	0.9	0.8	61.8	87	1.4
128-150+	40.4	19.1	0.8	0.8	63.0	97	1.3

* *percent of water dispersible clay size carbonate*

BM SPOT – 5 : BRAHMNI, HORTICULTURE BANANA



Classification	:	Very fine, smectitic, hyperthermic Typic Haplusterts
Location	:	1 km west of Brahmni village Lat. 20°53'3.2"N Long. 78°41'48.5"E
Physiographic position	:	Lower Maharashtra Deccan Plateau
Topography and slope	:	Flat to undulating; 3-8% (50-150 m)
Vegetation	:	Babul, Neem, Teak
Land Use	:	Banana
Parent material	:	Basaltic alluvium
Sampled by	:	T. Bhattacharyya, P. Chandran, S.K. Ray, K.V. Kapse, K.P. Mundhe and P. Thakur
Date of collection	:	26-12-2006

Ap	0-13 cm	Clay, very dark grayish brown colour (10YR 3/2M), medium moderate to subangular blocky structure; slightly hard, very friable, slightly plastic and plastic, very fine, medium and coarse roots, fine, many pores, coarse lime nodules, slightly effervescence, moderately alkaline (pH 8.1), clear smooth boundary.
Bw1	13-32 cm	Clay, very dark grayish brown colour (10YR 3/2M), medium moderate subangular blocky structure, very friable, slightly plastic and plastic, very fine, few roots, fine many pores, fine lime nodules, slightly effervescence, moderately alkaline (pH 8.2), clear smooth boundary
Bw2	32-59 cm	Clay, very dark grayish brown colour (10YR 3/2M), medium to moderate subangular blocky structure, slightly hard, friable very plastic to sticky plastic, many medium roots, fine many pores; fine lime nodules, slightly effervescence, moderately alkaline (pH 8.0), gradually smooth boundary, pressure faces.
Bss1	59-81 cm	Clay, very dark grayish brown colour (10YR 3/2M), slickensides forming parallelopipeds that breaks into medium, moderate

		angular blocky structure, friable, very sticky and very plastic, fine few roots, fine lime nodules and slightly effervescent, moderately alkaline (pH 8.0).
Bss2	81-115 cm	Clay, very dark grayish brown colour (10YR 3/2M), slickensides forming parallelopipeds that breaks into medium, moderate angular blocky structure, friable very sticky and very plastic, few fine roots, fine lime nodules and slightly effervescent, moderately alkaline (pH 8.0), smooth boundary.
BCk	115-145 cm	Clay, very dark grayish brown to dark yellowish brown (10YR 3.5/4) medium, moderate subangular blocky structure, loose, friable, very sticky to sticky plastic consistent, common few roots, coarse lime nodules <25-30%, strong effervescent, moderately alkaline (pH 8.2), smooth boundary.

Morphological Properties of Soil

Horizon	Depth (cm)	Boundary [1]		Matrix colour (M) [2]	Texture [3]	Coarse fragments (%)	Structure [4]		
		D	T				S	G	Ty
Ap	0-13			10YR 3/2	c	5-10	m	2	sbk
Bw1	13-32			10YR 3/2	c	<5	m	2	sbk
Bw2	32-59	c	s	10YR 3/2	c	<5	m	2	abk
Bss1	59-81	c	s	10YR 3/2	c	<5	m	2	abk
Bss2	81-115	g	s	10YR 3/2	c	<5	m	2	abk
BCk	115-145			10YR 3/2	c	25-30	m	2	abk

Depth (cm)	Consistence [5]			Roots [7]		Effer vesc ence	Other features	Cracks
	D	M	W	S	Q	e	--	
0-13	sh	vfr	sp	vfm	fe	e	--	
13-32	sh	vfr	sp	vfm	fe	e	Pressure faces	
32-59	sh	f	vsps	f	c	e	ss	
59-81	sh	f	vsps	f	f	e	ss	
81-115	sh	f	vsps	f	f	e	--	
115-145	h	fr	vsps	f	f			

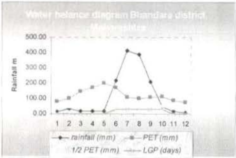
Physical Properties of Soil

Horizon	Depth (cm)	Particle size distribution		
		Sand (2.0-0.05)	Silt (0.05-0.002)	Clay (<0.002)
		←------% of <2 mm ----->		
Ap	0-13	1	34	65
Bw1	13-32	1	34	65
Bw2	32-59	2	33	65
Bss1	59-81	1	30	69
Bss2	81-115	1	30	69
BCk	115-145	25	45	30

Chemical Properties of Soil

Depth (cm)	pH (1:2.5) water	OC %	Extractable Bases					CEC	B.S. (%)
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Sum		
			←-------------------cmol (p+) kg^{-1}-------------------->						
0-13	8.1	0.92	53.14	7.59	0.15	1.55	62.41	69.59	90
13-32	8.2	0.73	53.94	10.07	0.19	0.91	64/31	57.01	113
32-59	8.0	0.53	57.94	11.97	0.21	0.64	70.76	57.45	123
59-81	8.0	0.47	56.79	16.23	0.21	0.67	73.39	57.95	127
81-115	8.0	0.46	58.24	14.59	0.21	0.59	73.63	56.86	129
115-145	8.2	0.24	51.48	15.53	0.25	0.35	67.31	49.82	135

BM SPOT – 6 : DIGHORI, AGRICULTURE
Paddy



Classification	:	Very fine, smectitic, hyperthermic Typic Haplusterts
Location	:	About 600 m west of Dighori village, Bhandara M.S. Lat. 21°07'23.2"N Long. 79°43'08.3"E
Physiographic position	:	Lower Maharashtra, Deccan Plateau
Topography and slope	:	Very gently sloping; 1-3% (50-150 m)
Vegetation	:	Ber, Babul, Palas
Land Use	:	Paddy
Parent material	:	Basaltic Alluvium
Sampled by	:	T. Bhattacharyya, P. Chandran, S.K. Ray, S.L. Durge and Shrikant Chivhane
Date of collection	:	15/02/08

Ap	0-13 cm	Brown to dark grayish brown (10YR 4/2M) clay; medium moderate subangular blocky structure; slightly plastic on wet, firm on moist, very hard on dry; very fine to fine roots are common loamy; calcium and iron nodules are common; very fine to fine pores are few; average soil matrix in non-calcareous; clear and smooth boundary.
Bw	13-27 cm	Brown (10YR 4/3DM) clay; medium moderate subangular blocky structure with pressure faces; slightly plastic on wet friable on moist and very hard on dry; very fine roots are many and fine roots are few; medium nodules of iron and calcium are common; clear and smooth boundary.
Bw2	27-53 cm	Brown (10YR 4/3M) clay; medium strong subangular blocky structure; slightly plastic on wet; friable on moist and very hard on dry; very fine roots are many and fine roots are few; coarse and medium nodules of iron are few; very fine to fine nodules of calcium are common; gradual smooth boundary.
Bss1	53-76 cm	Brown to dark yellowish brown (10YR 4/3.5M) clay; medium moderate angular blocky structure with well developed

		slickensides, slightly plastic on wet, friable on moist and very hard on dry; very fine roots are common; very fine, fine and medium nodules of iron are common; very fine nodules of calcium are many and fine nodules are few; slightly effervescence; gradual and smooth boundary.
Bss2	76-105 cm	Dark yellowish brown (10YR 4/4M); medium moderate angular blocky structure with well developed slickensides; slightly plastic on wet, friable on moist; few very fine roots; fine to coarse nodules of iron are common; very fine and fine nodules of calcium are common; slight effervescence; gradually smooth boundary.
Bss3	105-160 cm	Dark yellowish (10YR 4/6M) clay; medium strong angular blocky structure with well developed slickensides; slightly plastic on wet and friable on moist; few very fine roots; fine to coarse iron nodules are few; very fine calcium nodules are few; slightly effervescence.

Morphological properties of soils

Hori-zon	Depth (cm)	Bound-ary [1]		Matrix colour (M) [2]	Texture [3]	Coarse fragments (%)	Structure [4]		
		D	T				S	G	Ty
Ap	0-13	c	s	10YR 4/2	c	5	m	2	sbk
Bw1	13-27	c	s	10YR 4/3	c	5	m	2	sbk
Bw2	27-53	g	s	10YR 4/3	c	5	m	3	sk
Bss1	53-76	g	s	10YR 4/3.5	c	2	m	2	abk
Bss2	76-105	g	s	10YR 4/4	c	2	m	2	abk
Bss3	105-160			10YR 4/6	c	2	m	3	abk

Depth (cm)	Consistence [5]			Roots [7]		Effervescence	Other features	Cracks
	D	M	W	S	Q			
0-13	vh	fi	sp	vf,f	m,c	nil/e	--	3-5 cm
13-27	h	fr	sp	vf,f	m,f	nil/e	--	
27-53	vh	fr	sp	vf,f	m,f	e	--	
53-76	vh	fr	sp	vf	c	e	--	
76-105		fr	sp	vf	f	e	--	
105-160		fr	sp	vf	f		--	

Physical properties of soils

Horizon	Depth (cm)	Particle size distribution		
		Sand (%)	Silt (%)	Total Clay (%)
Ap	0-13	22.2	37.0	57.8

Depth (cm)	Water Retention		COLE	AWC (%)	HC cm/hr
	33 kPa (%)	1500 kPa (%)			
0-13	22.22	12.07	0.15	17.0	

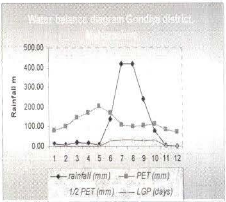
Chemical properties of soils

Depth (cm)	pH (1:2.5) water	EC (dS m^{-1})	SOC (%)	$CaCO_3$ (%)	SIC
0-13	6.50	0.16	1.07	1.72	0.20
13-27	7.77	0.20	0.39	4.02	0.48
27-53	7.83	0.18	0.29	2.10	0.25
53-76	7.85	0.21	0.24	0	0
76-105	7.84	0.20	0.25	0.75	0.09
105-160	7.87	0.23	0.27	0.43	0.05

Profile showing different features of Dhigori soil series

Polygonal cracks in Dhigori soils

BM SPOT – 7 : RAJEGAON, GONDIA
AGRICULTURE (Paddy)



Classification	:	Fine, smectitic, hyperthermic Vertic Haplustalfs
Location	:	500 m away from state highway 275 at east of Rajegaon, Gondia. Lat. 21°35'51.7"N Long. 80°14'25.9"E
Physiographic position	:	Lower Maharashtra, Deccan Plateau
Topography and slope	:	Very gently sloping; 3-8% (50-150 m)
Vegetation	:	Bamboo, Palas, Hiwar, Hanua
Land Use	:	Paddy
Parent material	:	Alluvium (mixed)
Sampled by	:	T. Bhattacharyya, P. Chandran, S.K. Ray, S.L. Durge and Shrikant Chivhane
Date of collection	:	14/02/08

Ap	0-10 cm	Brown (7.5YR 3/3M) clay; medium moderate subangular blocky structure; hard, friable sticky plastic; many very fine to fine roots; very fine to fine pores are common, clear and smooth boundary.
Bt1	10-25 cm	Strong brown (7.5YR 4/6) clay; medium subangular blocky structure; hard, friable sticky, plastic; many to common fine and very fine roots; fine nodules of iron ore; few to common; few pores are common; clear and smooth boundary.
Bt2	25-55 cm	Dark grayish brown (10YR 4/2M) sandy clay; medium moderate subangular blocky; hard, friable sticky, plastic, very few fine roots; fine iron nodules are common to few; few pores are common; gradual smooth boundary.
Bt3	55-77 cm	Dark grayish brown (10YR 4/2M) clay; medium moderate subangular blocky structure; hard friable sticky, plastic;

	cm	very fine, roots, nodules of iron and pores are common; clear and smooth boundary.
Bt4	77-107 cm	Dark grayish brown to very dark grayish brown (10YR 3.5/3M) clay; medium strong subangular blocky structure; plastic on wet and friable on moist; very fine roots are few; slight effervescence; clear smooth boundary.
Bw/Bt5	107-150 cm	Brown colour (10YR 4/3M) clay; medium moderate subangular blocky structure; firm and friable sticky, plastic; few to very fine roots; clear and smooth boundary

Morphological properties of soils

Hori-zon	Depth (cm)	Bound-ary [1]		Matrix colour (M) [2]	Tex ture [3]	Coarse fragme nts (%)	Structure [4]		
		D	T				S	G	Ty
Ap	0-10	c	s	7.5YR 3/3	c	2	m	2	sbk
Bt1	10-25	c	s	7.5YR 4/6	c	1	m	3	sbk
Bt2	25-55	g	s	10YR 4/3	sc	1	m	2	sbk
Bt3	55-74	c	s	10YR 4/3	sc	1	m	2	sbk
Bt4	74-107	c	s	10YR 4/3	c	2	m	3	sbk
Bw/Bt5	107-150+			10YR 4/3	c	3	m	2	sbk

Depth (cm)	Consistence [5]			Roots [7]		Effer vesc ence	Other features	Cracks
	D	M	W	S	Q			
0-10		Fr	p	vf,f	m	Nil	--	1-2 cm
10-25		fr	p	vf,f	m,c	Nil	--	
25-55		fr	p	vf	f	Nil	--	
55-74		fr	p	vf	f	Nil	--	
74-107		fr/fi	p	vf	f	e	--	
107-150+		fr/fi	p	vf	f	e	--	

Physical properties of soils

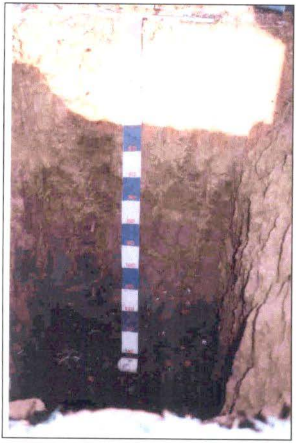
Horizon	Depth (cm)	Particle size distribution		
		Sand (%)	Silt (%)	Total Clay (%)
Ap	0-10	34.9	89.1	37.7

Depth (cm)	Water Retention		COLE	AWC (%)	HC cm/hr
	33 kPa (%)	1500 kPa (%)			
0-10	19.42	10.28	0.08	12.93	

Chemical properties of soils

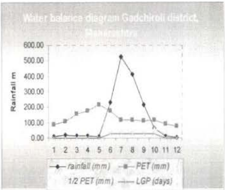
Depth (cm)	pH (1:2.5) water	EC (dS m^{-1})	SOC (%)	$CaCO_3$ (%)	SIC
0-10	5.64	0.10	0.93	0.86	0.10
10-25	7.10	0.09	0.28	0.57	0.06
25-55	7.00	0.31	0.20	1.15	0.13
55-74	6.88	0.25	0.9	1.15	0.13
74-107	8.73	0.72	0.14	1.72	0.20
107-150+	8.74	0.81	0.11	2.01	0.24

Landscape of Rajegaon soil series



Profile showing different features of Rajegaon soil series

BM SPOT – 8 : KURUL, GADCHIROLI, AGRICULTURE (Paddy + Chickpea)



Classification	:	Fine, smectitic, hyperthermic Ustic Endoaquents
Location	:	About 1 km south west of Kurul village, Gadchiroli Lat 19°57'27"N Long 79°59'39"E
Physiographic position	:	Lower Maharashtra, Deccan Plateau
Topography and slope	:	Very gently sloping; 3-8% (50-150 m)
Vegetation	:	Mahua, Sag, Arjun, Tamarind, Palas
Land Use	:	Paddy, Chickpea
Parent material	:	Alluvium
Sampled by	:	T. Bhattacharyya, P. Chandran, S.K. Ray, S.L. Durge and Shrikant Chivhane
Date of collection	:	13/02/08

Ap	0-12 cm	Very dark grayish brown (10YR 3/2) clay; fine weak subangular blocky structure; mollusk shell in upper layer; soft, very friable, sticky and plastic; fine roots are many; very fine nodules are few; many fine pores; slight effervescence.
Bw1	12-28 cm	Very dark grayish brown (10YR 3/2) clay; medium moderate subangular blocky structure; many very fine and fine roots; slight effervescence; few nodules of calcium carbonate; clear and smooth boundary.
Bw2	28-50 cm	Brown (10YR 4/3M) clay; medium moderate subangular blocky structure; very friable sticky and plastic; fine roots are common, very fine nodules of iron and calcium carbonate are few to common; slight effervescence; gradual smooth boundary.
Bw3	50-76 cm	Brown (10YR 4/3) clay; medium weak subangular blocky structure; very friable on moist and sticky on wet; fine roots

	cm	are few; fine nodules iron are common; very fine nodules of calcium carbonate are few; slight effervescence gradual smooth boundary.
Bss1	76-101	Dark grayish brown to very dark grayish brown (10YR 3.5/2M) clay; medium moderate subangular blocky structure; very friable on moist and sticky on wet; fine roots are few; very fine nodules of iron and calcium carbonate are few to common; slight effervescence; clear and smooth boundary.
Bss2	101-126 cm	Dark grayish brown to very dark grayish brown (10YR 3.5/2M) clay; medium moderate subangular blocky to angular blocky structure with well developed slickensides; very friable sticky and plastic; very fine roots are few; very fine nodules of iron and calcium carbonate are few to common; slight effervescence; gradual smooth boundary.
Bss3	126-150 cm	Dark grayish brown to very dark grayish brown (10YR 3.5/2) clay; medium moderate subangular blocky structure with well developed slickensides; very friable sticky and plastic; very fine roots are few; very fine nodules of iron and calcium carbonate are few; slight effervescence.

Morphological properties of soils

Hori-zon	Depth (cm)	Bound-ary [1]		Matrix colour (M) [2]	Tex ture [3]	Coarse fragme nts (%)	Structure[4]		
		D	T				S	G	Ty
Ap	0-12			10YR 3/2	c	2	f	1	sbk
Bw1	12-28	c	s	10YR 3/2	c	3	m	2	sbk
Bw2	28-50	c	s	10YR 4/3	c	3	m	2	sbk
Bw3	50-76	g	s	10YR 3.5/2	c	3	m	1	sbk
Bss1	76-101	c	s	10YR 3.5/2	c	2	m	2	sbk/abk
Bss2	101-126	g	s	10YR 3.5/2	c	2			sbk/abk
Bw Bss3	126-150			10YR 3.5/2	c	2			sbk/abk

Depth (cm)	Consistence[5]			Roots[7]		Effer vesc ence	Other features	Cracks
	D	M	W	S	Q			
0-12	s	vfr	sp	vf,f	m	e	--	
12-28		fr	sp	vf,f	m	e	--	
28-50		vfr	sp	vf,f	c	e	--	
50-76		vfr	sp	vf,f	c	e	--	
76-101		fr	sp	vf	f	e	--	
101-126		fr	sp	vf	f	e	--	
126-150		vfr		vf	f	e	--	

Physical properties of soils

Horizon	Depth (cm)	Particle size distribution		
		Sand (%)	Silt (%)	Total Clay (%)
Ap	0-12	30.987	31.75	46.9

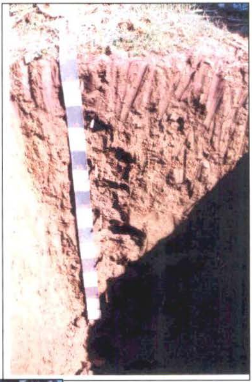
Depth (cm)	Bulk density Mg dm^{-3}	Water Retention		COLE	AWC (%)	HC cm/hr
		33 kPa (%)	1500 kPa (%)			
0-12	1.48	23.39	11.18	0.15	17.0	

Chemical properties of soils

Depth (cm)	pH (1:2.5) water	EC (dS m^{-1})	SOC (%)	$CaCO_3$ (%)	SIC
0-12	7.75	0.84	1.74	2.01	0.29
12-28	7.95	0.25	0.54	1.15	0.13
28-50	8.12	0.18	0.31	1.15	0.13
50-76	6.50	0.92	0.21	1.15	0.13
76-101	6.92	0.56	0.16	1.43	0.17
101-126	8.00	0.22	0.16	1.72	0.20
126-150	7.98	0.18	0.06	1.43	0.17

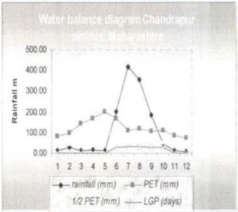
Landscape of Kurul soil series

Profile showing different features of Kurul soil series



Field after paddy harvesting

BM SPOT – 9 : HALDI, DEGRADED FOREST



Classification	:	Fine, smectitic, hyperthermic Vertic Haplustalfs
Location	:	750 m south from Haldi village; Chandrapur, M.S. Lat. 20°02'60.8"N Long. 79°29'19.0"E
Physiographic position	:	Lower Maharashtra, Deccan Plateau
Topography and slope	:	Gently sloping; 3-8% (50-150 m)
Vegetation	:	Mixed natural forest, Sag, Tendu, Kalamb, Bambu, Tamarind
Land Use	:	Forest
Parent material	:	Basaltic Alluvium
Sampled by	:	T. Bhattacharyya, P. Chandran, S.L. Durge; Kamlesh Kapse, Kailash Mundhe and Pravin Thakur
Date of collection	:	

Ap	0-14 cm	Very dark grayish brown (10YR 3/2M) clay; medium weak subangular blocky structure; slightly plastic on wet, slightly sticky on moist and friable on dry; very fine to fine roots are many to few; fine nodules of manganese are few and pores are many; clear and smooth boundary.
Bw	14-46 cm	Dark grayish brown (10YR 3/4M) clay; medium strong angular blocky structure; slightly plastic on wet, sticky on moist and hard friable on dry; few, medium roots are many to few; fine nodules of manganese are few; fine pores are many; clear wavy boundary.
Bss1	46-82 cm	Dark brown (10YR 3/3M) clay; coarse strong angular blocky structure; slightly plastic on wet, friable on moist and hard on dry; fine to medium roots and pores are few; medium to coarse nodules of manganese are few to many; strong effervescence; gradual wavy boundary.

Bss2	82-114 cm	Dark brown (10YR 3/3M) clay; coarse strong angular blocky structure; slightly plastic on wet, very firm on moist and hard on dry; fine to medium roots are few; strong effervescence; gradual smooth boundary.
Bss3	114-135 cm	Dark yellowish brown (10YR 3/4M) clay; coarse strong angular blocky structure; slightly plastic on wet, very firm on moist and hard on dry; fine to medium roots are few; medium roots of manganese are few; slight effervescence.

Morphological properties of soils

Hori-zon	Depth (cm)	Bound-ary[1]		Matrix colour (M)[2]	Texture[3]	Coarse fragments (%)	Structure[4]		
		D	T				S	G	Ty
Ap	0-14	c	s	10YR 3/2	c	<1-2	m	1	sbk
Bw	14-46	c	w	10YR 3/4	c	--	m	3	abk
Bsst	46-82	g	w	10YR 3/3	c	--	c	3	abk
Bsst	82-114	g	s	10YR 3/3	c	--	c	3	abk
Bsst	114-135			10YR 3/4	c	--	c	5	abk

Depth (cm)	Consistence[5]			Roots[7]		Effervescence	Other features	Cracks
	D	M	W	S	Q			
0-14	h	s	ps	vf,f	m,f	--	--	
14-46	h	s	ps	f,m	m,f	--	--	
46-82	h	fr	sp	v,m	f,f	es	--	
82-114	h	vfri	sp	f,m	f,f	es	--	
114-135	h	vfi	sp	f,m	f,f	e	--	

Physical properties of soils

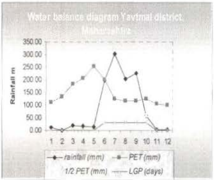
Horizon	Depth (cm)	Particle size distribution		
		Sand (%)	Silt (%)	Total Clay (%)
Ap	0-14	46.15	27.05	41.0

Depth (cm)	Bulk density Mg dm^{-3}	Water Retention		COLE	AWC (%)	HC cm/hr
		33 kPa (%)	1500 kPa (%)			
0-14	1.6	12.43	6.68	0.13	9.2	

Chemical properties of soils

Depth (cm)	pH (1:2.5) water	EC (dS m^{-1})	SOC (%)	$CaCO_3$ (%)	SIC
0-14	4.23	0.038	0.25	--	--
14-46	5.84	0.023	0.53	--	--
46-82	8.53	0.152	0.19	--	--
82-114	9.16	0.325	0.18	--	--
114-135	9.59	0.525	0.17	--	--

BM SPOT – 10 : PAHUR, AGRICULTURE (Cotton, Jowar, Chickpea)



Classification	:	Very fine, smectitic, hyperthermic Sodic Haplusterts
Location	:	West of Pahur village, Yavatmal Lat. 20°08'15"N Long. 78°05'50"E
Physiographic position	:	Lower Maharashtra, Deccan Plateau
Topography and slope	:	Very gently sloping; 1-3% (50-150 m)
Vegetation	:	Acacia, Palas, Neem, Mango, Ber
Land Use	:	Cotton, Jowar, Chickpea
Parent material	:	Basaltic Alluvium

Ap	0-19 cm	Very dark to dark grayish brown (10YR 3.5/2M) clay; moderate medium subangular blocky structure; very plastic on wet, very sticky on moist and hard on dry; few very fien and medium fine roots are common; common fine lime nodules; common very fine pores; moderately alkaline (pH 8.3); slightly effervescence; clear and smooth boundary.
Bw	19-40 cm	Very dark grayish brown (10YR 3/2M) clay; moderate medium subangular blocky structure with pressure faces on surface of peds; very plastic on wet, very sticky on moist and friable on dry; common fine, few medium roots; many fine and medium lime nodules; fine pores are common; moderately alkaline (pH 8.4); slightly effervescence; gradual smooth boundary.
Bss1	40-78 cm	Very dark grayish brown (10YR 3/2M) clay; strong, medium to coarse angular structure with wedge shaped aggregate and slickenside that break into small angular peds; friable, very sticky and very plastic; common fine, few medium roots; common and medium lime nodules; strongly effervescence; gradual smooth boundary.

Bss2	78-122 cm	Very dark gray to very dark grayish brown (10YR 3/2M) clay; strong medium to coarse angular blocky structure with well developed wedge shaped aggregates and slickenside that break into strong angular peds; friable, very sticky and very plastic; few fine roots; common fine and medium line nodules; strong alkaline (pH 8.4); strongly effervescent; gradual smooth boundary.
Bss3	122-150+ cm	Very dark gray to very dark grayish brown (10YR 4/3M) clay; strong medium to coarse angular blocky structure with well developed wedge shaped aggregates and slickensides that break into strong angular peds; friable, very sticky and very plastic; few fine roots; common fine and medium lime nodules; strongly alkaline (pH 8.9); strongly effervescent.

Morphological properties of soils

Hori-zon	Depth (cm)	Bound-ary [1]		Matrix colour (M) [2]	Texture [3]	Coarse fragments (%)	Structure [4]		
		D	T				S	G	Ty
Ap	0-19	c	s	10YR 3/2	c	2-3	m	2	sbk
Bw	19-40	g	s	10YR 3/2	c	2-3	m	2	sbk
Bss1	40-78	g	s	10YR 3/2	c	2-3	m	3	absk/abk
Bss2	78-122	g	s	10YR 3/1.5	c	2-3	m/c	3	abk
Bss3	122-150	g	s	10YR 3/1.5	c	3-5	m/c	3	abk

Depth (cm)	Consistence [5]			Roots [7]		Effervescence	Other features	Cracks
	D	M	W	S	Q			
0-19	h	fr	sp	vf,f	fe	es	--	10
19-40		fr	vsvp	f,m	d	es	Pressure faces	5
40-78		fi	vsvp	f,m	d	e	Slickensides	5
78-122		vfi	vsvp	v,m	f	e	Slickensides	5
122-150		vfi	vsvp	v,m	f	e	Slickensides	2

Physical properties of soils

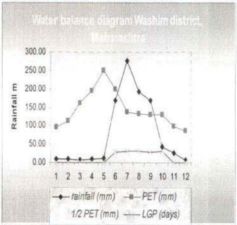
Horizon	Depth (cm)	Particle size distribution		
		Sand (%)	Silt (%)	Total Clay (%)
Ap	0-19	3.2	41.2	55.6
Bw	19-40	1.5	43.7	54.8
Bss1	40-78	1.5	38.2	60.3
Bss2	78-122	4.0	38.3	57.7
Bss3	122-150	1.8	32.2	66.0

Depth (cm)	Bulk density Mg dm^{-3}	Water Retention		COLE	AWC (%)	HC cm/hr
		33 kPa (%)	1500 kPa (%)			
0-19	1.4	46.3	26.9	0.2		1.0
19-40	1.5	44.1	27.4	0.1		0.8
40-78	1.6	48.3	31.7	0.1		0.3
78-122	1.6	45.7	26.7	0.1		0.3
122-150	1.6	54.5	30.2	0.2		0.3

Chemical properties of soils

Horizon	Depth (cm)	pH (1:2.5) water	EC (dS m^{-1})	SOC (%)	$CaCO_3$ (%)
Ap	0-19	8,3	0.23	0.90	8.2
Bw	19-40	8.4	0.19	0.65	8.2
Bss1	40-78	8.6	0.27	0.62	8.8
Bss2	78-122	8.6	0.31	0.47	8.8
Bss3	122-150	8.9	0.33	0.69	9.8

BM SPOT – 11 : WARDHA (HISAI), AGRICULTURE
Cotton, Jowar



Classification	:	Fine, smectitic, hyperthermic Chromic Haplusterts
Location	:	500 m toward south of Hisai village Lat. 20°20'02.6"N Long. 77°17'53.3"E
Physiographic position	:	Lower Maharashtra, Deccan Plateau
Topography and slope	:	Very gently sloping; 1-3% (50-150 m)
Vegetation	:	Neem, Mango, Casia, Palqas, Bambu, Shivar
Land Use	:	Cotton, Jowar, Mung
Parent material	:	Alluvium
Sampled by	:	T. Bhattacharyya, S.K. Ray, S.L. Durge and Shrikant Chivhane
Date of collection	:	14/03/08

Ap	0-10 cm	Brown to dark yellowish brown (10YR 4/3.5 M) clay; medium weak subangular blocky structure; plastic on wet; friable sticky on moist and slightly hard on dry; fine to very fine roots and nodules of calcium are many to common; fine to medium pores are many; strong effervescence; clear and smooth boundary.
Bw1	10-31 cm	Dark grayish brown colour (10YR 4/2M) clay; massive to medium weak subangular blocky structure; friable, sticky, plastic; fine to very fine roots are few to common; fine to very fine nodules of calcium and pores are common to many; strong effervescence; clear and smooth boundary.
Bw2	31-53 cm	Dark grayish brown to brown (10YR 4/2.5M) clay; medium moderate subangular blocky structure; friable, sticky, plastic; fine to very fine roots are common to few; nodules of calcium carbonate are common; strong effervescence;

		gradual smooth boundary.
Bss1	53-81 cm	Dark grayish brown to brown (10YR 4/2.5M) clay; medium moderate subangular blocky structure; friable to slight firm; sticky plastic; very fine to fine roots are few; nodules of calcium carbonate are common to few; slightly effervescence; gradual smooth boundary.
Bss2	81-114 cm	Dark grayish brown to brown (10YR 4/2.5M) clay; medium to coarse strong angular blocky; friable to slightly firm, very sticky very plastic; very fine to fine roots and nodules of calcium carbonate are common to fine; slight effervescence; gradual smooth boundary.
Bss3	114-150+ cm	Brown (10YR 4/3M) clay; medium to coarse strong angular blocky structure; friable, slightly firm, very sticky, very plastic; very fine to fine roots are few; nodules of calcium carbonate are common to few; slight effervescence.

Morphological properties of soils

Hori-zon	Depth (cm)	Bound-ary [1]		Matrix colour (M) [2]	Tex ture [3]	Coarse fragments (%)	Structure [4]		
		D	T				S	G	Ty
Ap	0-10	c	s	10YR 4/3.5	c	3	m	1	bk
Bw1	10-31	c	s	10YR 4/2	c	5	m	2	sbk
Bw2	31-53	g	s	10Yr 4/2.5	c	5	m	2	sbk
Bss1	53-81	g	s	10YR 4/2.5	c	2	m	2	abk
Bss2	81-114	g	s	10YR 4/2.5	c	2	m	3	abk
Bss3	114-150+			10YR 4/3	c	3	m	3	abk

Depth (cm)	Consistence [5]			Roots [7]		Effervescence	Other features	Cracks
	D	M	W	S	Q			
0-10	sh	vfr	sp	vf,f	m,c	es		3-5 cm
10-31		fr	sp	vf,f	c,f	es		
31-53		fr	sp	vf,f	c,f	es		
53-81	fr	sfi	sp	vf	f	e		
81-114	fr	sfi	vsvp	vf	f	e		
114-150+	fr	sfi	vsvp	vf	f	e		

Physical properties of soils

Horizon	Depth (cm)	Particle size distribution		
		Sand (%)	Silt (%)	Total Clay (%)
Ap	0-10	0.5	45.5	54.9

Depth (cm)	Bulk density Mg dm^{-3}	Water Retention		COLE	AWC (%)	HC cm/hr
		33 kPa (%)	1500 kPa (%)			
0-10	1.5	41.35	23.27	0.22	27.12	

Chemical properties of soils

Depth (cm)	pH (1:2.5) water	EC (dS m^{-1})	SOC (%)	$CaCO_3$ (%)	SIC
0-10	8.30	0.36	0.33	10.8	1.29
10-31	8.25	0.32	0.26	7.8	0.93
31-53	8.66	0.46	0.16	7.8	0.93
53-81	8.71	0.78	0.14	4.3	0.51
81-114	8.50	0.76	0.21	3.0	0.36
114-150+	8.78	0.69	0.20	3.6	0.43

Profile showing different features of Hisai soil series

Closer view of slickensides

Landscape of Hisai soil series