# EVALUATIONS OF SOIL CARBON SEQUESTRATION POTENTIAL IN DIFFERENT LANDUSE SYSTEMS OF DEWA BLOCK, BARABANKI, U.P.

**A Thesis Submitted to**
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**For the Degree of**
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**in**
**Environmental Science**

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**June, 2017**

*Dedicated to*
*Lord Krishna*

# CERTIFICATE

This is to certify that the thesis, entitled **“Evaluations of Soil Carbon Sequestration Potential in different landuse systems of Dewa Block, Barabanki, U.P.”** submitted by **Miss Neetu Pandey** for the award of Degree of Doctor of Philosophy by Babu Banarasi Das University, Lucknow is a record of authentic work carried out by her under my supervision. To the best of my knowledge, the matter embodied in this thesis is the original work of the candidate and has not been submitted elsewhere for the award of any other degree or diploma.

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**Place:**
**Date:**

# DECLARATION

I, hereby, declare that the work presented in this thesis, entitled "Evaluations of Soil Carbon Sequestration Potential in different landuse systems of Dewa block, Barabanki, U.P." in fulfillment of the requirements for the award of Degree of Doctor of Philosophy of Babu Banarasi Das University, Lucknow is an authentic record of my own research work carried out under the supervision of **Dr. Pramod Kumar Singh,** Associate Professor, Department of Chemistry, School of Applied Sciences, Babu Banarasi Das University, Lucknow.

I also declare that the work embodied in the present thesis is my original work and has not been submitted by me for any other Degree or Diploma of any university or institution.

**(Neetu Pandey)**

Date

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# PREFACE

Soil carbon sequestration potential is considered one of the most important factors of soil properties which decide the soil health. It is key to soil fertility, productivity and quality. There is a growing interest in assessing the role of soil as a sink for carbon under different land use systems as increase in soil organic carbon content by 0.01% could lead to sequestration of carbon that can compensate the annual increase of atmospheric carbon dioxide concentration. Different landuse systems, viz; forested, cultivated and uncultivated showed different amount of organic carbon due to the different agricultural practices carried out. The sites selected for the research was due to their diverse soil quality which was required for the findings.

In present study soil carbon sequestration potential in different land use (i.e., forested, cultivated and uncultivated land) were studied in different soil series of Dewa block, District Barabanki, U.P. The main purpose of this study was characterized, classified and to estimate carbon sequestration potential in different soil series. Dewa block were categorized in eight soil series i.e., Gangauli, Bajgahani, Sihali, Ukhadi, Nayagaon, Dadra, Nigari and Maharaur soil series on the basis of his characteristic feature. Gangauli and Sihali soil series were Udic Ustochrepts while Bajgahani, Nayagaon and Maharaur were Aeric Halaquept. Ukhdi and Nigari were Natric Ustochrepts but Dadra soil series was Typic Ustochrepts.

The three decades data comparison with the present data showed the increased organic content and carbon sequestration potential in the soils which proved the effect of climate change on soil organic carbon stock. Forested land showed the maximum carbon sequestration potential in every soil series showed the role of trees in sequestering of atmospheric carbon and utilizing it in proper manner in todays scenario of changing climate.

Before three decades, soil carbon sequestration in Udic Ustochrepts (Gangauli and Sihali soil series) was ranged 20.34-32.41 Mt $CO_2$ equivalent $ha^{-1}$ in surface while in subsurface it was ranged 29.72-33.02 Mt $CO_2$ equivalent $ha^{-1}$ that was slightly higher than surface soil. Present time it was significantly increased after three decades in surface (53.95 – 58.92 Mt $CO_2$ equivalent $ha^{-1}$) as well as in subsurface soil (41.77 – 59.01 Mt $CO_2$ equivalent $ha^{-1}$) which was less than surface soil. Similar trends were also observed in Aeric Halaquept (Bajgahani, Nayagaon and Maharaur soil series), Natric Ustochrept (Ukhdi and Nigari soil series) and Typic Ustochrept (Dadra soil series). Although, Aeric Halaquept had reported least carbon sequestration in surface soil (0.79-22.58 Mt $CO_2$ equivalent $ha^{-1}$) and subsurface soil (6.03-25.79 Mt $CO_2$ equivalent $ha^{-1}$) before three decades which was significantly increased after three decades in surface soil (67.41-71.19 Mt $CO_2$ equivalent $ha^{-1}$) and subsurface soil (67.43-73.73 Mt $CO_2$ equivalent $ha^{-1}$) and Natric Ustocrept had also low carbon sequestration in surface(3.23-4.69 Mt $CO_2$ equivalent $ha^{-1}$) and in subsurface soil ( 10.38-16.95 Mt $CO_2$ equivalent $ha^{-1}$) before three decades which was significantly increased in present both in surface soil (55.68-58.92 Mt $CO_2$ equivalent $ha^{-1}$) and subsurface soil (55.31-66.40 Mt $CO_2$ equivalent $ha^{-1}$).

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# INTRODUCTION

Soil is said to be the mother of nature. Soil maintains the energy flow and balance the ecosystem. Any change in environment influences the soil and also can be controlled by the soil. Soil is the storage of different organic and inorganic minerals and materials. Soil shows diversity in its character, composition structure and behavior etc. characteristics of the soil vary widely from place to place. Every well developed, undisturbed soil has its own distinctive profile characteristics, and is utilized in soil classification and survey. The upper layers or horizons of a soil profile generally contain considerable amounts of organic matter and are usually darkened appreciably just because of its abundant storage. The layers below considered as sub soils contains less organic matter comparatively to top soil. Soil enrichment can be done by proper cultivation and incorporation of organic residues. The organic matter content of a soil is small, however, is far greater than the low percentage would indicate. Organic matter increases the amount of water holding capacity. The chemical and physical properties of soils are controlled largely by clay and Humus which are centers of activity around which chemical reactions and nutrient exchange occur. Some seventeen elements have been found to be universally essential for growth out of which fourteen comes from soil solids. Carbon stored in soils represents the largest carbon pool in nearly all terrestrial biomes and thus it has a huge potential for either sequestering or releasing carbon into the atmosphere.

Soil carbon is important as it determines ecosystem and agro-ecosystem functions, influencing soil fertility, water-holding capacity and other soil parameters. It is also of global importance because of its role in the global carbon cycle and therefore, the part it plays in the mitigation of atmospheric levels of greenhouse gases (GHGs), with special reference to $CO_2$. Soil carbon sequestration is the process of transferring carbon dioxide from the atmosphere into the soil through crop residues and other organic solids, and in a form that is not immediately emitted. This transfer or sequestering of carbon helps to off-set emissions from fossil fuel combustion and other carbon-emitting activities while enhancing soil quality and long-term agronomic productivity.

World is facing varieties of manageable and unmanageable environmental issues. Among all the environmental issues, the major global issue of nowadays is the changing climate, which has moved in a very remarkable way of public concern in limited period of time. Day by day increasing pollution lead to this remarkable change in the Earth`s climate, which has led to scientist discussion debates and a matter of research. Human activities have resulted in the alteration of the composition of our atmosphere triggering change in the Earth's climate. The world's population has grown at an alarming rate with a corresponding increase in demand for natural resources, energy, food, and goods. As a consequence of increase in consumption, vast quantities of gases and effluents are discharged that change the composition of the atmosphere and its capacity to regulate its temperature.

The rise in the global temperature is caused by the accumulation of the so-called "greenhouse gases", namely, carbon dioxide ($CO_2$), methane, nitrous oxide, and chlorofluorocarbons. Energy received from the sun is absorbed as short wavelength radiation and is eventually returned to space as long wavelength infrared radiation. Greenhouse gases absorb the infrared radiation, trapping it in the atmosphere in the form of heat energy. By increasing the atmosphere's ability to absorb infrared energy, the greenhouse gases are disturbing the way the climate maintains the balance between incoming and outgoing energy. This increases the probability of occurrence of unseen and unpredictable events across the planet.

There has been an increase of average global surface temperature by 0.6 $^{0}$C during the last 100 years as a consequence of human activities, such as deforestation and burning of fossil fuels. The Intergovernmental Panel on Climate Change (IPCC) stated in its Third Assessment Report that the globally averaged surface temperature is projected to increase by 1.4 °C to 5.8 °C from 1990 to 2100 under business-as-usual, and sea levels by 9 cm to 88 cm over the same period. If nothing is done to prevent or limit these changes, they will have major consequences for the ecosystem.

This sudden and high rate of climate change lead to environment issues like global warming, acid rain, stratospheric ozone depletion, landslides and many more hilarious environmental issues. which is induced by the GHG`s present in atmosphere, that which are produced by the uncontrolled human practices of fossil fuel combustion, cutting down of trees, soil degradation and many more devastating steps taken up by humans for their survival. According to the Inter-governmental Panel on Climate Change (IPCC, 2007) a temperature increase between 1.1 and 6.4°C by the end of the 21$^{st}$ Century due to GHG`s has been reported. Since the industrial revolution, there has been a drastic increase in the atmospheric concentration of carbon dioxide ($CO_2$) and other greenhouse gases like methane ($CH_4$), nitrous oxide ($N_2O$) etc. Warm seasons will become dryer in the interior of most mid-latitude continents, increasing the frequency of droughts and land degradation. This will be particularly serious for areas where land degradation, desertification and droughts are already severe. Additionally, tropical diseases will extend beyond their present geographic range. A report released by WWF shows that human induced global warming was a key factor in the severity of the 2002 drought in Australia, which has been regarded as the worst ever. Rising sea levels are the scaring fact nowadays for the whole world. It is hence important for the suffering countries like one is India to take proactive steps to fight back such environmental issues. The increasing global population so enormously leads to the enormous usage of natural resources which is remarkable, as high consumption of such natural resources leads to consequences like pollution due to discharging gases and affecting the capacity of atmosphere in regulating temperature.

The atmospheric concentration of $CO_2$ has increased from 280 ppmv in 1750 to 367 ppmv in 1999 and is currently increasing at the rate of 1.5 ppmv/year or 3.3 Pg C/year [1 Pg (petagram) = billion ton=1015g] (IPCC, 2001). At present the amount of $CO_2$ in the atmosphere crossed the range of 390 ppmv (IPCC 2013). It is alarming to note that the atmospheric methane ($CH_4$) concentration has increased from about 700 to 1745 ppmv over the same period and is increasing at the rate of 7 ppbv/year. Likewise, the atmospheric concentration of nitrous oxide ($N_2O$) has also increased from about 270 ppbv in 1750 to 314 ppbv and is increasing at the rate of 0.8 ppbv/year (IPCC, 2001). This anthropogenic enhancement of GHG`s in the atmosphere and the subsequent cumulative radiative forcing of all these GHG`s has led to an amplification in the average global surface temperature of 0.6°C since the late $19^{th}$ century, with the current warming rate of 0.17°C/decade (IPCC, 2001). The observed rate of increase of the global mean temperature is in excess of the critical rate of 0.1°C/decade beyond which the ecosystems cannot adjust. Out of different atmospheric gases, oxides of carbon are said to be the major pollutant, and considered as main greenhouse gas. The EPA lumped carbon dioxide with five other gases -- methane, nitrous oxide, hydro fluorocarbons, per fluorocarbons and sulfur hexafluoride into a single class for regulatory purposes. That's because they share similar properties: All are long-lived and well-mixed in the atmosphere; all trap heat that otherwise would leave the earth and go into outer space; and all are "directly emitted as greenhouse gases" rather than forming later in the atmosphere. (Johnson, 2009). These increasing GHG`s are uncontrollable. The concentration of $CO_2$ in the atmosphere has risen from close to 280 parts per million (ppm) in 1800, at first slowly and then progressively faster to a value of 367 ppm in 1999, Atmospheric $CO_2$ is, however, increasing only at about half the rate of fossil fuel emissions; the rest of the $CO_2$emitted either dissolves in sea water and mixes into the deep ocean, or is taken up by terrestrial ecosystems (Helene and Ibarra, 1999).

The two most important anthropogenic processes responsible for the release of carbon dioxide into the atmosphere are burning of fossil fuels (coal, oil and natural gas) and soil disturbances (Houghton, 1995). Soils have a pivotal role in determining global carbon cycle dynamics by serving as the link between the atmosphere, vegetation and oceans. Globally, the soil carbon pool is estimated at 2,500 Gt (1 Gt = $10^9$ t) to 2 meters deep. Out of this, the soil organic carbon pool comprises 1,550 Gt, while the soil inorganic carbon and elemental pools make up the remaining 950 Gt (Batjes, 1996). The soil carbon pool is more than three times the size of the atmospheric pool (760Gt) and about 4.5 times the size of the biotic pool (560Gt). The annual fluxes of $CO_2$ from atmosphere to land (Global Net Primary Productivity (NPP) and land to atmosphere (respiration and fire) are of the order of 60Pg $Cy^{-1}$ (IPCC, 2000). The size of the pool of soil organic carbon (SOC) is therefore large compared to gross and net annual fluxes of carbon to and from the terrestrial biosphere. Because of the large quantity of carbon (C) stored in soils, small modifications in soil C status may have a significant effect on the global C balance and therefore on climate change (Gonzalez et. al., 2004). Soil maintains the energy flow and balance the ecosystem. Any change in environment influences the soil and also can be controlled by the soil. Soil is the storage of different organic and inorganic minerals and materials. Soil shows diversity in its character, composition structure and behavior etc. characteristics of the soil vary widely from place to place. Every well developed, undisturbed soil has its own distinctive profile characteristics, and is utilized in soil classification and survey.

The upper layers or horizons of a soil profile generally contain considerable amounts of organic matter and are usually darkened appreciably just because of its abundant storage. The layers below considered as subsoils contains less organic matter comparatively to top soil. Soil enrichment can be done by proper cultivation and incorporation of organic residues. The organic matter content of a soil is small, however, is far greater than the low percentage would indicate. Organic matter increases the amount of water holding capacity. The chemical and physical properties of soils are controlled largely by clay and humus which are centers of activity around which chemical reactions and nutrient exchange occur. Carbon stored in soils represents the largest carbon pool in nearly all terrestrial biomes and thus it has a huge potential for either sequestering or releasing carbon into the atmosphere. It is therefore important to understand the dynamics of soil carbon as well as its role in terrestrial ecosystem carbon balance and the global carbon cycle. Soil carbon is the last major pool of the carbon cycle. The carbon that is fixed by plants is transferred to the soil via dead plant matter. This dead organic matter creates a substrate which decomposes and respires back to the atmosphere as $CO_2$ or $CH_4$ depending on the availability of oxygen in the soil. Soil carbon is also oxidized by combustion and returned to the atmosphere as $CO_2$ (Lal, 2004). Soil carbon is primarily composed of biomass and non-biomass sources. Some of the carbon compounds are easily digested and respired by the microbes resulting in a relatively short residence time. Others, like lignin, humic acid or substrate encapsulated in soil aggregates are very difficult for the biomass to absorb and have long residence times.

Through terrestrial ecosystem, carbon dioxide capture in form of biomass and that have been recycled in soil in form of Soil Organic Carbon (SOC). Balanced ecosystem can only be achieved by restoration of degraded ecosystem, which can be carried out by the process of carbon sequestration. Carbon sequestration is the process in which carbon is captured from the atmosphere and utilized for the soil enrichment, by long term storage for mitigating and avoiding dangerous Climate Change. The carbon captured can be done either biologically, chemically or physically. Planting of trees or crops on barren or degraded land or pastures is the biological way of Carbon sequestration. Climate change is one of the most significant global challenges of our time and addressing it requires the urgent formulation of comprehensive and effective policy responses. The elemental and inorganic forms of soil carbon primarily result from mineral weathering and are less responsive to land management than soil organic carbon. Different fractions or soil organic carbon pools have different functions within the soil system. Crop residues are readily broken down and serve as substrates to soil microorganisms in the form of humus. The humus fraction can be classified into two depending on the level of decomposability: The first is active humus that is still subject to further decomposition, and the other is passive humus (or recalcitrant carbon), the highly stable, insoluble form that is not subject to further decomposition. Some very stable humus complexes can remain in the soil for centuries or millennia (Post and Kwon, 2000). The soil organic carbon pool represents a dynamic balance between gains and losses. The amount changes over time depending on photosynthetic C added and the rate of its decay.

The potential carbon storage is controlled primarily by pedological factors including soil texture and clay mineralogy, depth, bulk density, aeration and proportion of coarse fragments etc. SOC is recognized to consist of various fractions varying in degree of decomposition, recalcitrance and turn-over rate (Huang et. al., 2009). Some SOC factions, such as particulate organic carbon (POC), labile organic carbon (CL) and potential carbon mineralization (PCM) have been considered as more sensitive indicators for disturbance than total SOC (Chan, 2001; Purakayastha et. al.,2008; Gong et. al.,2009). Particulate Organic Carbon (POC) has been considered as an intermediate pool of SOC between active and slow fractions that change rapidly over time due to changes in management practices. The POC also provides substrates for microorganisms and influences soil aggregation. POC is broken down relatively quickly but more slowly than other crop residues and is important for soil structure, energy for biological processes, and provision of nutrients for plants. Due to its greater labiality, POC is a more sensitive indicator of land use changes and management than SOC (Cambardella and Elliott, 1992, 1993; Cambardella et. al., 2001). Among the different forms of SOC, labile organic carbon (CL) with turn over time of a few days to months can be considered as a fine indicator of soil quality, which influences soil function in specific ways and is more sensitive to changes in soil management practices (Cambardella, 1998; Hoyle et. al., 2006). Potential carbon mineralization (PCM) and Microbial biomass carbon (MBC) are biologically active fractions of SOC that change rapidly with time could better reflect changes in soil quality and productivity that alter nutrient dynamics due to immobilization- mineralization (Saffigna et. al., 1989; Bremner and Kissel, 1992).

Accumulating evidence suggests that these fractions of soil organic matter are more important in maintaining soil quality and are, therefore, more sensitive indicators (Cambardella and Elliott, 1992; Duxbury and Nkambule, 1994; Chan, 1997).

Inter-aggregates resulting from physico-chemical and biological interaction in soil ecosystem can physically protect the organic carbon from decomposers. Especially, Water Stable Aggregate (WSA) has been recognized as one of the standard features of soil quality, sensitive to land management practices, as well as relating to erosion, carbon dynamics, and material transport (Kyung et. al., 2010). The loss and gain of organic C in soils depend on soil type, soil temperature, soil erosion, vegetation type and management. Apart from this, the level of SOC in a particular soil is depended on many factors including land use and land use management. Land use change is a global concern due to its adverse effect on climate through soil based emission of greenhouse gases (GHGs) (Batjes, 1996; Lal et. al., 1997; Post et. al., 1999). The loss of soil organic carbon by conversion of natural vegetation to cultivated use is well known. Various land uses result in very rapid declines in soil organic matter (Jenny 1941, Davidson and Ackerman 1993, Mann 1986, Schlesinger 1985, Post and Mann 1990). Deforestation, land use change from forest to grazing land or agricultural land are examples of human activities that increase atmospheric concentration of GHGs, especially $CO_2$ and $CH_4$ (Shrestha et al., 2007). The atmospheric carbon (C) pool has steadily increased since 1850 and is currently increasing at the rate of 0.5% per year due to burning of fossil fuels and land use changes (Lal, 2002). The $CO_2$ emission from land use change only was estimated to be 1.7 Pg C $yr^{-1}$ in 1980-1989 and 1.6 Pg C $yr^{-1}$ in 1989-1998 (IPCC, 2000).

The current rate of carbon loss due to land use change and related land change processes (erosion, tillage operations, biomass burning, excessive fertilizers, residue removal, and drainage of peat lands) is between 0.7 and 2.1 Gt carbon per year. This is more than 50 percent of the carbon absorbed by land. Soil erosion is the major land degradation process that emits soil carbon. Globally, soil erosion accounts for up to 1.2 Gt of C emitted to the atmosphere annually. Each year, the terrestrial carbon pool assimilates 120 Gt C from the atmosphere in the form of gross primary productivity (or photosynthesis). Soil respiration, the flux of microbial and plant-respired $CO_2$ from the soil surface to the atmosphere, estimated to be 75 to 100 Gt C per year is he next largest terrestrial carbon flux (Raich and Potter, 1995). It is about 60 times the annual contribution of land-use change and about 11times that of fossil fuel to atmospheric emissions. Thus, a small change in soil respiration can significantly alter the balance of atmospheric $CO_2$ concentration compared to soil carbon stores. Soil respiration is regulated by several factors including temperature, moisture, vegetation type, nitrogen content and level of aeration of the soil. Climate change is positively correlated with increasing rate of soil respiration. Higher temperatures trigger microbes to speed up their consumption of plant residues and other organic matter. Variations in temperature are significantly and positively correlated with changes in global soil respiration (Lamberty and Thompson, 2010). A rise in temperature by 2°C is estimated to release an additional 10 Gt C per year to the atmosphere through soil respiration (Friedlingstein et. al., 2006). Tillage operations can significantly affect soil respiration. Conventional tillage leads to the destruction of soil aggregates, excessive respiration and soil organic matter decomposition, leading to reduced crop production and decreased resilience of the soil ecosystem. Excessive application of large amounts of nitrogenous fertilizer can markedly increase root biomass and stimulate soil respiration rates. Soil can be a source or a sink of atmospheric C depending upon land use and management (Lal, 2003). Soils represent the major reservoir of organic carbon. At the global level, the soil organic matter (SOM) pool (estimated to 1m depth) contains about 1580 Pg of carbon, about 610 Pg stored in the vegetation and about 750 Pg present in the atmosphere (Schimel, 1995). About one third of organic soil carbon occurs in forests and another third in grasslands and savannas, the rest in wetlands, croplands and other biomes. Consequently, any net carbon loss from soils will increase the $CO_2$ concentration in the atmosphere and in water bodies, whereas net accumulation in soil carbon (or sedimentation in rivers or lakes etc.) can contribute to the reduction of the atmospheric carbon pool (Ellert et. al., 2001). This cycling of carbon is increasingly influenced by human activities (IPCC, 2007). Thus atmospheric $CO_2$ concentrations have been increasing globally due to soil based emissions; the question of reducing these emissions is gaining increased importance. SOC storage has been widely considered as a measure for mitigating global climate change through C sequestration in soils (Huang et al., 2009). Soil C sequestration can be achieved by increasing the net flux of C from the atmosphere to the terrestrial biosphere by increasing global C inputs to the soil (via increasing NPP), by storing a larger proportion of the C from NPP in the longer-term C pools in the soil, or by reducing C losses from the soils by slowing decomposition. For soil C sinks, agricultural practices are the best way to increase C stocks in soils. Soil C sinks are not permanent and will continue only for as long as appropriate management practices are maintained. If a land-management or land use change is reversed, the C accumulated will be lost, usually more rapidly than it was accumulated (Smith et. al., 1996). For the greatest potential of soil C sequestration to be realized, new C sinks, once established, need to be preserved in perpetuity. Multiple land uses especially agriculture land, forestland, grassland and wetland act as source and sink of carbon. Soil carbon sequestration potential of different land uses varies on spatial and temporal basis along with the interplay of environmental externalities, land use changes and management practices. Soil carbon sequestration has been identified as a potential mitigation practice to help attenuate the rate of increase of atmospheric $CO_2$ which is the major GHG behind climate change. As the source of the major bulk of the soil carbon is contributed by the soil organic carbon (84 to 97%) it is necessary to embark upon regional level studies focused on the organic carbon and dynamics in relation to climate change so as to formulate a management plan emphasizing minimum global warming potential.

Soil is the important carbon (C) pool (organic and inorganic) as it contains three times more C than in atmosphere and 3.8 times more C than in biotic pool (Batjes and Sombroek, 1997; Lal et. al., 1997). It can be a source or a sink of atmospheric C depending upon land use and management (Lal, 2003).For a given soil type, SOC stock can also vary, the stock being determined by the balance of net C inputs to the soil (as organic matter) and net losses of C from the soil (as carbon dioxide, dissolved organic C and loss through erosion). Organic matter is a crucial fraction of soil affecting attributes and processes known to influence ecosystem functioning and productivity. The amount of organic matter stored in soils is controlled by natural site-specific factors such as parent material, climate, topography, land cover and human-induced factors associated with land use (Schils et al., 2008; Pineiro et al., 2010). Land use can be an important factor mitigating climate change, as it may have an impact on soil organic matter (SOM) storage (Schils et. al., 2008). From the global evidence it can be seen that the effects of land use change on soil carbon stocks are of concern in the context of international policy agendas on the mitigation of global greenhouse gas emissions (GHGs) (UNFCCC, 2003). Other studies (Batjes, 1996; Lal et. al., 1997; Post et. al., 1999) also showed that land use change has a global concern due to its adverse effect on climate through emission of GHGs. Land use change is rapid in the developing countries and the problem has been increasing due to population growth and increasing land scarcity (Lal, 2000; Upadhyay, 2006) which leads to encroachment into forests and/or crop intensification. The rates of C sequestration and its underlying mechanisms, however, have rarely been determined in multiple, replicated, differently managed ecosystems on the same soil types. Most long term experiments on land use change show significant changes in SOC (Smith et. al., 2000, 2001, 2002). SOC tends to be lost when converting grasslands, forest or other native ecosystems to croplands, or by draining, cultivating or liming highly organic soils. SOC tends to increase when restoring grasslands, forests or native vegetation on former croplands, or by restoring organic soils to their native condition. When the land is managed with appropriate management practices that increases C inputs to the soil (e.g. improved residue and manure management) or reduce losses (e.g. reduced tillage, reduced residue removal) help to maintain or increase SOC levels. If a land management or land use change is reversed, the C accumulated will be lost, usually more rapidly thanit was accumulated (Smith et al., 1996).

Changes in land use are foreseeable for serving the societal needs which alter the soil carbon stock. Delineating the aspect that determine the extent of the current soil carbon stock and the balance between carbon inputs and soil carbon losses and also the soil - land use functional system is decisive in predicting the effects of future land use change on the net greenhouse gas stability, and to the development of a strategy for 'carbon conscious' management of the land surface. A scientific basis for the understanding of the role of land use and land use change and current management aspects in carbon sequestration is therefore crucial to the sustainable management of the carbon reservoir.

The present study area is Dewa Block, Barabanki district comprises all the land use categories as described by IPCC for the carbon inventory under multiple land use systems. The district Barabanki lies between 27°19' and 26°30' north latitude, and 80°05' and 81°51' east longitude; it runs in a south-easterly direction, confined by the nearly parallel streams of the Ghaghara and Gomti surrounded by Baharich, Sitapur, lucknow, Raibareli, Sultanpur and Faizabad district. The district consist of 06 Sub Division (Tehasil), 17 C.D. Blocks, 163 Nayaya Panchayat 833 Village Panchayat and 2360 revenue village with a geographical area of about 2981 sq. km. present a complex variety of landscape and falls under Eastern plain Agro Climatic Zone . However the influence of various soil series with unique characteristic features significantly influence the soil carbon storage of multiple land use categories. The soil carbon dynamics of the present study area has not been assessed yet and remains as a limitation in a grass root level system approach.

## 1.1 Aims and Objectives

The present study aims to explain the role of selected multiple land use categories i.e. forested, cultivated and uncultivated on the soil organic carbon (SOC) and carbon sequestration potential in different land use of Dewa Block with following aims and objectives .

- To characterized and classified the soils of Dewa block, Barabanki, U.P.
- To estimate the organic carbon, soil organic carbon stocks and soil carbon sequestration potential in forested land, cultivated land and uncultivated land.
- Comparative study of change in current soil carbon stock and soil carbon sequestration potential with three decade before soil condition of Dewa Block.
- To estimate the role of soils to capture and store of carbon.
- To determine the soil carbon dynamics of a selected soil series and land use.

# Chapter 2
# Review of Literature

# REVIEW OF LITERATURE

## 2.1 Problem concern with climate change

Global warming has emerged as one of the most prominent global environmental issues which is caused by the increase in the concentration of greenhouse gases (GHGs) in the atmosphere. According to the Inter-governmental Panel on Climate Change (IPCC, 2007) a temperature increase between 1.1 and 6.4°C by the end of the 21st Century due to GHGs has been reported. The atmospheric concentration of $CO_2$ has increased from 280 ppmv in 1750 to 367 ppmv in 1999 and is currently increasing at the rate of 1.5 ppmv /year or 3.3 Pg C/year [1 Pg (petagram) = billion ton=$10^{15}$g] (IPCC 2001 and Stern 2006).

There has been an increase of average global surface temperature by 0.6 $^{0}$C during the last 100 years as a consequence of human activities, such as deforestation and burning of fossil fuels. The Intergovernmental Panel on Climate Change (IPCC) stated in its Third Assessment Report is that the globally averaged surface temperature is projected to increase by 1.4 °C to 5.8 °C from 1990 to 2100 under business-as-usual, and sea levels by 9 cm to 88 cm over the same period. If nothing is done to prevent or limit these changes, they will have major consequences for the ecosystem (IPCC (2001). The effects of climate change are manifest in several ways. Globally, precipitation is on the rise. In the Northern Hemisphere, precipitation has increased by 0.5% to 1.0% per decade whereas the increase in tropical countries has been 0.2% to 0.3% per decade (Hitz and Smith 2004). The changes in the global climate have caused a reduction of the snow pack in northern latitudes, a melting of mountain glaciers, a thawing of the Arctic permafrost, and a shrinking of the polar ice caps. The average sea level of the world's oceans has risen 10 cm to 20 cm in the last century. It is generally accepted that our climate is changing due to increased concentration of green house gases. Temperature affects almost all aspects of terrestrial carbon processes; increasing earth's surface temperature likely enhances ecosystem carbon fluxes, potentially feeding back to a buildup of atmospheric $CO_2$ concentration and climate dynamics (Luo et. al., 2007). Anthropogenic activities have led to notable changes in the earth's climate including increase in the global temperature over the 20th century by $0.6 \pm 0.2^{\circ}C$ at an average rate of increase of $0.17^{\circ}C$/decade since 1950, sea level rise over the 20th century of 0.1 to 0.2 m, increase in precipitation of 0.5 to 1.0%/decade, and increase in frequency of extreme events and heavy precipitation by 2 to 4% (IPCC, 2001). The continuous and rapid increase in carbon dioxide and other greenhouse gases (GHG`s) in the atmosphere could lead to significant climate change (IPCC, 2007).

The total carbon dioxide-equivalent emissions from India are estimated to be 1,001,352 Gg (1000 Mt), which is about three percent of the total global carbon dioxide-equivalent emissions. Based on this, the per capita carbon dioxide-equivalent emissions for 1990 are estimated to be 1.194 tonn or 325 kg of carbon. In comparison, the per capita emissions for Japan and the US are 2400 and 5400 kg of carbon respectively in 1990. India's $CO_2$ emissions are far below the developed countries but it will be one of the nations which could possibly be seriously affected by global warming and the resulting climate change, partly due to its high population density and partly due to its long coast line. There is a difference between stabilizing $CO_2$ emissions and stabilizing atmospheric concentrations of $CO_2$ (USCCSP, 2009).

The most important reservoirs of $CO_2$ are atmosphere, lithosphere, biosphere and oceans. Most of the carbon in the atmosphere exists as carbon dioxide. $CO_2$ is the principal anthropogenic greenhouse gas that affects the earth's radioactive balance (IPCC 2001; Broadmeadow et. al., 2003). The amount of $CO_2$ present in the atmosphere (although small, 0.037%) plays a crucial role to maintain the earth surface temperature (IPCC, 2001). The atmospheric concentration of $CO_2$ has historically oscillated between about 180ppm during glacial periods and 280ppm during interglacial periods (Falkowski et. al., 2000). Due to burning of fossil fuels, cement production, deforestation and agricultural development, the atmospheric $CO_2$ concentration increased from the pre-industrial level of about 280ppm (parts per million) to 391.19ppm in 2011 (NOAA, 2011). The anthropogenic $CO_2$ that did not accumulate in the atmosphere must have been taken up by the ocean, by the land biosphere, or by a combination of both (Sabine et. al., 2004).

At present the amount of $CO_2$ in the atmosphere crossed the range of 390 ppmv (IPCC 2013). This anthropogenic enhancement of GHGs in the atmosphere and the subsequent cumulative radiative forcing of all these GHGs has led to an amplification in the average global surface temperature of 0.6°C since the late 19th century, with the current warming rate of 0.17°C/decade (IPCC, 2001). Amongst the various green house gases, $CO_2$ is the most important, contributing 60% of the global warming followed by methane (15%) and nitrous oxide (5%) (Pathak et al., 2003). Soils of the world are potentially viable sinks for atmospheric carbon (C) and may significantly contribute to mitigation of global climate change (Lal et. al., 1997). The increase in atmospheric carbon dioxide ($CO_2$) concentrations due to missions from fossil fuel combustion is contributing to recent climate change which is among the major challenges facing the world. Lorenz and Lal, 2014 stated that Carbon storage is widely acknowledged as one of the most valuable forest ecosystem services. Bello et.al., 2015 examined that deforestation, logging, fragmentation, fire and climate change have significant effects on tropical carbon stocks. Sedjo, 2001 suggested that a major problem being faced by human society is that the global temperature is believed to be rising due to human activity that releases carbon dioxide to the atmosphere, i.e., global warming. The major culprit is thought to be fossil fuel burning, which is releasing increasing amounts of carbon dioxide in the atmosphere.

Anthropogenic activities have led to notable changes in the earth's climate including increase in the global temperature over the 20th century by $0.6 \pm 0.2^{\circ}C$ at an average rate of increase of $0.17^{\circ}C$/decade since 1950, sea level rise over the 20th century of 0.1 to 0.2 m, increase in precipitation of 0.5 to 1.0%/decade, and increase in frequency of extreme events and heavy precipitation by 2 to 4% (IPCC, 2001). There are a number of anthropogenic greenhouse gases. These include carbon dioxide (chemical formula: $CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), and a group of gases referred to as halocarbons. The emissions reductions necessary to stabilize the atmospheric concentrations of these gases varies. (Meehl et. al, 2007) $CO_2$ is the most important of the anthropogenic greenhouse gases (IPCC, 2007). Widespread concern about global climate change has led to interest in reducing emissions of carbon dioxide ($CO_2$) and, under certain circumstances, in counting additional carbon absorbed in soils and vegetation as part of the emissions reductions.

**2.2 Climate change mitigation**

Reducing concentrations of carbon dioxide ($CO_2$) and other green- house gases (GHG's) in Earth's atmosphere is identified as one of the most pressing modern-day environmental issues (IPCC 2007). Widespread concern about global climate change has led to interest in reducing emissions of carbon dioxide ($CO_2$) and, under certain circumstances, in counting additional carbon absorbed in soils and vegetation as part of the emissions reductions. It may consider options to increase the carbon stored (sequestered) in forests as it debates this and related issues.

Climate change mitigation generally involves reductions in human (anthropogenic) emissions of greenhouse gases (IPCC, 2007). Climate change mitigation consists of actions to limit the magnitude or rate of long-term climate change (Fischer et al., 2007). Mitigation may also be achieved by increasing the capacity of carbon sinks, e.g., through reforestation. Mitigation policies can substantially reduce the risks associated with human-induced global warming. These consequences will include geographic shifts in the occurrence of different species and/or the extinction of species. Changes in rainfall patterns will put pressure on water resources in many regions, which will, in turn, affect both irrigation and drinking water supplies. Extreme weather events and floods will become more frequent with their increasing economic costs and human suffering.

Oceans contain carbon in the form of bicarbonate or carbonate ions (Korhonen et al., 2002). There are three forms of carbon present on earth viz., 1) elemental 2) inorganic and 3) organic (Schumacher, 2002). The primary sources for elemental carbon in soils and sediments are as incomplete combustion products of organic matter from geologic sources (i.e., graphite and coal), or dispersion of these carbon forms during mining, processing, or combustion of these materials (Schumacher, 2002). Inorganic carbon in the soil occurs largely in carbonate minerals, such as calcium carbonate ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$) (Nieder and Benbi, 2008). The naturally occurring organic carbon (OC) forms are mainly derived from the decomposition of plants and animals. In soils a wide variety of OC forms are present, ranging from freshly deposited litter such as leaves, twigs, and branches to highly decomposed forms such as humus (Buringh, 1984). Plant litter and microbial biomass are the major parent materials for soil organic matter (SOM) formation (Knabner, 2002; Kramer and Gleixner, 2006). The three forms of carbon (elemental, organic and inorganic) are recycling between the reservoirs such as ocean, biosphere, atmosphere and living things by photosynthesis, respiration, burning, burial of organic matter, decomposition, and weathering processes (West, 2008).

Ocean is one of the largest reservoirs of carbon. The atmosphere and the ocean have powerful exchange of carbon. The total exchange of carbon between atmosphere and oceans is controlled by two principal processes viz., the solubility (or physical) pump and the biological pump (U.S.Department of Energy, 2005). In the past 200 years the oceans have absorbed approximately half of the $CO_2$ produced by fossil fuel burning and cement production (Ravens, 2005). The pH of our ocean surface waters has already fallen by about 0.1 units from about 8.16 to 8.05 since the beginning of the industrial revolution around 200 years ago (The Royal Society, 2005). If global emissions of $CO_2$ from human activities continue to rise on current trends then the average pH of the oceans could fall by 0.5 units (equivalent to a threefold increase in the concentration of hydrogen ions) by the year 2100 (Ravens,2005) many of the ecological, chemical, and geological elements of the deep sea and, therefore, the effects of injecting carbon dioxide into the ocean, are widely unknown (Nieder and Benbi, 2008).The two main forms of carbon in the sea are carbonate ($CO_3$) and bicarbonate ions ($HCO_3$). Bicarbonate ions are created when $CO_2$ molecules dissolved water under go a chemical reaction and combine with hydrogen (West, 2008). About 88% of the inorganic carbon in the sea is made up of bicarbonate ions (West, 2008). Carbon transfers relatively slowly from the surface layers of the sea to the depths (Siegenthaler and Sarmiento, 1993).

Soil carbon sequestration is yet another strategy towards mitigation of climate change. Soil carbon pool plays a crucial role in the soil quality, availability of plant nutrients, environmental functions and global carbon cycle (Srinivasarao et. al., 2009b).

To mitigate the effect of atmospheric $CO_2$, carbon capture and storage (CCS) has been found to be an important tool. Soils capture and store both organic and inorganic forms of carbon and thus act both as source and sink for atmospheric $CO_2$ (Bhattacharyya et.al 2008). Carbon sequestration has been suggested as a means to help mitigate the increase in atmospheric carbon dioxide concentration (Mangalassery et. al., 2014). De-Deyn, et. al., (2008) proposed that a trait-based approach will help to develop strategies to preserve and promote carbon sequestration.

Forests considered to a sink as well as a source of carbon dioxide, are reported to be a major component of the carbon reserves in the world's ecosystems (Houghton, 2007). The name "carbon" actually comes from the latin word *carbo,* meaning charcoal (West, 2008). It is the backbone of all kinds of structural and functional compounds necessary for life. Carbon exists throughout the planet in several reservoirs and in a variety of forms (The Royal Society, 2005). Tropical reforestation (TR) has been highlighted as an important intervention for climate change mitigation because of its carbon storage potential. Reforestation can ameliorate climate-associated impacts of altered hydrological cycles in watersheds, protect coastal areas from increased storms, and provide habitat to reduce the probability of species' extinctions under a changing climate (Locatelli et. al., 2015).

Atmospheric $CO_2$ enters terrestrial ecosystem by the process of photosynthesis. Photosynthesis is a natural process by which plants fix $CO_2$ to produce carbohydrates, which are then used in different metabolic pathways (Jimenez et. al., 2007). This carbon is stored in plapt components including trunks, branches, leaves and roots (Kishwan et al., 2009). The biomass carbon enters the soil through the decomposition, a key process in the carbon cycle due to its two interrelated sub-processes, i.e., mineralization and humification (Jimenez et. al., 2007). Mineralization is the process by which organic molecules are converted into inorganic forms assimilable by plants, and humification is the process by which soil organic matter levels are maintained, during mineralization $CO_2$ is emitted from respiration activities of soil microorganisms (Jimeijez et. al., 2007). Of the 120 Pg $CO_2$-C absorbed by photosynthesis, 60 Pg is returned back to the atmosphere through plant respiration and decomposition of soil organic matter or soil respiration (Lal, 2008).

The terrestrial biosphere plays a prominent role in the global carbon (C) cycle. Although a net source of C, some terrestrial ecosystems are currently accumulating C and it appears feasible to manage existing terrestrial (forest, agronomic, desert) ecosystems to maintain or increase C storage (Wisniewskil et.al, 1993). Sequestration of carbon in terrestrial ecosystems is a low-cost option that may be available in the near-term to mitigate increasing atmospheric $CO_2$ concentrations. In terrestrial ecosystems, forest ecosystems contain more carbon per unit area than any other land types (accounting for 60% of total carbon in terrestrial ecosystems) and their soils are of major importance for carbon storage (FAO, 2001). Forest vegetation and soils constitute a major terrestrial carbon pool with the potential to absorb and store $CO_2$ from the atmosphere (Lal, 2005; Kaul et al., 2010). Forest ecosystems are open system and exchange carbon, energy and materials with other systems including adjacent forests, aquatic ecosystems and the atmosphere. Thus, a forest ecosystem is never in equilibrium (Lorenz and Lal, 2010). Trees, the major components of forests, absorb large amounts of $CO_2$ by photosynthesis, and forests return an almost equal amount to the atmosphere by auto-and heterotrophic respiration (Lorenz and Lal, 2010). Forest ecosystems can be managed to sequester and store globally significant amounts of C. Agro ecosystems and arid lands could be managed to conserve existing terrestrial C but $CO_2$ sequestration rates by vegetation in these systems is relatively low. Biomass from forest agro ecosystem has the potential to be used as an energy source and trees could be used to conserve energy in urban environments. Some ecosystem management practices that result in C sequestration and conservation provide ancillary benefits (Wisniewskil et.al, 1993). The carbon sink capacity of the world's agricultural and degraded soils is 50 to 66% of the historic carbon loss of 42 to 78 gigatons of carbon. The rate of soil organic carbon sequestration with adoption of recommended technologies depends on soil texture and structure, rainfall, temperature, farming system, and soil management. Strategies to increase the soil carbon pool include soil restoration and woodland regeneration, no-till farming, cover crops, nutrient management, mannuring and sludge application, improved grazing, water conservation and harvesting, efficient irrigation, agro-forestry practices and growing energy crops on spare lands. An increase of 1 ton of soil carbon pool of degraded cropland soils may increase crop yield by 20 to 40 kg/ha for wheat, 10 to 20 kg/ha for maize, and 0.5 to 1 kg/ha for cowpeas. As well as enhancing food security, carbon sequestration has the potential to offset fossil fuel emissions by 0.4 to 1.2 gigatons of carbon per year, or 5 to 15% of the global fossil-fuel emissions (Lal, 2004). The magnitude of $CO_2$ emissions from agricultural and deforestation activities is estimated at about 1.6 x $10^3$ million t C $y^{-1}$ and SOC sequestration potential could offset about 15% of global $CO_2$ emission.

**2.3 Carbon sequestration potential and global carbon Pool**

Soil carbon has gained increased interest in the recent past owing to its importance in carbon sequestration studies and its potential impact on sustainable crop production. Carbon sequestration implies removing atmosphere carbon and storing it in natural reservoirs for extended periods (Lal, 2011). Soil carbon sequestration is the process of transferring carbon dioxide from the atmosphere into the soil through crop residues and other organic solids and in a form that is not immediately emitted. This transfer or sequestering of carbon helps to off-set emissions from fossil fuel combustion and other carbon-emitting activities while enhancing soil quality and long-term agronomic productivity. However, accuracy in estimating soil carbon sequestration to determine best management practices is hindered by inherent variability of soil properties (Srinivasarao et al., 2008, 2009b).

Carbon sequestration can be defined as the capture and secure storage of carbon that would otherwise be emitted to or remain in the atmosphere. The idea is to (1) prevent carbon emissions produced by human activities from reaching the atmosphere by capturing and diverting them to secure storage, or (2) remove carbon from the atmosphere by various means and store it (Kaisi, 2008). Carbon sequestration implies transfer of atmospheric $CO_2$ into other long-lived global pools including oceanic, pedologic, biotic and geological strata to reduce the net rate of increase in atmospheric $CO_2$ (Lal, 2008). Carbon sequestration implies capture and storage of atmospheric CO2 into long lived pools in ocean, geologic basalts, vegetation and soil by biotic and abioti strategies (Lal, 2004a). The capture and/or injected $CO_2$ is reacted with water to form carbonic acid ($H_2CO_3$) and subsequently the carbonic acid is encountered to form carbon bearing ionic minerals, finally further break down of these minerals could precipitate new carbonate minerals that would fix capture and /or injected in its most secure state over thousands to millions of years (Kumar, 2007). In contrast to oceanic and geologic carbon storage techniques, the terrestrial carbon sequestration in biotic strategies is based on natural process of photosynthesis and transfer of fixed atmospheric $CO_2$ into vegetative biomass and SOM pools. (Kishwan et. al. 2009 and Lal, 2008). The environmental perspective includes the removal of $CO_2$ from the atmosphere, the improvement of soil quality, and the increase in biodiversity (Batjes and Sombroek, 1997, Batjes, 1999, Lal and Bruce., 1999).

$CO_2$ is cycled through four main global carbon stocks: the atmosphere, the oceans, fossil fuels, and terrestrial biomass and soils (Fig 1). According to Watson et al. (2000), over the period 1989-1998, activities in the energy and building sectors increased atmospheric carbon levels by 6.3 Gigatons of carbon per year (Gt C $yr^{-1}$). Land-use change and forestry (LUCF) activities released 60 Gt C $yr^{-1}$ into the atmosphere and absorbed 60.7 Gt C $yr^{-1}$ with a net effect of decreasing atmospheric carbon levels by 0.7 Gt C $yr^{-1}$. Oceans removed about 2.3 Gt C $yr^{-1}$ from the atmosphere. The net result of these fluxes over the last 10 to 15 years is that atmospheric carbon levels have increased by about 3.3 Gt C $yr^{-1}$. Human activities release carbon as carbon dioxide by various means which alter carbon pools; the most important of these alterations is the transfer of carbon from its geologic pool to its atmospheric pool.

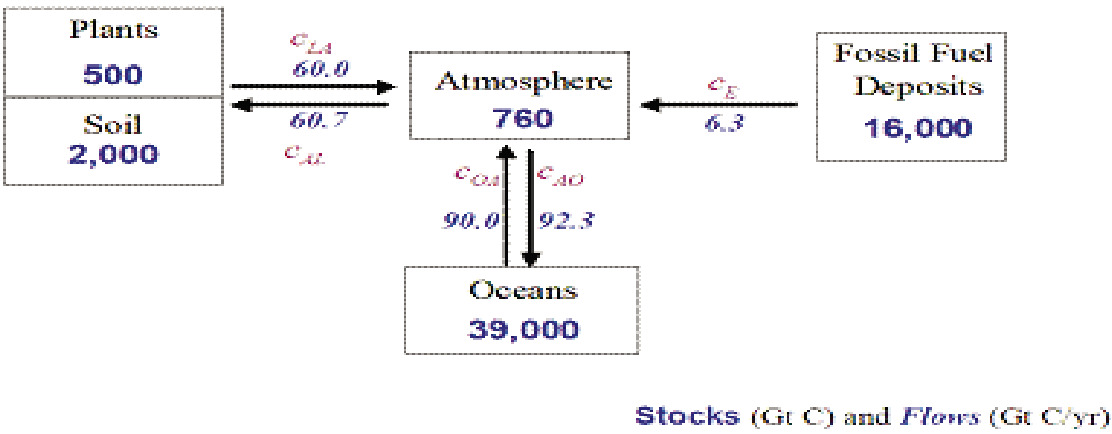


**Fig: 2.1 The global carbon cycle (Based on Watson et al., 2000)**

Carbon sequestration is currently being considered as a way to mitigate the greenhouse effects and simultaneously to combat land degradation (Olsson and Ardo, 2002). The environmental perspectives of carbon sequestration involve improvement in soil quality, and increase in biodiversity (Batjes, 1999). Heath and Smith (2000) argued that sequestering carbon will improve soil quality, as organic carbon influences many soil chemical and physical attributes including water holding capacity, nutrient retention, pH, structure and stability, and bulk density and penetration. Ganuza and Almendros (2003) found that C accumulation in soil was regulated mainly by climatic factors, where edaphic variables such as the state of the exchange complex and texture played an important role in carbon sequestration.

The global geographical area of India is 328.7 Mha (million hectares) or about 2.5% of the world total land area of the world (Lal, 2004). Of these, 161.8 Mha of arable land (11.8% of the world) of which 57 Mha (21.3% of the world) is irrigated, 68.35 Mha of forest and wood land (21.3% of the world), 11.05Mha of permanent pasture (0.3% of the world) and 7.95 Mha of permanent crops (6% of the world (Lal, 2004). Maintaining or arresting the decline in soil organic matter (SOM) is the most potent weapon in fighting against soil degradation and for ensuring sustainability of agriculture in tropical regions. In India nearly 60 per cent of agriculture is rainfed, covering the categories of arid, semi-arid and sub-humid climatic zones. Consequences of depletion of organic matter are poor soil physical health, loss of favorable biology and occurrence of multiple nutrient deficiencies. In the rainfed arid, semi-arid and sub-humid tracts, apart from poor rain water management, depletion of nutrients caused by organic matter deficiency is one of the important causes of soil degradation. Improving organic matter is, therefore, crucial to sustenance of soil quality and future agricultural productivity. Humus is known to favor many useful physical, chemical and biological processes that occur within the soil (Srinivasarao et al., 2011c).

Dry lands are generally low in fertility, low in organic matter, and hence candidates for carbon sequestration (Srinivasarao et. al., 2003; 2012a). Carbon storage in the soil profile not only improves fertility but also abates global warming. Several soils, production and management factors influence carbon sequestration; and it is important to identify production and management factors that enhance carbon sequestrations in dryland soils. However, the highest contribution of organic carbon to total carbon stock was under upland rice system. Organic carbon stocks in surface layer of the soils increased with rainfall while inorganic carbon stocks in soils were found in the regions with less than 550 mm annual rainfall. CEC showed better correlation with organic carbon stocks than clay content in soils. Results suggest that Indian dryland soils are low in organic carbon but have potential to sequester. Further potential of tropical soils to sequester more C in soil could be harnessed by identifying appropriate production systems and management practices for sustainable development and improved livelihoods in the tropics (Srinivasarao et al., 2009b).

Soil organic matter (SOM) is an important source of nutrients for plant growth in meaningless, and is itself influenced by land use, soil type, parent material, time, climate and vegetation. It is also one of the important factors affecting soil quality, sustainability of agriculture, soil aggregate permanence and crop yield (Karchegani, et. al., 2012). The soil texture was loam in the upper soil layers but changed to silt loam as the depth increased. Bulk density increased with soil depth, and had a negative relationship with soil organic C. A significant positive correlation between SOC and clay content was observed. About 69 % of soil carbon in the profile was confined to the upper 40 cm soil layer where C stock ranged from 8.5 to 15.2 t C $ha^{-1}$(Singh, et. al.,2011). Conservation of biodiversity and mitigation of the fallout of climate change are two major environmental challenges today. The relationship between plant biodiversity and soil organic carbon (SOC) sequestration has become a subject of considerable scientific interest. The Earth’s terrestrial vegetation plays a pivotal role in the global carbon cycle. Not only are tremendous amounts of carbon stored in the terrestrial vegetation, but large amounts are also actively exchanged between vegetation and the atmosphere. In agroforestry systems C sequestration is a dynamic process and can be divided into phases. At establishment, many systems are likely to be sources of green house gases (loss of C and N from vegetation and soil). Then follows a quick accumulation phase and at maturation period, wherein tons of C are stored in the boles, stems, roots of trees and in the soil. At the end of the rotation period, when the trees are harvested and the land returned to cropping (sequential systems), part of the C is released back to the atmosphere (Saha et. al 2012).

The global soil organic carbon storage corresponds to 615 Gt C in the top 0.2 m depth and 2344 Gt C in depths of up to 3 m, which is more than the combined C content of biomass and atmospheric $CO_2$. Soils constitute the largest pool of actively cycling carbon (C) in terrestrial ecosystems and stock about 1500- 2000 Gt C (to a depth of 1 m) in various organic forms ranging from recent plant litter to charcoal, to very old, humified compounds and 800 to 1000 Gt as inorganic carbon or carbonate carbon. The total quantity of $CO_2$, C exchanged annually between the land and atmosphere as gross primary productivity is estimated at 120 Gt C $yr^{-1}$and about half of it is released by plant respiration. Soils are the largest carbon reservoirs of the terrestrial carbon. Soils contain 3.5% of the earth`s carbon reserves, compared with 1.7% in the atmosphere, 8.9% in fossil fuels, 1.0% in biota and 84.9% in the oceans (Lal, 1995). Mean residence time of soil organic carbon pools have the slowest turnover rates in terrestrial ecosystems and thus C sequestration in soils has the potential to mitigate $CO_2$ emission to the atmosphere. Furthermore, higher carbon stabilization in soil is benefitting the other ecosystem functioning like improvement in soil structure, water holding capacity, nutrient retention, buffering capacity and greater availability of substrates for soil organisms. However, little is known about the actual achievable carbon level in soil under different agro-ecological regions of the country. Soil organic matter increases due to increasing humus in the soil. This humus depends on the soil type, climate, rainfall, soil porosity, water holding capacity and vegetation. SOM directly influences the growth and yield of the plant and fertility of the soil. SOC stocks increases due to turnover of greater plant biomass into the soil (Pal et.al 2015). The soil holds twice as much carbon as does the atmosphere, and most soil carbon is derived from recent photosynthesis that takes carbon into root structures and further into below-ground storage via exudates (Kell 2012).

Soil is the important carbon (C) pool (organic and inorganic) as it contains three times more C than in atmosphere and 3.8 times more C than in biotic pool (Batjes and Sombroek, 1997; Lal et.al. 1997). It can be a source or a sink of atmospheric C depending upon land use and management (Lal, 2003).The impact of land-use changes on organic carbon pools in the mineral soil depends on long-term site-specific factors (e.g. climate, topography and parent material) and is often overridden by the high spatial heterogeneity of soil organic carbon (Brown and Lugo, 1982; Smithson and Giller, 2002; Schwendenmann et al. 2007). Land-based carbon sequestration-a process whereby plants and trees, through photosynthesis processes, trap atmospheric CO2 and fix carbon into soil and plant body mass has drawn attention as a strategy for GHG reduction (Butt and Carl, 2004). The amount of organic matter stored in soils is controlled by natural site-specific factors such as parent material, climate, topography, land cover and human-induced factors associated with land use (Schils et al., 2008; Pineiro et al., 2010). In general, SOC stocks increased as the mean annual rainfall increased. On the other hand, soil inorganic carbon (SIC) stocks decreased from 156.4 Mg $ha^{-1}$ to 25.97 Mg $ha^{-1}$ with the increase in mean annual rainfall from <550mmto >1100 mm. As the SIC stocks were more dominant than SOC, total carbon stocks decreased from 183.79 Mg $ha^{-1}$ with increase in mean annual rainfall from <550 mm to >1100 mm in the arid environment 70.24 Mg $ha^{-1}$ in sub-humid regions. Carbon stocks in diverse soil types and rainfall zones (Srinivasarao et al., 2006b, 2009b, 2011b). Aridity in the climate is responsible for the formation of pedogenic calcium carbonate and this is a reverse process to the enhancement in soil organic carbon. Thus, increase in C sequestration via soil organic carbon enhancement in the soil would induce dissolution of native calcium carbonate and the leaching of SIC would also result in carbon sequestration (Sahrawat, 2003). In the present scenario of differing climatic parameters such as temperature and annual rainfall in some areas of the country, it will continue to remain as a potential threat for carbon sequestration in tropical soils of the Indian sub-continent (Eswaran et al., 1993).

Land use can be an important factor mitigating climate change, as it may have an impact on soil organic matter (SOM) storage (Schils *et al*., 2008). From the global evidence it can be seen that the effects of land use change on soil carbon stocks are of concern in the context of international policy agendas on the mitigation of global greenhouse gas emissions (GHGs) (UNFCCC). Other studies (Batjes, 1996; Lal et al., 1997; Post et al., 1999) also showed that land use change has a global concern due to its adverse effect on climate through emission of GHGs. Land use change is rapid in the developing countries and the problem has been increasing due to population growth and increasing land scarcity (Lal, 2000; Upadhyay et.al., 2006) which leads to encroachment into forests and/or crop intensification. If a land management or land use change is reversed, the C accumulated will be lost, usually more rapidly than it was accumulated (Smith *et al*.,1996).

Soil C pool is important for nutrient cycling in forest ecosystems and global C balance and has been of interest in understanding the effect of forest soil management on soil C pool (Ussiri and Johnson, 2007)**.** The global soil carbon (C) pool of 2500 gigatons (Gt) includes about 1550 Gt of soil organic carbon (SOC) and 950 Gt of soil inorganic carbon (SIC). The soil carbon pool is more than three times the size of the atmospheric pool (760Gt) and about 4.5 times the size of the biotic pool (560Gt). The annual fluxes of CO2 from atmosphere to land (global Net Primary Productivity (NPP) and land to atmosphere (respiration and fire) are of the order of 60Pg $Cy^{-1}$ (IPCC, 2000)**.** The soil C pool is 3.3 times the size of the atmospheric pool (760Gt) and 4.5 times the size of the biotic pool (560 Gt). The total carbon pool in forest ecosystem was recently estimated to be about 1150 Gt **(**Dixon et al. 1994)**,** of which 49% is in the boreal forests, 14% in temperate forests and 37% in tropical forests. A further 1000 Gt are estimated to reside in non-forest ecosystems, such as savannas, grasslands, tundra, peat lands and wetlands **(**Adams et al. 1990). According to the figures of Dixon et al. (1994)**,** 65% of the carbon is stored as soil organic carbon, and 31% as living biomass. The soil organic carbon (SOC) pool, in particular, is the only terrestrial pool storing some carbon (C) for millennia which can be deliberately enhanced by agroforestry practices. Up to 2.2 Pg C may be sequestered above and belowground over 50 years in agroforestry systems, but estimations on global land area occupied by agroforestry systems are particularly uncertain **(**Lorenz and Lal 2014)**.** Understanding the role of the soil-vegetation system in the carbon cycle is important. Movement of carbon inside the soil across different physical and chemical pools is crucial to maintain the soil as a sink or turn it into a source. Understanding these processes at the tropics becomes more imperative because of the heterogeneity of the carbon pool, and also of the diverse vegetable cover. (Dinakaran and Krishnayya, 2008).

Laganiere et. al., (2010) studied the influence of afforestation on SOC and indicates that the main factors that contribute to restoring SOC stocks after afforestation are previous land use, tree species planted, soil clay content, pre-planting disturbance and, to a lesser extent, climatic zone. Specifically, this meta-analysis (1) indicates that the positive impact of afforestation on SOC stocks is more pronounced in cropland soils than in pastures or natural grasslands; (2) suggests that broadleaf tree species have a greater capacity to accumulate SOC than coniferous species; (3) underscores that afforestation using pine species does not result in a net loss of the whole soil-profile carbon stocks compared with initial values (agricultural soil) when the surface organic layer is included in the accounting; (4) demonstrates that clay-rich soils (>33%) have a greater capacity to accumulate SOC than soils with a lower clay content (<33%); (5) indicates that minimizing preplanting disturbances may increase the rate at which SOC stocks are replenished; and (6) suggests that afforestation carried out in the boreal climate zone results in small SOC losses compared with other climate zones.

In temperate regions, management changes for an increase in C involve increase in cropping frequency (reducing bare fallow), increasing use of forages in crop rotations, reducing tillage intensity and frequency, better crop residue management, and adopting agroforestry wile in the tropics, agroforestry remains the primary method by which sequestration rates may be significantly increased. Increases in soil C may be achieved through improved fertility of cropland/pasture; on extensive systems with shifting cultivation cropped fallows and cover crops may be beneficial and adopting agro forestry or foresting marginal cropland is also an alternative. In addition, in the tropics it is imperative to reduce the clearing of forests for conversion to cropland. C sequestration in agricultural soils can make only modest contributions (3–6% of fossil fuel contributions) to mitigation of overall greenhouse gas emissions. However, effective mitigation policies will not be based on any single 'magic bullet' solutions, but rather on many modest reductions which are economically efficient and which confer additional benefits to society. In this context, soil C sequestration is a significant mitigation option(Hutchinson et.al

2007). Afforestation is a common strategy that over the course of decades leads to the incorporation of carbon dioxide ($CO_2$) in plant biomass. However, site types such as wetlands and peatlands may even be a source of greenhouse gases when they are afforested. Adapted management of existing forests may have a less obvious or slower effect on the terrestrial C pool (Jand et.al., 2007).

Forest ecosystems can be managed to sequester and store globally significant amounts of C. Agro-ecosystems and arid lands could be managed to conserve existing terrestrial C but $CO_2$ sequestration rates by vegetation in these systems is relatively low. Some ecosystem management practices that result in C sequestration and conservation provide ancillary benefits (Wisniewskil et.al, 1993). Soil C stocks increase after land use changes from native forest to pasture (+ 8%), crop to pasture (+ 19%), crop to plantation (+ 18%), and crop to secondary forest (+ 53%). Wherever one of the land use changes decreased soil C, the reverse process usually increased soil carbon and vice versa (Guo and Gifford, 2002). They also suggested that broadleaf tree plantations placed onto prior native forest or pastures did not affect soil C stocks whereas pine plantations reduced soil C stocks by 12-15**.**

Kirby and Potvin., 2007 found that managed forests stored an average of 335 Mg C $ha^{-1}$, traditional agroforests an average of 145 Mg C $ha^{-1}$ and pastures an average of 46 Mg C $ha^{-1}$ including all vegetation-based C stocks and soil C to 40 cm depth. They conclude that protecting forests from conversion to pasture would have the greatest positive impact on C stocks, even though the forests are managed by community members for timber and non-timber forest products.

### 2.4 Carbon sequestration in agriculture

Food production in developing countries, estimated at 1223 million metric tons (Mg), must be increased by 778 million Mg or 2–5 per cent $y^{-1}$ between 2000 and 2025 to meet the needs of an increased population and projected change in diet (Lal 2006). He showed that crop yields can be increased by 20–70 kg $ha^{-1}$ for wheat, 10–50 kg $ha^{–1}$ for rice, and 30–300 kg $ha^{–1}$ for maize with every 1Mg $ha^{-1}$ increase in soil organic carbon pool in the root zone. Increase in soil organic carbon pool by 1Mg $ha^{-1}$ $y^{-1}$ can increase food grain production by 32 million $Mgy^{-1}$ in developing countries. While advancing food security, this strategy would also off-set fossil fuel emissions at the rate of $0.5PgCy^{-1}$ through carbons sequestration in agricultural soils of developing countries.

The carbon sink capacity of the world's agricultural and degraded soils is 50 to 66% of the historic carbon loss of 42 to 78 gigatons of carbon (Lal, 2004). Global circulation models estimate the magnitude and time-scale of these changes and their effects on drought, floods, industry, agriculture etc. (Peiris et. al., 1996). The rate of soil organic carbon sequestration with adoption of recommended technologies depends on soil texture and structure, rainfall, temperature, farming system, and soil management. Strategies to increase the soil carbon pool include soil restoration and woodland regeneration, no-till farming, cover crops, nutrient management, manuring and sludge application, improved grazing, water conservation and harvesting, efficient irrigation, agroforestry practices, efficient use of pesticides, irrigation, and farm machinery and growing energy crops on spare lands. (West and Marland, 2002; Baker et.al, 2007 and Lal, 2008).

Smith et al. (2008) expected that agriculture will account for about 90 % by 2030 of the global mitigation potential through soil C sequestration. C sequestration in wheat-based production systems on the Indo-Gangetic Plain (IGP) on conversion to no-tillage is estimated to be 44.1 Mt C over 20 years. Implementing no-tillage practices in maize–wheat and cotton–wheat production systems would yield an additional 6.6 Mt C (Grace et. al., 2012). This offset is equivalent to 9.6% of India's annual greenhouse gas emissions (519 Mt C) from all sectors (excluding land use change and forestry), or less than one percent per annum. According to Yan et.al (2007) arable land soils generally have lower organic carbon (C) levels than soils under native vegetation; increasing the C stocks through improved management which suggested as an effective means to sequester $CO_2$ from the atmosphere. The C sequestration by agricultural soils is affected by many environmental factors (such as climate and soil conditions), biological processes (crop C fixation, decomposition and transformation), and crop and soil management (e.g. tillage and manure application). They found that practicing no-tillage on 50% of the arable lands and returning 50% of the crop residue to soils would lead to an annual soil C sequestration of 32.5 Tg, which accounts for about 4% of China's current annual C emission.

Lal (2004) assessed of the potential of carbon sequestration in soils of 8 countries in South Asia (Afghanistan, Bangladesh, Bhutan, India, Iran, Nepal, Pakistan and Sri Lanka) made on the basis of the available information on the area and soil C dynamics for different land use and soil management practices. Out of a total land area of 642 Mha, 218 Mha is cropland including 89 Mha of irrigated cropland, 85 Mha is forest and woodland, 13 Mha is permanent crops and 94 Mha is permanent pasture. Estimates of area affected by soil degradation processes include 82 Mha by water erosion, 11 Mha by wind erosion, 11 Mha by fertility decline, 13 Mha by waterlogging, 33 Mha by salinization, and 83 Mha by desertification. SOC concentration in most agricultural soils is <10 g/kg. The rate of SOC sequestration is low (<200 kg/ha/y) with a total potential of 25 to 50 Tg C/yr for several decades.

## 2.5 Carbon sequestration in Agro-forestry

Agro-forestry provides a unique opportunity to combine the twin objectives of climate change adaptation and mitigation. It has the ability to enhance the resilience of the system for coping with the adverse impacts of climate change. agroforestry systems offer important opportunities for creating synergies between both adaptation and mitigation actions (Murthy et.al, 2013). India is a large developing country with more than seventy per cent population earning their livelihood from diverse land use activities. Changing climate is a worry for the nation but the country cannot afford to slow down the developing/developmental activities. Landuse activities in irrigated agro-ecosystems have started shifting from traditional agriculture to smart agriculture to meet the country's food requirements and secure livelihood security (Sharma and Chaudhry, 2015). Agro-forestry has many potential, such as enhance the overall (biomass) productivity, soil fertility improvement, soil conservation, nutrient cycling, micro-climate improvement, carbon sequestration, bio drainage, bio energy and bio fuel etc. Agroforestry provides a unique opportunity to combine the twin objectives of climate change adaptation and mitigation. It has the ability to enhance the resilience of the system for coping with the adverse impacts of climate change (Pandey, 2002, Schoeneberger, 2009; Fanish and Priya, 2013; Murthy et.al.,2013; Lorenz and Lal 2014).

During the past three decades, agroforestry has become recognized the world over as an integrated approach to sustainable land use because of its production and environmental benefits. The perceived potential is based on the premise that the greater efficiency of integrated systems in resource (nutrients, light, and water) capture and utilization than single-species systems will result in greater net C sequestration (Nair et.al, 2009). They estimated that the area currently under agroforestry worldwide is 1,023 million ha. Additionally, substantial extent of areas of unproductive crop, grass, and forest lands as well as degraded lands could be brought under agroforestry. The extent of C sequestered in any agroforestry system will depend on a number of site-specific biological, climatic, soil, and management factors.

Using afforestation alone, however, ignores current sequestration due to growth; an increase in SOC stocks is seen due to turnover of greater plant biomass into the soils of Indo-Gangetic Alluvial Plains. (Pal, et. al. 2015). It is well recognized as a land use practice capable of producing biomass for bio-power and bio fuels.

Tropical forest ecosystems (TFEs) occupy 1.8 billion hectares (Bha) of the total area of 4.2 Bha in forest biomes. The terrestrial C pool in TFEs comprises 120 Mg/ha (tons) in vegetation and 123 Mg/ha in soil to 1-m depth. Soil vegetation C pool ratio ranges from 0.9 to 1.2 and increases with increase in latitude. Total C pool is 212 petagrams in vegetation and 216 Pg in soil. The soil C pool of TFEs represents about 14% of the global soil organic C (SOC) pool of 1550 Pg. Deforestation and conversion of natural to agricultural ecosystems depletes the C pool. Thus, the SOC pool can be enhanced by restoration of degraded soils, and conversion to planted fallows, agroforestry, plantations, improved pastures, and mulch farming. The rate of SOC sequestration in soils is 100-1000 kg C/ha/yr, and total potential of SOC sequestration in TFEs is 200-500 Tg C/yr for two to five decades ( Lal, 2005).

Estimated carbon stock of agroforestry systems in Africa range from 1.0 to 18.0 Mg C $ha^{-1}$ in aboveground biomass and up to 200 Mg C $ha^{-1}$ in soils and their C sequestration potential from 0.4 to 3.5 Mg C $ha^{-1}$ $yr^{-1}$ ( Nair and Nair 2014). The C sequestration potential of agroforestry systems is estimated between 12 and 228 $Mgha^{-1}$ with a median value of 95 $Mgha^{-1}$ Therefore, based on the earth's area that is suitable for the practice (585–1215 × $10^6$ ha), 1.1–2.2 Pg C could be stored in the terrestrial ecosystems over the next 50 years(Albrecht and Kandji, 2003). Average carbon storage by agroforestry practices has been estimated as 9, 21, 50, and 63 Mg C $ha^{-1}$ in semiarid, sub humid, humid, and temperate regions. For smallholder agroforestry systems in the tropics, potential C sequestration rates range from 1.5 to 3.5 Mg C $ha^{-1}$ $yr^{-1}$ (Montagnini and Nair, 2004). The total C-stock in a 32-yr old larch stand *(Larix sibirica*) was 276 Mg $ha^{-1}$, compared to 157 Mg C $ha^{-1}$ on an adjacent grazed pasture. This indicates mean C-sequestration of 2.6 Mg $ha^{-1}$ $yr^{-1}$. A 54-year old native birch stand (*Betula pubescens*) had total C-stock of 149 Mg $ha^{-1}$ and mean C-sequestration rate of 1.0 Mg $ha^{-1}$ $yr^{-1}$. A 40-year old Sitka spruce stand (*Picea sitchensis*) had a total C-stock of 431 Mg $ha^{-1}$ and mean C-sequestration rate of 3.0 Mg $ha^{-1}$ $yr^{-1}$.The increase in C-stocks at the afforestation sites was mostly due to an accumulation in the trees and the litter layer (Snorrason et.al, 2002). C sequestration potential of agroforestry systems between 12 and 228 Mg $ha^{-1}$ with a median value of 95 Mg $ha^{-1}$. Therefore, based on the earth's area that is suitable for the practice, 1.1–2.2 Pg C could be stored in the terrestrial ecosystems over the next 50 years (Saha et.al, 2012).

An re⁻crop value of 0.95 for western ecoregions was on average 0.23 units lower than that of the eastern ecoregions, indicating a lower decomposition rate of SOC (Bolinder et.al, 2008). Although the estimated annual C inputs to soil for small-grain cereals were on average 7.5% higher in the eastern ecoregions (305 vs. 285 g C $m^{-2}$ $yr^{-1}$), the overall results suggest that the western ecoregions would have a greater potential to maintain high SOC levels in the long term. However, these parameters varied between ecoregions and, consequently, the SOC sequestration potential was not always higher for the western ecoregions. The effect of fallow was on average 0.04, i.e., SOC decomposed slightly faster under fallow.

Singh et. al., (2011) estimated the distribution of carbon in soil profile in agroecosystems of Indo- Gangetic Plains and explored the factors which are responsible for distribution. They observed that soil texture was loam in the upper soil layers but changed to silt loam as the depth increased. Bulk density increased with soil depth, and had a negative relationship with soil organic C. A significant positive correlation between SOC and clay content was observed. About 69 % of soil carbon in the profile was confined to the upper 40 cm soil layer where C stock ranged from 8.5 to 15.2 t C $ha^{-1}$. They estimated the agricultural soils of Indo-Gangetic Plains may contain 12.4 to 22.6 t $ha^{-1}$ of organic C in the top 1 m soil depth. Since agricultural soils contain significantly lower C content than the soils of natural forest ecosystem in the same climate zone, management practices such as residue placement and reduced or no tillage are required to enhance C sequestration. So, a mix of agroforestry with crop fields may be an option to enhance C sequestration in soils.

**2.6 Carbon Sequestration in forestry**

The total area of the world's forest stands at 3.952 billion hectare (FAO 2005), which was about 30% of the total land area of the world. It is estimated that the world's forests store 283 Gt of Carbon in their biomass alone, and 638 Gt of carbon in the ecosystem as a whole including dead wood, litter and soil up to 30 cm depth. Tropical forests are also critical to the global carbon cycle because half of the world's biomass carbon is stocked in the forests and 14% of the world soil carbon is located in the soil of tropical forests (FAO, 2006; IPCC, 2001). The significant influence of tropical forests on carbon cycle is attributed to the high rate of primary production besides the large pool and flux sizes (Brown and Lugo, 1984). The aboveground biomass constitutes the major portion of the carbon pool (Ravindranath and Ostwald, 2008). Estimating the amount of forest biomass is required for estimating the forest's potential to sequester and store carbon in the forest ecosystem (Wang et. al., 2004). Tropical forests harbor most of the world's carbon, yet very little is known about the levels of carbon storage in many tropical forests (Baishya et al. 2009). Soil organic C pools consist of various fractions varying in degree of decomposition, recalcitrance, and turnover rate. Forest management practices affect these fractions differently (Ghani et. al., 2003).

Managing forests through forestry, agro forestry and plantation forests is seen as an important opportunity for climate change mitigation and adaptation (Canadell and Raupach, 2008; IPCC, 2007). The carbon stocks in different types of forests ecosystems have been estimated on the basis of forest inventories and using appropriate conversion factor to both biomass and carbon (Chhabra et. al., 2002; Dadhwal et. al., 2009; Kumar et. al., 2011; Lal and Singh, 2000; Patil et. al., 2010; Rabindranath et. al., 1997; Sahu et. al., 2015). Litter fall constitutes an important component of organic matter dynamics in a forest and its input depends upon vegetation composition, age of trees, canopy cover, weather conditions and biotic factors (Bargali, 1995; Lodhiyal and Lodhiyal, 1997; Rawat and Singh, 1988). Soil carbon sequestration is also important in maintaining a balance in greenhouse gas emissions and is strongly related to site conditions, *i.e.*, soil structure, initial soil carbon content, climate (Montagnini and Nair, 2004; Nair et. al., 2009). Soil carbon in its various pools within the soil, provides structure and stability to soil (Palm et al., 2007). Soil organic carbon is controlled by the balance of carbon inputs from plant production and outputs through decomposition (Schlesinger, 1977) and its storage is the most accepted method for long term carbon sequestration in terrestrial ecosystems. Soil carbon pool enhancement and optimization is essential for social, ecological and economic sustainability. The soil organic carbon, which is 30% of the total global carbon, is stored in sub-tropical and tropical ecosystems. However, it is being rapidly lost due to deforestation. Tree plantations have been advocated as C sink. However, little is known about the rates of C turnover and sequestration into soil organic matter under sub-tropical and tropical tree plantations. Removal of trees from the forest displaces a large amount of sequestered carbon (IPCC 2000) and consequently reduces the SOC held in soil profiles (Glaser et. al., 2000). The impact of deforestation on SOC decrease is more pronounced in the upper soil layer (Sombroek et. al., 1993) than the deeper layer. Gradual conversion of forest and grassland to cropland has resulted in significant losses of soil carbon worldwide (Lal 2002). The importance of forest ecosystems in the global carbon cycle and the necessity to accurately evaluate the amount of C stored in forest ecosystems (Korner, 2006). The carbon pool of a forest ecosystem varies with age (Clark et al. 2004). While young and middle-aged forest stands act as active carbon sinks, old stands are moderate to small C sinks or even C sources depending on the forest type and species composition (Desai et. al. 2005, Law et. al., 2004).

Forest ecosystems are the largest pool of biomass and carbon among all the terrestrial ecosystem. They absorb large quantities of $CO_2$ form the atmosphere through photosynthesis, and also return a large quantity of sequestered carbon (C) back to the atmosphere through autotrophic and heterotrophic $CO_2$ efflux (Lorenz and Lal, 2010). It has been estimated that about 234 Pg C are stored in the aboveground compartment, 62 Pg C in the belowground compartment, 42 Pg C in the dead woody compartment, 23 Pg C in litter compartment, and a maximum carbon sink of 398 Pg C in the forest soils (Kindermann et. al. 2008). The tropical forests store large amount of carbon and are therefore important in the global terrestrial carbon cycle (Houghton 1996; Houghton et. al. 2001). However, very little is known about the levels of carbon storage in different tropical forests (Baishya et. al. 2009).

Forests are a large sink of carbon and their role in carbon cycles is well recognized (Sedjo, 2001 and Murthy et. al., 2013). Kuruppuarachchi et. al., (2016) investigated the relationships amongst floristic, soil and climatic parameters and their control on carbon sequestration (CS) in two selected forest stands of Sri Lanka and said observed that dry zone forests are seen to be more climatic sensitive and vulnerable than the wet zone forests in Sri Lanka due to influence of more climatic parameters that govern the soil organic carbon fractions.

Approximately half of the tropical biome is in some stage of recovery from past human disturbance, most of which is in secondary forests growing on abandoned agricultural lands and pastures. Reforestation of these abandoned lands, both natural and managed, has been proposed as a means to help offset increasing carbon emissions to the atmosphere (Silver et. al., 2000). They discuss the potential of these forests to serve as sinks for atmospheric carbon dioxide in aboveground biomass and soils, observed that tropical reforestation has the potential to serve as a carbon offset mechanism both above- and belowground for at least 40 to 80 years. Oren et. al.,

(2001) stated that Northern mid-latitude forests are a large terrestrial carbon sink1±4. Ignoring nutrient limitations, large increases in carbon sequestration from carbon dioxide ($CO_2$) fertilization are expected in these forests. Yet, forests are usually relegated to sites of moderate to poor fertility, where tree growth is often limited by nutrient supply, in particular nitrogen. In two forest experiments on maturing pines exposed to elevated atmospheric $CO_2$, the $CO_2$-induced biomass carbon increment without added nutrients was undetectable at a nutritionally poor site, and the stimulation at a nutritionally moderate site was transient, stabilizing at a marginal gain after three years. However, a large synergistic gain from higher $CO_2$ and nutrients were detected with nutrients added. This gain was even larger at the poor site (threefold higher than the expected additive effect) than at the moderate site (twofold higher). Thus, fertility can restrain the response of wood carbon sequestration to increased atmospheric $CO_2$. Assessment of future carbon sequestration should consider the limitations imposed by soil fertility, as well as interactions with nitrogen deposition. Iverson et. al., (1993) assessed the difference between 2 indices of potential and actual carbon sequestration of forests on a regional scale in the continental part of tropical Asia by using GIS. This difference represents the degree to which forest biomass has been reduced (degraded) from its potential maximum caused by the long history of human impacts on the landscape. The difference indicates the relative amount of new biomass carbon which could be added to particular areas of land if they were protected, free from human disturbance, so that they could accumulate biomass up to their potential with no social, economic, or political constraints. Areas of highest technical suitability included the lowland moist and lowland seasonal ecofloristic zones, closed forests, and Peninsular

Malaysia and India. On average, the technically suitable present forest lands could sequester an additional 90 Mg C $ha^{-1}$ in aboveground biomass.

Annual carbon uptake by the 1.24 million ha of plantation forest in New Zealand was calculated and observed that the plantation forests of New Zealand stored approximately 4.5±0.8 million tonnes C in the year between 1 April 1988 and 1 April 1989, increasing total plantation carbon storage to approximately 88 million tonnes C in April 1989. Without harvest, the average annual carbon uptake of the New Zealand plantation estate between 1988 and 1989 would have been approximately 6.4 tonnes C/ha (Hollinger et. al., 1993). Plantation roundwood removals were equivalent to 2.7 tonnes C/ha, so that average carbon storage was approximately 3.6 tonnes C/ha. The annual storage of carbon in the New Zealand plantation estate in 1988-89 was equivalent to approximately 70% of total New Zealand fossil fuel emissions, but was <0.1% of total global fossil fuel emissions. US forests sequestered carbon in the 1990s at a rate of 80 Tg $yr^{-1}$ but came close to carbon equilibrium by the 2020s. The dominant factors driving this change were an increasing forest harvest, a decreasing forest land base and a reduction in average stand age. Scenarios in which alternative forest policy options were implemented related to increased paper recycling and increased afforestation produced long-term increases in carbon sequestration on the forest land base of up to 15 Tg $yr^{-1}$ (Turner et.al, 1995).

**2.7 Carbon sequestration in Wet land**

In light of global climate change and potential mitigation strategies, environmental water allocations may be used to restore or enhance carbon sequestration in floodplain wetlands. Coastal wetlands play an important but complex role in the global carbon cycle, contributing to the ecosystem service of greenhouse gas regulation through carbon sequestration (Hansen and Nestlerode 2014). With their wealth of stored carbon, wetlands provide a potential sink for atmospheric carbon, but if not managed properly could become sources of greenhouse gases (GHGs) such as carbon dioxide and methane(Mitra et. al., 2005; Adhikari et. al., 2009).

In India, the total land area of 329 Mha, 297 Mha is the land area comprising 162 Mha of arable land, 69 Mha of forest and woodland, 11 Mha of permanent pasture, 8 Mha of permanent crops and 58Mha is other land uses. The soil organic carbon (SOC) pool is estimated at 21 Pg to 30-cm depth and 63 Pg to 150-cm depth. The soil inorganic carbon (SIC) pool is estimated at 196 Pg to 1-m depth. The SOC concentration in most cultivated soils is less than 5 g/kg compared with 15 to 20 g/kg in uncultivated soils. (Lal, 2004). Wetlands in the northern Gulf of Mexico coastal region potentially store 34–47 Mg C $ha^{-1}$ and could potentially accumulate 11,517 Gg C $year^{-1}$.

Wetlands conversion of to agricultural land in the American tropics, through traditional agricultural practices such as shifting cultivation, has not been able to maintain stocks of soil organic carbon (SOC), and increasing population pressure has led to shortened fallow periods, causing further losses of soil fertility. However, land management practices such as agroforestry can provide a sustainable alternative to single cropping because of its ability to maintain or increase the SOC pool .They observed that SOC and N pools were significantly higher ($p < 0.05$) in the 19-year-old alley crop compared to the sole crop, but not significantly different ($p < 0.05$) in the 10-year-old system.

Cahoon et.al., (2003) compiled data for 154 sites in mangroves and salt marshes from the western and eastern Atlantic and Pacific coasts, as well as the Indian Ocean, Mediterranean Ocean, and Gulf of Mexico. The average soil carbon density of mangrove swamps (0.055 ± 0.004 g $cm^{-3}$) is significantly higher than the salt marsh average (0.039 ± 0.003 g $cm^{-3}$). Soil carbon density in mangrove swamps and Spartina patens marshes declines with increasing average annual temperature, due to increased decay rates at higher temperatures. In contrast, carbon sequestration rates were not significantly different between mangrove swamps and salt marshes. Variability in sediment accumulation rates within marshes is a major control of carbon sequestration rates masking any relationship with climatic parameters. Globally, these combined wetlands store at least 44.6 Tg C $yr^{-1}$.

The dynamic modeling of carbon flux results from seven detailed studies by Mitsch et. al., (2011) of temperate and tropical wetlands and from 14 other wetland studies by others that methane emissions become unimportant within 300 years compared to carbon sequestration in wetlands. They estimated that the world's wetlands, despite being only about 5–8 % of the terrestrial landscape, may currently be net carbon sinks of about 830 $Tg^{-1}$ year of carbon with an average.

Wetland ecosystems are significant carbon sinks (Bernal and Mitsch, 2012). Their high productivity and presence of water gives them the ability to efficiently sequester carbon in the soil, serving as a potential tool to mitigate the net greenhouse effect of carbon emissions to the atmosphere and abate climate change. Bernal and Mitsch, (2012) explored the efficiency of freshwater wetlands sequestering carbon under different climates, wetland types, and vegetation communities, in order to assess the conditions that favor carbon accumulation and found significant differences on carbon sequestration between wetland types in temperate and tropical regions, being consistently higher in the studied forested wetlands (260 ± 58 g C $m^{-2}$ $y^{-1}$) than the riverine ones (113 ± 27 g C $m^{-2}$ $y^{-1}$), indicating the importance of wetland productivity and the type of organic matter entering the system. The stability of organic matter and assessment of roles of biotic and abiotic factors in regulating C exchanges between wetland ecosystems and the atmosphere may not only enhance the understanding of fundamental biogeochemical and eco-physical processes regulating C transformation in aquatic and terrestrial systems, but also help in the endeavors of reduction of anthropogenic $CO_2$ in the atmosphere with long-term parity, and enhance the accuracy of global C budgets (Pant et.al., 2015).

Carbon fixation under wetland anaerobic soil conditions provides unique conditions for long term storage of carbon into histosols. However, this carbon sequestration process is intimately linked to methane emission from wetlands. The potential contribution of this emitted methane to the greenhouse effect can be mitigated by the removal of atmospheric $CO_2$ and storage into peat. The balance of $CH_4$ and $CO_2$ exchange can provide an index of a wetland's greenhouse gas (carbon) contribution to the atmosphere (Whiting and Chanton, 2001). They relate the atmospheric global warming potential of methane (GWPM) with annual methane emission/carbon dioxide exchange ratio of wetlands ranging from the boreal zone to the near-subtropics. They also reported annual measurements of the relationship between methane emission and net carbon fixation in three wetland ecosystems. The ratio of methane released to annual net carbon fixed varies from 0.05 to 0.20 on a molar basis. Although these wetlands function as a sink for $CO_2$, the 21.8-fold greater infrared absorptivity of $CH_4$ relative to $CO_2$ (GWPM) over a relatively short time horizon (20 years) would indicate that the release of methane still contributes to the overall greenhouse effect. As GWPM decreases over longer time horizons (100 years), our analyses suggest that the subtropical and temperate wetlands attenuate global warming, and northern wetlands may be perched on the ‘‘greenhouse compensation’’ point. Considering a 500-year time horizon, these wetlands can be regarded as sinks for greenhouse gas warming potential, and thus attenuate the greenhouse warming of the atmosphere.

A proportion of the C captured in plant biomass is partitioned to roots, where it enters the pools of soil organic C and soil inorganic C and can be sequestered for millennia. Bioenergy crops serve the dual role of providing biofuel that offsets fossil-fuel greenhouse gas (GHG) emissions and sequestering C in the soil through extensive root systems. Carbon captured in plant biomass can also contribute to C sequestration through the deliberate addition of biochar to soil, wood burial, or the use of durable plant products (Jansson et. al., 2010).

Nunery and Keeton in 2010 observed that carbon sequestration was significantly greater for ‘‘no management’’ compared to any of the active management scenarios. Of the harvest treatments, those favoring high levels of structural retention and decreased harvesting frequency stored the greatest amounts of carbon.

Schroder and Pesch, 2011 found the computations yielded an estimation of 146.7 M t C sequestered in the forests of North Rhine- Westphalia corresponding to 168.6 t/ha. They also observed that overall mean of C sequestration amounted for 177 t C/ha which is 8.4 t C/ha higher than what was calculated in the study and 14 t C/ha below the roughly guessed German-wide mean of 191 t C/ha. Thus surface estimations of C pools in living forest trees/dead wood, the humus layer and the mineral soil enable to map the fixation of the greenhouse gas $CO_2$ in forests at the regional scale (Schroder and Pesch, 2011).

**2.7 Carbon sequestration in grazing land**

Global estimates are that grazing lands occupy 3.6 billion ha and account for about one-fourth of potential carbon (C) sequestration in world soils. They remove the equivalent of 20% of the carbon dioxide ($CO_2$) released annually into the earth’s atmosphere from global deforestation and land-use changes. Atmospheric $CO_2$ enters grazing lands soils through photosynthetic assimilation by green plants, subsequent cycling, and sequestration of some of that C as SOC to in turn contribute to the ability of grazing lands to provide societal (environmental and economic) benefits in every country where they exist. Environmental benefits provided include maintenance and well-being of immediate and surrounding soil and water resources, air quality, human and wildlife habitat, and esthetics. Grazing lands contribute to the economic well-being of those living on the land, to trade, and to exchange of goods and services derived from them at local, regional, or national levels. Rates of SOC sequestration vary with climate, soil, and management; examples and conditions selected from US literature illustrate the SOC sequestration that might be achieved (Follett and Reed, 2010). Soils could potentially sequester up to 13.8 Mt C in 25 years if active sand dunes in the study area were to be protected by exclosures. When agricultural land is no longer used for cultivation and allowed to revert to natural vegetation or replanted to perennial vegetation, soil organic carbon can accumulate by processes that essentially reverse some of the effects responsible for soil organic carbon losses from when the land was converted from perennial vegetation (Post and Kwon, 2000). The carbon sink capacity of the world’s agricultural and degraded soils is 50 to 66% of the historic carbon loss of 42 to 78 gigatons of carbon. The rate of soil organic carbon sequestration with adoption of recommended technologies depends on soil texture and structure, rainfall, temperature, farming system, and soil management. Strategies to increase the soil carbon pool include soil restoration and woodland regeneration, no-till farming, cover crops, nutrient management, manuring and sludge application, improved grazing, water conservation and harvesting, efficient irrigation, agro forestry practices, and growing energy crops on spare lands (Lal, et al.,2004).Grazing lands are estimated to contain 10–30% of the world's soil organic carbon. The USA has about 336 Mha of grazing lands of which rangelands account for 48% (Schumana et. al, 2002). Changes in rangeland soil C can occur in response to a wide range of management and environmental factors. Grazing, fire, and fertilization have been shown to affect soil C storage in rangelands, as has converting marginal croplands into grasslands. They observed that carbon losses due to soil erosion can influence soil C storage on rangelands both by reducing soil productivity in source areas and potentially increasing it in depositional areas, and by redistributing the C to areas where soil organic matter mineralization rates are different. Proper grazing management increased soil C storage on US rangelands from 0.1to 0.3 Mg C $ha^{-1}year^{-1}$ and new grasslands have been shown to store as much as 0.6 Mg C $ha^{-1}year^{-1}$.

Silvipastoral systems can better sequester carbon in soil and biomass and help to improve soil conditions (Mangalassery et. al., 2014). The silvipastoral system sequestered 36.3% to 60.0% more total soil organic carbon stock compared to the tree system and 27.1–70.8% more in comparison to the pasture system. The soil organic carbon and net carbon sequestered were greater in the silvipastoral system.

Thus, silvipastoral system involving trees and grasses can help in better sequestration of atmospheric system compared with systems containing only trees or pasture.

The relationship of carbon sequestration to mean annual precipitation is negative for both the 0 to 10 cm (0 to 3.9 in) and 0 to 30 cm (0 to 11.8 in) soil depths across stocking rates. The threshold from positive to negative carbon change occurs at approximately 440 mm (17.3 in) of precipitation for the 0 to 10 cm soil depth and at 600 mm (23.6 in) for the 0 to 30 cm soil depth (Derner and Schuman, 2007). Sudha et. al., 2007 observed that the baseline carbon stock was estimated to be 45.3 t C/ha, predominately in soils. The additional carbon sequestration potential under the project scenario for 30 years is estimated to be 12.8 t C/ha/year inclusive of harvest regimes and carbon emissions due to biomass burning and fertilizer application.

# Chapter 3
# Materials and Methods

# MATERIALS AND METHODS

## 3.1 Study area

Lucknow, the capital of Uttar Pradesh is situated 123 m above sea level. It is situatedon 26.30 & 27.10 North latitude and 80.30 & 81.13 East longitude. Lucknow covers anarea of 3,244 sq.km. It is surrounded on the eastern side by District Barabanki, on the western side by district Unnao, on the southern side by Raebareli and on the northern side by Sitapur and Hardoi districts.

This Zone comprise supper and middle Gangatic alluvial plains including Ghaghara, Gomati interfluves and Bihar plains havemoderately large moisture availability with 150-180 days growing period and Dry Sub Humid Climate. These areas have two dry seasons i.e. summer and winter with Ustic typic soil moisture regimes. Major drainage passes through river Ghaghara, and other tributaries in the district. Due to topographical and hydrological situation total precipitation received in drainage congestion about 30%area of the district is affected every year by low, medium and high flood which causes miseries to animals and human population and some wet lands are also situated in the district. The productivity of these areas is also affected adversely due to floods needs attention.

The principal crops are rice, wheat, pulse and other food grains and sugarcane. The district is for the most part flat to monotony, there is an utter absence of mountains; the most elevated point is about four hundred and thirty feet above the sea; and there are few points of view from which any expanse of country can be surveyed. The verdure and beauty of the groves with which it is studded in every direction redeem the prospect from bare ugliness, and when the spring crops are green and the jhils yet full of water, the richness of the landscape is very striking.

Here and there patches of uncultivated waste are to be seen, but a high assessment and security of tenure are rapidly converting them into waving fields of corn. Towards the north, especially along the old bank of the Ghaghra, the ground is undulating and richly wooded, while to the south there is a gentle slope down to the Gomti. The monotonous level is broken on the north by an abrupt fall, the ridge running parallel to the Ghaghra at a distance of from one mile (1.6 km) to three miles (5 km), is said to indicate what was formerly the right bank of the river. The district is intersected at various parts by rugged ravines. The principal river in the district is the Ghaghra, at a short distance from Bahramghat; in the Fatehpur tahsil the rivers Chauka and Sarda meet, and their united stream is called the Ghaghra. Both those component rivers take their rise in the Himalaya and at their confluence form a stream, which at Bahramghat is in the rainy season from one and a half to two miles (3 km), and in the dry season half mile in breadth. The river is not utilized for purposes of irrigation. District Barabanki has been divided into six subdivisions, popularly known as tehsils, Barabanki encompasses 15 such Blocks. According to the 2011 census Barabanki district has a population of 2,673,581. The district has a population density of 740 inhabitants per square kilometer. Barabanki has a sex ratio of 887 females for every 1000 males and a literacy rate of 47.39%.

**Table 3.01: Area, Production and Productivity of major crops cultivated in the district**

| Crop | Area (ha) | Production (q) | Productivity (Q/ha) |
|---|---|---|---|
| Paddy | 179338 | 416602 | 23.23 |
| Arhar | 8787 | 7705 | 8.77 |
| Groundnut | 1026 | 822 | 8.01 |
| Wheat | 162040 | 470888 | 29.06 |
| Potato | 14011 | 274391 | 195.84 |
| Mustard | 10950 | 12658 | 11.56 |
| Urd | 6214 | 1510 | 2.43 |
| Sugarcane | 13816 | 710585 | 514.32 |
| Mentha | 47523 | 4752300 kg | 115.00 kg/ha. |

**3.2 Dewa Block of District Barabanki**

Block Dewa, district Barabanki is a part of Faizabad region. Block Dewa is situated in the Barabanki district in between the parallel of $26^0$– $55^I$ to $27^0$ -$5^{I}$`N` latitude and $81^0$-$8^I$to $15^0$`E` longitude. The headquarter of the block Dewa is 13km. away from Barabanki on Barabanki to Fatehpur road and about 25 km. away from Lucknow. It is connected by road only. It is surrounded by block Banki and Masauli, in the East, Banki in South, Fatehpur in North of the same district and Chinhut block of Lucknow district in the West.

The total area of the block is about 26676 ha and comprised of 10 nyayapanchayats which includes 125 villages.

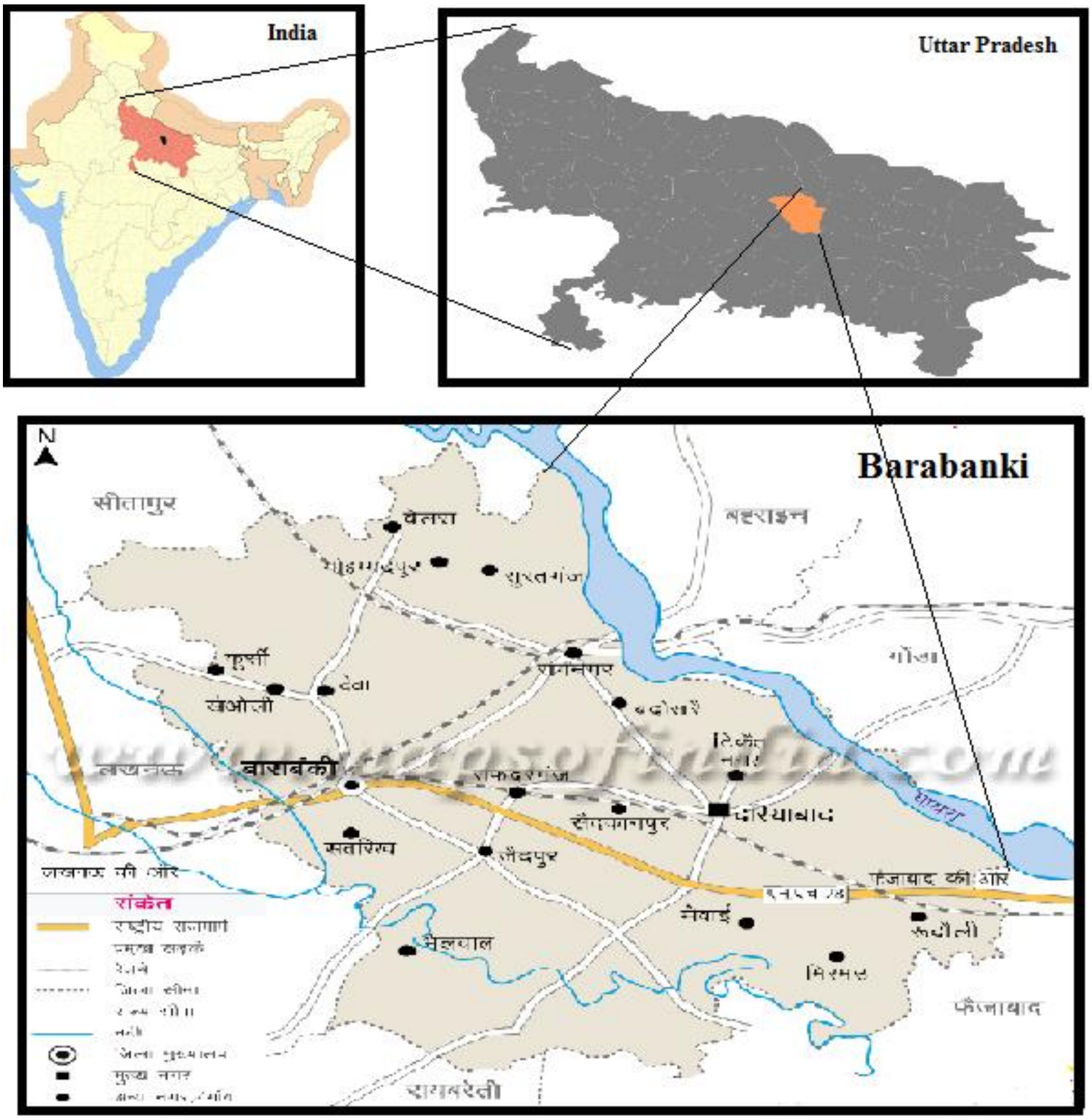


**Fig. 3.01.:- Topographical presentation of Dewa Block, District Barabanki**

### 3.2.1 Physiography, Relief and Drainage

The Block is situated between the Kalyani and Rethriver, which are tributary of river Gomti. The natural water course had divided into entire area into four physiographic divisions. Besides canal system has also sculptured the landscape with some relief variations. The major physiographic divisions are:

1. Moderately sloppy and old alluvial (upland)
2. Nearly plains old alluvial (mid upland)

3. Nearly plains old alluvial (mid land)
4. Nearly plains but temporary water logged area concave topography.

The general slope direction of the area is form South East to South- West. During monsoon season , river Kalyani and Reth swell to considerable extent as such flood the adjoining plains which also results flooding and denudation of concavities.

### 3.2.2 Climate

The climate of the block is semiarid, subtropical monsoonic. The cold days start from 15$^{th}$ November and last upto 15$^{th}$ March but severe cold days are December and May, June are hottest summer months. Monsoon sets generally by the end of June and upto first week of October.

There is no meteorological observatory in the district. Therefore, the data related to all the parameters of the climate expecting rains gas been extrapolated from meteorological observatory Rahman Khera soil conservation training Centre, Lucknow (based on 1972-1981). The rainfall data is obtained from tehsil headquarter Nawabganj, district Barabanki. Tgemetereological parameters are presented in Table 2.1. average rainfall is 98.8 mm which is highest in the district based on analysis of rainfall data from (1978-1987).

The above table reveals that July to September are rainiest months. During this period nearly 88% annual rainfall is received in about 36 days. The highest rainfall recorded in month of September is 345.5 mm & minimum in the month of November is 4.28 mm.

### 3.2.3 Temperature

Extreme mean maximum temperature of $36.6^0$ C and $37.1^0$ C are recorded in month of May and June and thus they are the hottest months. The month of April also quite hot with a mean temperature of $27.4^0$C.the mean minimum temperature in the month of December and January is $6.8^0$C and $7.1^0$C respectively.

### 3.2.4 Relative Humidity

The relative humidity is 63% maximum of 75.7% in the month of August. During April and May atmosphere is dry with mean relatives humidity 54.6% and 50.3% respectively.

### Wind Speed

Wind speed is quite moderate about 6km. in the month of May. During monsoon season, it ranges from 4-5 km per hour and Easterly wind prevail Westerly are dominant during winter season. Dust and storms occur during premonsoon (April to June) on an average for 1-2 days in a month

**Table 3.02.Climatological Parameter (based on observation of 1972-1981)**

| month | Temperature | | | Rainfall in mm (Rainy days) 1978-1987 | Relative Humidity (Average)% | Wind velocity km/hour |
|---|---|---|---|---|---|---|
| | Max | Min | Avg. | | | |
| January | 21.6 | 7.1 | 14.3 | 20.08(1.5) | 64.1 | 3.89 |
| February | 24.2 | 7.5 | 15.8 | 19.18(1.9) | 62.5 | 5.19 |
| March | 31.4 | 7.5 | 22.1 | 9.36(0.9) | 58.1 | 5.62 |
| April | 36.9 | 18 | 27.4 | 0.06(0.4) | 54.6 | 5.73 |
| May | 36.6 | 23.2 | 31.4 | 20.37(1.3) | 50.3 | 6.26 |
| June | 37.1 | 24.6 | 30.8 | 119.8(5.4) | 62.6 | 5.12 |
| July | 33.6 | 26.0 | 29.8 | 325.99(13.8) | 74.8 | 5.24 |
| August | 32.6 | 25.1 | 28.8 | 243.0(12.8) | 75.7 | 4.5 |
| September | 32.0 | 23.7 | 27.8 | 345.5(10.3) | 73.9 | 4.36 |
| October | 32.4 | 12.6 | 17.5 | 53.45(1.7) | 62.7 | 2.81 |
| November | 27.8 | 7.6 | 11.3 | 4.28(0.3) | 62.5 | 2.47 |
| December | 23.6 | 6.8 | 6.8 | 20.34(0.6) | 63.6 | 2.93 |
| average | 30.8 | 15.8 | 21.9 | 98.8(50.9) | 63.0 | 4.51 |

### 3.2.5 Evaporation, sunshine and soil temperature regime

The mean potential evaporation attains maximum 185 mm during hot months May and June. In monsoon months it ranges between 116-126 mm and in winter between 47-73mm. The annual PET is about 1185mm. The sunshine is received on an average for 8 hours in winter, 10-11 hours in summer and 5-6 hours per day during monsoon.

The estimated MAST is $22.9^0$C. where MSST is $30.8^0$C and $11.8^0$C respectively. Thus the soil temperature regime is hyperthermic. The water balance computed from potential evapo-transpiration. PET and precipitation (p) indicate the major soil with hyperthermic temperature regime are dry for 90 or more cumulative days in some or all parts in moist year but is not dry in all parts for more than half the time in soils occurring on upland. However, in concavities/aquic moisture regime is also observed which leaves definite imprints on soil morphological expressions. An ombrothermic diagram on the basis of temperature and precipitation is presented in figure 3.02.

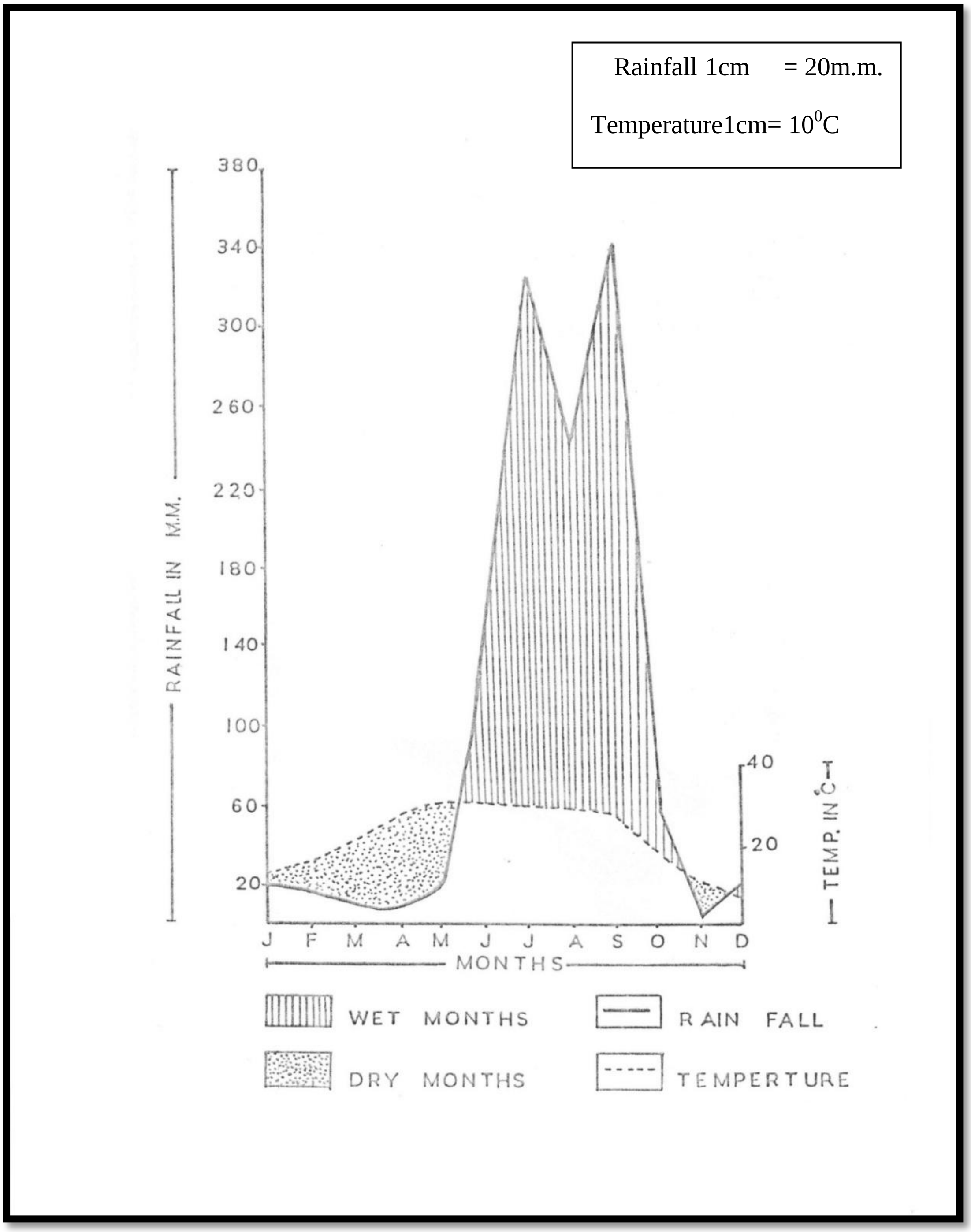


**Fig. 3.02.Ombothermic diagram of Dewa, District – Barabanki**

**3.3 Soil Formation**

The soil forming material is derived largely from the alluvial sediments originated from unconsolidated sedimentary rocks of Sivaliks of tertiary origin. The alluvial deposit belongs primarily to pleistocence and secondarily holocence period of quaternary era. The sediments have been primarily carried by river Gomti and secondary by Reth and Kalyani.

**3.4 Soil survey of Block Dewa**

(Based on Soil Survey report of Sharda Sahayak cad Project Lucknow, Uttar Pradesh), Barabanki.

| | | |
|---|---|---|
| Survey Area | : | 26676 ha. |
| Block | : | Dewa |
| Tehsil | : | NawabGanj |
| District | : | Barabanki |
| Irrigation System | : | Sharda Canal |
| Total area irrigated by different sources | : | 13724 ha. |
| Kind of soil survey | : | Detailed Soil Survey |
| Period of Soil Survey | : | April,1978 to Sept. 1988 |

**3.5 Soil Survey Procedure**

The technique envisaged in Soil Survey Manual published by All India Soil and Land use Survey IARI, New Delhi (1970) was adopted.

Though field to field survey was conducted yet to have control on check points, grid points were marked in the directions X and Y axis of codastral map at interval of 2.5 inches, 5 inches and 20 inches which represent area of 6.25, 25 and 400 ha. On the ground respectively and were subjected to auger, fertility and pedon studies respectively.

The selected samples (from profile and surface) were analyzed by analytical laboratory located at the Project headquarter Lucknow for detailed investigation.

Physiographic units were denoted using relief as drainage pattern as well as vegetation and other features on the map. Major distinguishing characters for identification of soil are texture, structure, pH, mottling, soil colour, various soil mapping units are marked in the map depending on phases due to intra series and inter series variation.

After detailed computation and interpretation of field and lab observation various land use capability, irrigability and engineering classes were worked out. The taxonomic units were finalized through discussion and deliberation in joint field reviews by core group members (Soil core of the Project).

The soils were classified as per soil taxonomy (Soil Survey Staff 1973 USDA).

### 3.6 Soil sample collection from different Sites for Carbon Sequestration assessment

In present study, information assembled concerning processes that regulate the amount and rate of change in SOC and use this information to interpret measurements of SOC accumulation. In this study, whole area of Dewa block were categorized in three categories on the basis of land use *i.e.*, forested area, cultivated area and uncultivated area. The basic information was based on Report on Detailed Soil Survey of block Dewa district Barabanki, (Report No. AG RIC 78, Jan 1989). As per Soil Survey Report, Dewa block was categorized in eight soil series on the basis of their characteristics feature. Thus eight soil series of Dewa block were selected for soil sampling. In each soil series three different land use system were selected i.e., forested, cultivated land and uncultivated land. The exact location of different soil sample collection sites were as follows:

**Site -1:**The first site was Pavaiya Viran village of Dewa block that belong to **Gangauli soil series**, situated at the distance of about 9km from Dewa to Chinhut road in right side 500m distance of the road.

**Plate 3.01. Showing different landuse sites (i.e., Cultivated at the top, Uncultivated in middle and forested down) of Gangauli soil series (Pavaiyaviran) of Dewa block, Barabanki.**

**Site-2:**The second site was Khajurpur village of Dewa Block that belong to **Sihali soil series**, situated at 10 km on Dewa road to Chinhut road in right side and Dewa to Barabanki distance is 13 km.

**Plate 3.02. Showing different landuse sites (i.e., Cultivated at the top, Uncultivated in middle and forested down) of Sihali (Khajurpur Village)soil series of Dewa block, Barabanki.**

Site -3:The third site was Chachera village of Dewa Block that belong to Bajgahani soil series situated at distance of 3km away from Dewa to Chinhut Road in right side at 9km from Dewa.

**Plate 3.03. Showing different landuse sites (i.e., Cultivated at the top, Uncultivated in middle and forested down) of Bajghani Soil Series (Chachera Village)soil series of Dewa block, Barabanki.**

**Site -4:**The fourth wasDewa village of Dewa Block that belong to**Dadra soil series**, situated on the right side at a distance of about 500mtr away from proper Dewa and from Barabanki only at the distance of 13km.

**Plate 3.04. Showing different landuse sites ( i.e., Cultivated at the top, Uncultivated in middle and forested down) of Dadra soil Series (Dewa Village)soil series of Dewa block, Barabanki.**

**Site -5:** The fifth site was village Khijirpur – Inayatpur of Dewa Block that belong to **Nigari soil series** situated at distance of 5km from Dewa on the bank of Barabanki branch (canal).

**Plate 3.05. Showing different landuse sites ( i.e., Cultivated at the top, Uncultivated in middle and forested down) of Nigarisoil Series (Khijirpur - Inayatpur)soil series of Dewa block, Barabanki.**

**Site -6:**The sixth site was village Ukhdi of Dewa Block that belong to Ukhdi soil series Nawabganj Tehsil, situated at the bank of Barabanki branch (canal) in right hand side at a distance of about 8 km from Dewa and andDewa is 13 km away from Barabanki on Barabanki to Fatehpur road.

**Plate 3.06. Showing different landuse sites (i.e., Cultivated at the top, Uncultivated in middle and forested down) of Ukhdi Soil Series (Ukhdi Village)soil series of Dewa block, Barabanki.**

**Site -7:** The seventh site was village Mahraur of Dewa Block that belong to Mahraur series situated at a distance of about 9 km linking with a distance of 2.5 km on Feeder Canal (Indira Canal) in left side.

**Plate 3.07. Showing different land use sites ( i.e., Cultivated at the top, Uncultivated in middle and forested down) of Mahraur Soil Series (Mahraur Village)soil series of Dewa block, Barabanki.**

**Site -8:**The eighth site was village Salarpurof Dewa Block that belong toNayagaon soil series situated in right side of Barabanki to Fatehpur road situated at about 18 km from Barabanki.


**Plate 3.08. Showing different land use sites ( i.e., Cultivated at the top, Uncultivated in middle and forested down) of Nayagaon Soil Series (Salarpur Village)soil series of Dewa block, Barabanki.**

From each soil series three land use system were selected. In each land use soil samples were collected in four replicate at different soil depth i.e., surface soil(0-15 cm depth) and subsurface soil (15-30 cm depth). The collected samples were brought to the laboratory and allowed to dry in shade. Loose stubbles attached grasses and bigger clods were first removed and then spread uniformly on polythene sheet for complete air drying. The air dried soil samples were powdered in agate mortar /grinder and then they were sieved through a 1 mm sieve and kept in polythene packets in dark place until analyzed.

**Plate 3.09.Showing soil samples ready to be analyzed.**

**3.7 Soil Sample Analysis**

Processed soil samples were analyzed for different physico-chemical properties of soil *viz* bulk density, soil texture, pH,Organic Carbon was determined.






**Plate 3.10: In Image A and Image B and C, soil samples can be seen being analyzed, Image D is of Soil Testing Lab, Alambagh where the samples were analyzed, Image E is of instrument Theodolite for measurement of angles in meterological survey .**

### 3.7.1 Bulk Density

Soil bulk density was measured as the ratio of the mass of dry soil per unit volume (g/ cm3). For this method, a vessel of known volume is filled with moist field sample. The soil was then thoroughly dried at $105^0$C and weighed.

### 3.7.2 Soil Texture

Soil texture was determined by mechanical analysis of sand, silt and clay by Bouycos hydrometer (Piper, 1967).

### 3.7.3 pH and EC

Soil pH and EC were determined by pH meter and conductivity meter method respectively in 1:2 soil water ratio (Jackson, 1973). Ground and sieved air dried soil (10g) was mixed with 20 ml double distilled water. After one hour the pH and EC reading were taken by ELICO LI pH meter and GENEI conductivity meter respectively.

### 3.7.4 Organic Carbon

Wakley and Black's (1934) rapid titration method was employed for the estimation of Organic Carbon. 0.5 g of soil sample was digested with chromic acid and sulphuric acid. Potassium dichromate was taken (10 ml) and the excess chromic acid was titrated against standard ammonium ferrous sulphate solution using diethylamine indicator. From this back titration quantity of chromic acid not reduced by the organic matter of the soil, was consumed in the oxidation of organic carbon was determined.The percentage of organic carbon was calculated using the formula:

Organic Carbon (%) = [10 x (B-T) x 0.003 x 100) / (W xB)]

Where

B = Blank titration value

T = Titration value of sample (ml)

W = Soil sample weight (g)

0.003 g is constant factor corresponding to 1 ml of $K_2Cr_2O_7$ to oxidize 0.003 g of carbon from organic matter.

**3.7.5 Soil Organic Carbon Stock(SOCS)**

SOC stock is generally measured in metric ton /ha. At several sites, soil samples were collected from different land use from different soil series of Dewa block which were used for making SOC measurements and compared to reference sample data to determine carbon additionality potential Equations for conversion of carbon (C) results to $CO_2$equivalents (Tian, et. al., 2009)was estimated from bulk density, soil depth and carbon concentration in soil of the respective soil depth using the following equation :

Soil Organic Carbon Stock (Mt/ha$^{-1}$):% $\frac{C}{100} * BD * AD * \frac{10,000}{ha}$ =MgC per ha

Where: %C= Mean percent carbon content of amended soil over the depth interval and treatment unit of interest

BD = Mean bulk density (in Mg/m$^3$)

AD = Amended soil depth interval of interest (in m)

M = meters

Mg = megagrams (metric tons)

Ha= hectare

### 3.7.6 Carbon Sequestration Potential

Carbon sequestration Potential was measured in metric ton per hectare:

$CO_2$ equivalent potential= $\frac{MgC}{ha} * \frac{\frac{44g}{moleCO2}}{\frac{12g}{mole\ C}}$ = Mg $CO_2$/ ha

**Total Carbon Stocks in Study Sites**

The soil organic carbon stocks and vegetation carbon stocks were summed up to estimate the total carbon stocks of the respective forest system. The carbon stocks of all the study sites were summed up to determine the carbon stocks of the different land use system.

### 3.7.7 Statistical Analysis

Statistical method and test of significance appropriate to the design were applied to the data for discriminating the treatment effects from chance effects. To elucidate the nature and magnitude of the effect, the level of significance was calculated by the 'F' test in the analysis of variance (Panse and Sukhatme, 1967).

# Chapter 4
# Results

## RESULTS

### 4.1 Characterization and classification of the soils of Dewa block, Barabanki, U.P.

Total area of Dewa block, Barabanki were categories in eight soil series i.e., Gangauli, Bajgahani, Sihali, Nigari and Maharaur soil series. Proportionate extent of different soil series were reported in table 4.01. The soil series (group of soil) and single soil (mapping unit) of the surveyed area were described here in details. For each soil series a typifying pedon was described (The guide to mapping unit was given in table 4.05).

Differentiating morphological characteristics of different soil series were given in table 4.03 and analytical results of different typifying pedon was presented in Table 4.04. Explanation of symbols used in present work was represented in Table 4.05 respectively. Every mapping unit had been subsequently interpreted for various of each mapping unit was presented in table No. 4.01. The sketch diagram and physiographic setting of each pedon was present in figure 4.01. The detail soil map, landuse capability class and landuse irrigibility class of Dewa Block was presented as fig No. 4.02, 4.03 and 4.04 respectively.

#### 4.1.1 Characterization and classification of soils of Dewa block

##### 4.1.1.1 Gangauli soil series:

Gangauli series was a member of coarse loamy, mixed, hyperthermic family of Udic Ustochrepts. These soils were very deep and well drained. The slope varies from 0-15%. The surface texture was sandy loam to loam under lain with loam to sandy loam subsoils. The surface colour was yellowish brown to dark yellowish brown. The soils were slight to very severly eroded. The ground water table fluctuate between 3-5 metre throughout the year. The water holding capacity was moderately low and permeability was moderate to moderately rapid.

**Table 4.1: Average and proportionate extent of different soil**

| S.No. | Soil Mapping Unit | Characteristics | Area (ha) | Area (%) |
|---|---|---|---|---|
| 1. | $G_1dB_1$ | Gangauli sandy loam, very deep, well drained, 1-3% slope, slightly eroded soils. | 650 | 2.4 |
| 2. | $G_1dC_2$ | Gangauli sandy loam, very deep, well drained, 3-5% slope, moderately eroded soils. | 112 | 0.4 |
| 3. | $S_leA_1$ | Sihali loam, very deep, moderately well drained, 0-1% slope, non to slightly eroded soils. | 2,474 | 9.3 |
| 4. | $S_lfA_1$ | Sihali silty loam, very deep, 3430 moderately well drained, 0-1% slope, non to slightly eroded soils. | 3430 | 12.9 |
| 5. | $S_leB_1$ | Sihali loam, very deep, moderately well drained, 1-3% slope, slightly eroded soils | 711 | 2.7 |
| 6. | $DrfA_1$ | Dadara silty loam, very deep, 7229 moderately well drained, 0-1% slope, non to slightly eroded soils. | 7229 | 27.1 |
| 7. | $DrfB_1$ | Dadara silty loam, vbery deep, moderately well drained, 1-3% slope, slightly eroded soils. | 465 | 1.7 |
| 8. | $NrfA_1$-1 | Nigari silty loam, very deep, moderately well drained , 0-1% slope, non to slightly eroded very strongly alkaline soils. | 773 | 3.0 |
| 9. | $NrfA_1$-2 | Nigari silty loam, very deep, moderately well drained, 0-1% slope, strongly alkaline, non to slightly eroded soil. | 263 | 0.9 |
| 10. | $UdfA_1$-1 | Ukhadi silty loam, very deep, moderately well drained, 0-1% slope, very strongly alkaline, non to slightly eroded soiuls. | 938 | 3.5 |
| 11. | $udfA_1$-2 | Ukhadi silty loam , very deep, moderately well xdrained, 0-1% slope, strongly alkaline, non to slightly eroded soils. | 444 | 1.7 |
| 12. | $mrfA_1$ | Mahraur silty loam, very deep, imperfectly drained, 0.1 % slope, very strongly alkaline, non to slightly eroded soils. | 1530 | 5.7 |
| 13. | $mrfB_1$ | Mahraur silty loam, very deep, imperfectly drained, 1-3% slope, strongly alkaline, slightly eroded soils. | 714 | 2.7 |

| | | | | |
|---|---|---|---|---|
| 14. | BhfA$_1$ | Bajgahani silty loam, very deep, poorly drained, 0-1% slope, very strogly alkaline , non to slightly eroded soils. | 418 | 1.6 |
| 15. | BhmA$_1$ | Bajgahani silty clay loam, very deep, poorly drained, 0-1% slope, stroly al;kaline , non to slightly eroded soils. | 332 | 1.2 |
| 16. | NgmA$_1$ | Nayagaon silty clay loam, very deep, poorly drained, 0-1% slope, moderately alkaline, non to slightly eroded soils. | 1527 | 5.7 |
| 17. | NgfA$_1$ | Nayagaon silty loam, very deep, imperfectly drained, 0-1% slope, moderately alkaline, non to slightly eroded soils. | 1470 | 5.5 |
| | Total | | 23480 | 88.0 |
| | | Miscellaneous | 3196 | 12.0 |
| | Grand Total | | 26676 | 100.0 |

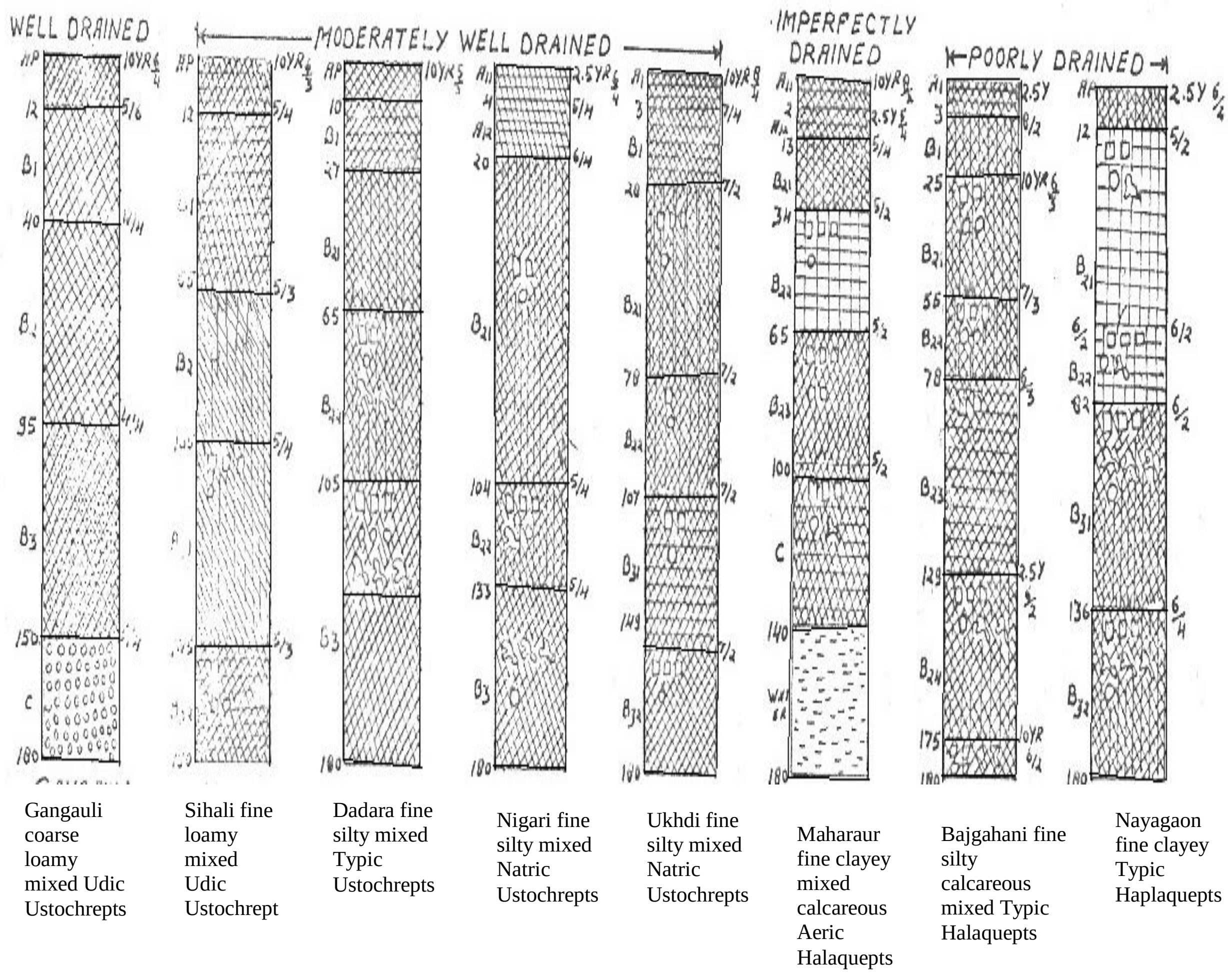


**Fig. 4.01. Schematic Diagram of Typifying pedons and Physiographic setting of identified soil of Dewa Block, Barabanki**

**4.1.1.1.1 Typifying Pedon (Gangauli Cultivated):**

**Ap (0-12cm)**: Light yellowish brown (10 yr 6/4D) and yellowish brown (10 yr 5/4M); sandy loam; weak, medium, sub angular, blocky structure, breaking into weak medium crumb; loose, non sticky and non plastic; many, fine to very fine roots; many fine interstitial pores; pH 7.5; clear and smooth boundary.

**B1/A3 (12-40cm):** Yellowish brown (10yr 5/6 M); loam. weak, medium, sub angular blocky structure, friable, slightly sticky and slightly plastic, common, fine to very fine roots, few coarse, moderately adhesive, partially filled, ortho-tubulic grano-tubules, many very fine discontinuous, simple, tubular imped pores, pH 7.4, gradual and smooth boundary.

**B2(40-95cm):** Dark yellowish brown (10yr 4/4 M); loam, moderate, medium, sub angular blocky structure; friable, slightly sticky and slightly plastic; common, very fine roots, common very fine discontinuous random simple tubular imped pores pH 7.5, gradual and smooth boundary.

**B3(95-150cm):** Dark yellowish brown(10yr 4/4 M); sandy loam, weak, medium, sub angular blocky structure friable slightly sticky and slightly plastic common very fine roots common very fine discontinuous random simple tubular imped pores pH 7.5 gradual and smooth boundary.

**C(150-180cm):** Yellowish brown (10yr 5/4 M); sandy loam, massive very friable non sticky and non plastic, common very fine interstitial pores, pH 7.3

**Table 4.02: Soil description, Dewa Block, Barabanki**

| S. No. | Physiographic Unit | Soil Mapping Unit | Series | Brief Description | Taxonomic Unit | Area in Hectare | Percent |
|---|---|---|---|---|---|---|---|
| 1 | Moderately slopy, old alluvial, upland well drained | Gl-d-B1 | Gangauli | Sandy loam, well drained, very deep, 1-3%slope, slightly eroded soils | Udic Ustochrepts | 550 | 24 |
| 2 | Moderately slopy, old alluvial, upland well drained | Gl-d-C2 | Gangauli | Sandy loam, well drained, very deep, 3-5%slope, moderate eroded soils | Udic Ustochrepts | 112 | 0.4 |
| 3 | Nearly plain, old alluvial, midland moderately well drained | Sl-e-A1 | Sihali | Very deep, moderately well drained, 0-1% slope, non to slightly eroded soils | Udic Ustochrepts | 2474 | 9.3 |
| 4 | Nearly plain, old alluvial, midland moderately well drained | Sl-f-A1 | Sihali | Silty loam, very deep, moderately well drained, 0-1% slope, slightly eroded soils | Udic Ustochrepts | 3430 | 12.9 |
| 5 | Nearly plain, old alluvial, midland moderately well drained | Sl-e-B1 | Sihali | Loam, very deep, moderately well drained, 1-3% slope, slightly eroded soils | Udic Ustochrepts | 711 | 2.7 |
| 6 | Nearly plain, old alluvial, midland moderately well drained | Dr-f-A1 | Dadra | Silty loam, very deep, moderately well drained, 0-1% slope, non to slightly eroded soils | Typic Ustochrepts | 7229 | 27.1 |
| 7 | Nearly plain, old alluvial, midland moderately well drained | Dr-f-B1 | Dadra | Silty loam, very deep, moderately well drained, 1-3% slope, slightly eroded soils | Typic Ustochrepts | 465 | 1.7 |
| 8 | Nearly plain, old alluvial, midland moderately well drained | Nr-f-A11 | Nigari | Silty loam, very deep, moderately well drained, 0-1% slope, strongly alkaline, non to slightly eroded soils | Natric Ustochrepts | 773 | 3.0 |
| 9 | Nearly plain, old alluvial, midland moderately well | Nr-f-A12 | Nigari | Silty loam, very deep, moderately well drained, 0-1% slope,strongly alkaline, | Natric Ustochrepts | 263 | 0.9 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | drained | | | non to slightly eroded soils | | | |
| 10 | Nearly plain, old alluvial, midland moderately well drained | Ud-f-A11 | Ukhdi | Silty loam, very deep, moderately well drained, 0-1% slope, very strongly alkaline, non to slightly eroded soils | Natric Ustochrepts | 938 | 3.5 |
| 11 | Nearly plain, old alluvial, midland moderately well drained | Ud-f-A12 | Ukhdi | Silty loam, very deep, moderately well drained, 0-1% slope, strongly alkaline, non to slightly eroded soils | Natric Ustochrepts | 444 | 1.7 |
| 12 | Nearly plain but temporarly water logged, mid low land, imperfectly drained | Mr-f-A1 | Mahraur | Silty loam, very deep, imperfectly drained, 0-1% slope, very strongly alkaline, non to slightly eroded soils | Aeric Halaquepts | 1530 | 5.7 |
| 13 | Nearly plain but temporarly water logged, mid low land, imperfectly drained | Mr-f-B1 | Mahraur | Silty loam, very deep, imperfectly drained, 1-3% slope, strongly alkaline,slightly eroded soils | Aeric Halaquepts | 714 | 2.7 |
| 14 | Gentle slopy, old alluvial, low land poorly drained | Bh-f-A1 | Bajgahani | Silty loam, very deep, poorly drained, 0-1% slope, very strongly alkaline, non to slightly eroded soils | Typic Halaquepts | 418 | 1.6 |
| 15 | Gentle slopy, old alluvial, low land poorly drained | Bh-m-A1 | Bajgahani | Silty clay loam, very deep, poorly drained, 0-1% slope, strongly alkaline, non to slightly eroded soils | Typic Halaquepts | 332 | 1.2 |
| 16 | Nearly plains but temporarly water logged. Concave topography. Lowland, poorly drained | Ng-m-A1 | Nayagaon | Silty clay loam, very deep, poorly drained, 0-1% slope, moderately alkaline, non to slightly eroded soils | Typic Halaquepts | 1527 | 5.7 |
| 17 | Nearly plains but temporarly water logged. Concave topography. Lowland, poorly drained | Ng-f-A1 | Nayagaon | Silty loam, very deep, poorly drained, 0-1% slope, imperfectly drained, moderately alkaline, non to slightly eroded soils | Typic Halaquepts | 1470 | 5.5 |

**Table : 4.03. Land use capability class, Dewa block, Barabanki**

| Map symbol | Soil Mapping Unit Included | Land Use Capability Classes | Description | Area in hectare | Percent |
|---|---|---|---|---|---|
| 1 | Sl-e-A1 (3)<br>Sl f A1 (4)<br>Dr f A1 (6) | I | Land that have no limitation for sustained production | 13133 | 49.3 |
| 2 | Gl d B1 (1)<br>Sl e B1 (5)<br>Dr f B1 (7) | IIe | Land that have moderate limitation of erosion for sustained production due to erosion | 1826 | 6.8 |
| 3 | Ng f A1 (7) | IIws | Land that have moderate limitation due to wetness for sustained production due to wetness | 1470 | 5.5 |
| 4 | Gl d C2 (2) | IIIe | Land that have severe limitation for moderate erosion for sustained production due to erosion | 112 | 0.5 |
| 5 | Nr f A12 (9)<br>Ud f A12 (11) | IIIs | Land that have severe limitation of alkalinity for sustained production due to alkalinity | 707 | 2.6 |
| 6 | Ngm A1 (16) | IIIws | Land that have severe limitation of wetness and moderate alkalinity for sustained production due to wetness and alkalinity | 1527 | 5.6 |
| 7 | Bhm A1 (15) | III rw1 | Land that have severe limitation of alkalinity and wetness for sustained production due to alkalinity and wetness | 332 | 1.2 |
| 8 | Mr f B1 (13) | IIIrw2 | Land that have severe limitation of alkalinity and wetness for sustained production due to alkalinity | 714 | 2.7 |
| 9 | Nr f A11 (8)<br>Ud f A11 (10) | IVs | Land that have severe limitation of alkalinity for sustained production due to strong alkalinity | 1711 | 6.5 |
| 10 | Mr f A1 (12)<br>Bh f A1 (14) | IVrw | Land that have very severe limitation of alkalinity and wetness for sustained production due to alkalinity and wetness | 1948 | 7.5 |

**Table No. 4.04: Land use irrigibility class, Dewa block, Barabanki**

| MAP SYMBOL | SOIL MAPPING UNIT | LAND USE IRRIGABILITY CLASSES | DESCRIPTION | AREA IN HECTARE | PERCENT |
|---|---|---|---|---|---|
| 1 | Sl l A1(3)<br>Sl f A1 (4)<br>Dr f A1 (6) | 1 | Land that has no limitations for sustained use under irrigation | 13,133 | 4.93 |
| 2 | Gl d B1 (1)<br>Sl l B1 (5)<br>Dr f B1 (7) | 2t | Land that have moderate limitations for sustained use under irrigation due to drainage | 1826 | 6.8 |
| 3 | Ngf A1 (17) | 2ds | Land that have moderate limitation for sustained use under irrigation due to wetness | 1470 | 5.5 |
| 4 | Gl d C2 (2) | 3t | Land that have severe limitation for sustained use under irrigation due to gentle topography | 112 | 0.4 |
| 5 | Nr f A12(9)<br>Ud f A12 (11) | 3s | Land that have severe limitation for sustained use under irrigation due to strong alkalinity | 707 | 2.6 |
| 6 | Ng m A1 (16) | 3ds | Land that have severe limitation for sustained use under irrigation due to poor drainage and moderate alkalinity | 1527 | 5.7 |
| 7 | Bh m A1 (15) | 3sd1 | Land that have severe limitation for sustained use under irrigability due to strong alkalinity and poor drainage | 332 | 1.2 |
| 8 | Mr f B1 (18) | 3sd2 | Land that have severe limitation for sustained use under irrigation due to strong alkalinity and wetness | 714 | 2.7 |
| 9 | Nr f A11 (8)<br>Ud f A11 (10) | 4s | Land that have severe limitation for sustained use under irrigation due to very strong alkalinity | 1711 | 6.5 |
| 10 | Mr f A1 (12)<br>Ud f A1 (14) | 4sd | Land that have very severe limitation for sustained use under irrigation due to very strong alkalinity | 1948 | 7.5 |

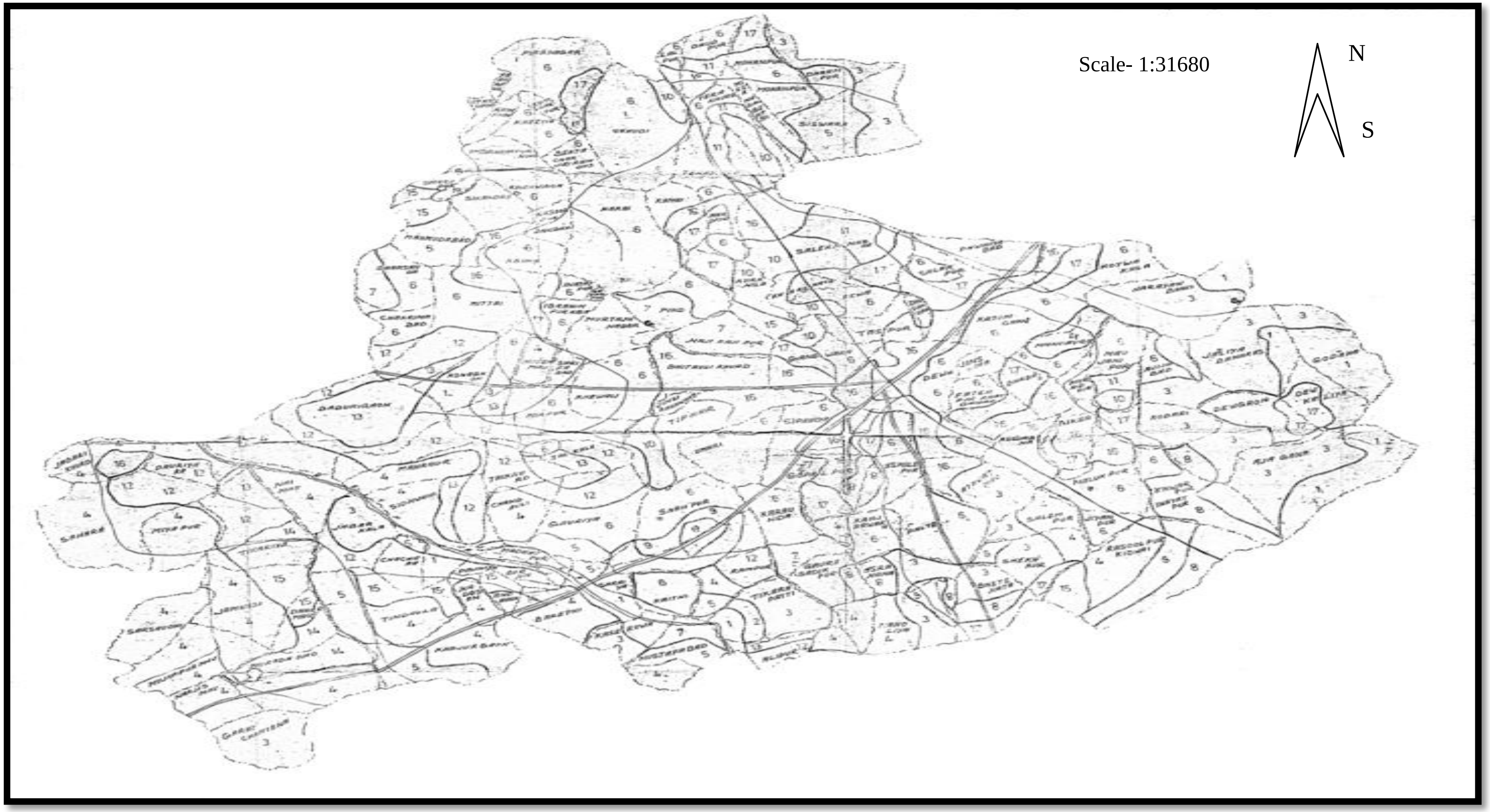


**Fig 4.02. Soil Map, Dewa Block, Barabanki**

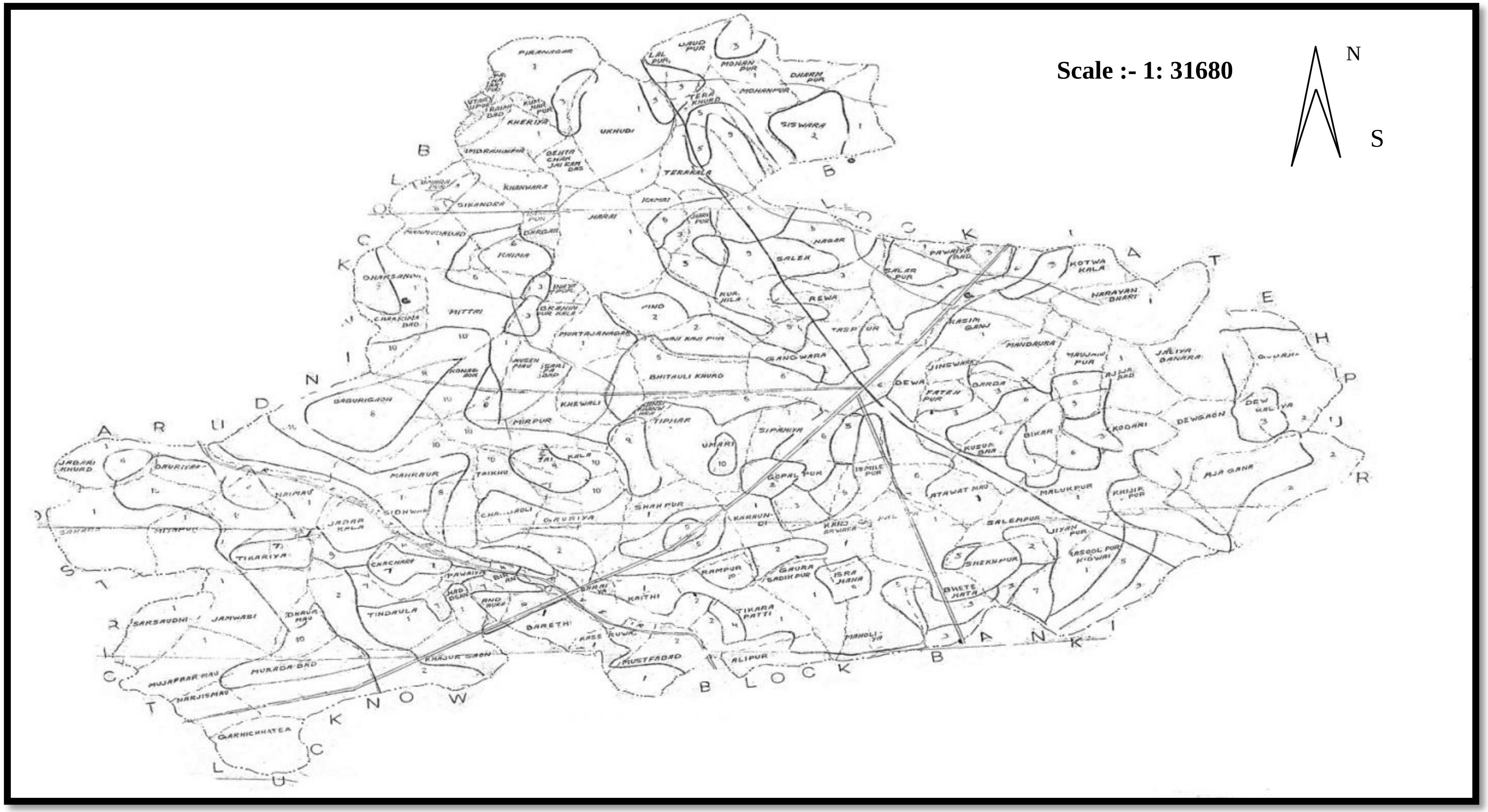


**Fig 4.03: Land use capability class, Dewa block, Barabanki**

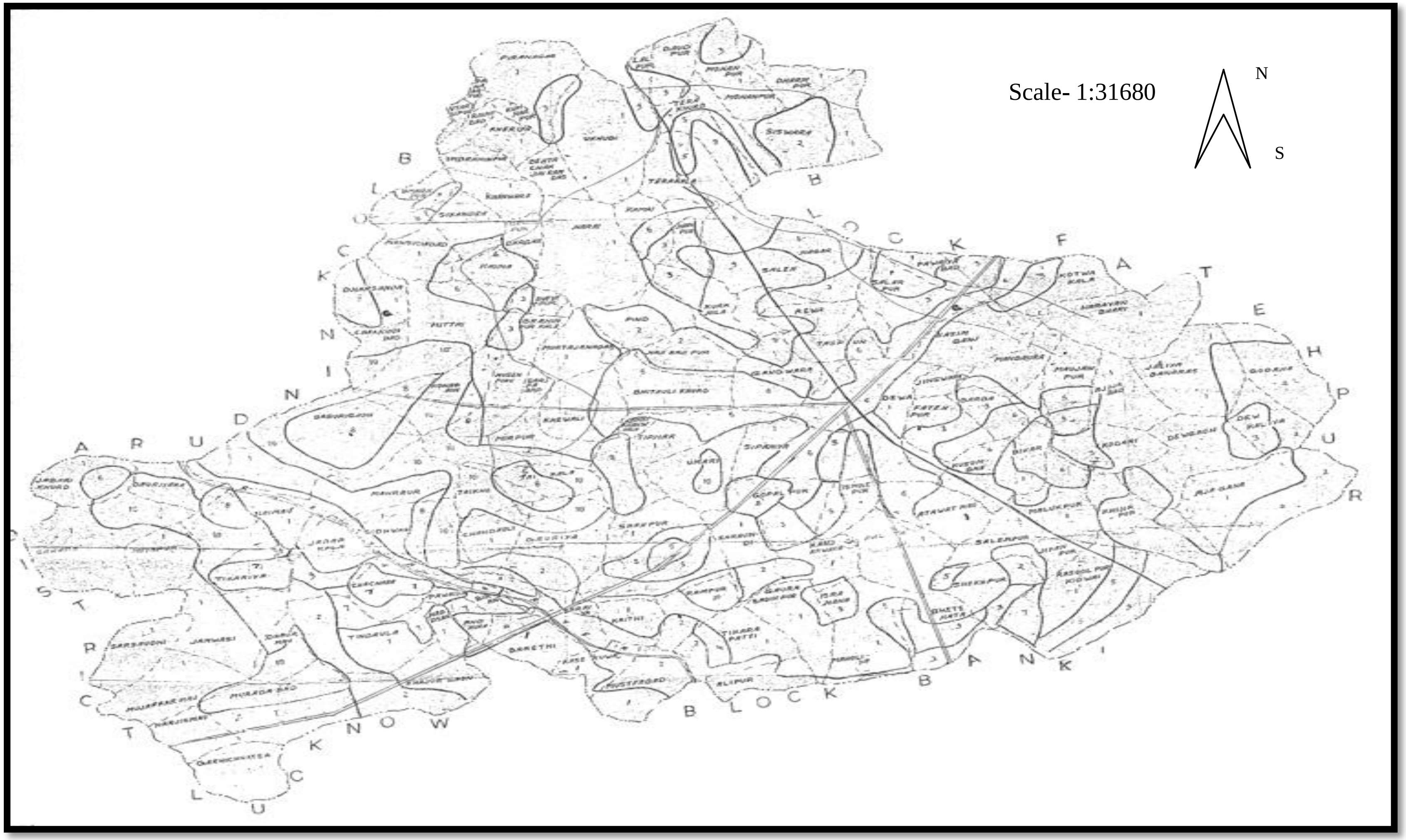


**Fig 4.04: Land use irrigibility class, Dewa block, Barabanki**

| Reference | Symbols |
|---|---|
| Village Boundary | |
| Block Boundary | |
| Road | |
| Canal | |
| Railway Line | |
| Irrigability Boundary | |
| River | |

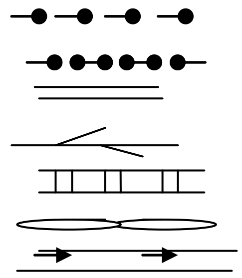

**Fig 4.05: Showing symbols for the maps, i.e., Fig 4.02, Fig 4.03 and Fig 4.04**

**4.1.1.1.2 Soil Mapping units of Gangauli Series:**

Two mapping units had been identified:

1. Gangauli Sandy loam, very deep, well drained, 1-3% slope, slightly eroded soils (GldB1). The soils of this mapping unit were very deep, well drained , occurring on up land with 1-3% slope. The surface texture was sandy loam. It had slight limitations of erosion. It response well to management for contour bunding and leveling.
2. Gangauli sandy loam, very deep well drained 3-5% slope, moderately eroded soils (Gl d C2). This mapping unit had similar characteristics described as above mapping unit. It differes only in slope which was 3-5%. It responses well to management for contour bunding and leveling.

**4.1.1.2 Sihali Series:**

Sihali Series was a member of fine loamy, mixed Hyperthermic family of Udic Ustochrepts. The soil was very deep , moderately well drained, the slope varies from 0-5%. The surface texture was loam to silty loam and underlain with Sicl to silt sub soils. The surface colour was pale brown. The soils were slight to moderately eroded. The ground water table fluctuate between 2-3 meter throughout the year. The water holding capacity was medium and permeability was moderate.

**4.1.2.1 Typifying Pedon (Sihali Cultivated)**

**Ap (0-12cm):** Pale brown (10 yr 6/3D) and brown (10 yr 5/3M); silty loam, weak fine subangular blocky structure slightly hard friable slightly sticky and slightly plastic, many fine discontinuous random simple tubular imped pores pH 7.5 clear and smooth boundary.

**B1(12-65cm)**: Yellowish brown (10yr 5/4 M); silty loam, moderate medium subangular blocky structure friable, slightly sticky and slightly plastic, common very fine roots, many , very fine discontinuous random simple tubular imped pores pH 7.7; gradual and smooth boundary.

**B21 (65-105cm**):Brown (10yr 5/3 M), silty clay loam, moderate coarse subagular blocky structure, firm, sticky and plastic, many medium faint (10 yr 5/6) yellowish brown mottles; few , fine, diffuse, ferromanganese, common, fine to very fine roots, common, fine to very fine, discontinuous, random, simple, tubular, imped pores, few, coarse, moderately adhesive, partially filled, orthotubulic aggrotubules, pH 7.6; gradual and smooth boundary.

**B22(105-145cm):** Yellowish brown (10yr 5/4 M) silty clay loam, moderate, coarse, subangular blocky structure, firm, sticky and plastic, many medium faint brownish yellow (1o yr 6/6) mottles, few fine to medium, diffuse/discrete ferromanganese;concretions few,fine, roots; common, very fine, discontinuous, random simple, tubular imped pores and few, fine interstitial pores, pH 7.5; gradual and smooth boundary.

**B3(145-180cm):** Brown (10yr 5/3 M); silty loam; moderate, medium subangular blocky structure, friable slightly sticky and slightly plastic few fine faint, yellowish brown (10 yr 5/4) mottles, common, medium, diffuse concretions fine roots, common, fine, interstitial pores; pH 7.3.

**4.1.1.2.2Type location**

The pedon was studied in plot No. 89 of village Khajur Gaon situated at a distance of 10km. on Dewa to Chinhut road in right side and Dewa to Barabanki distance was 13km.

**4.1.1.2.3 Range in characteristics**:

The thickness of column was more than 180 cm. the estimated MAST 22.9$^0$C, MSST 30.8$^0$C and MWST was 11.8$^0$C. The moisture control section was dry for more than 90 cumulative days but also consecutively moist for more than 90 days in the year.

The `A` horizon was 10-20 cm thick, its color was in hue 10yr, value 5-6 and chroma 3-4. The surface texture was silty loam to sandy loam. The `B` horizon was more than 150 cm thick. The color was in hue 10 yr, value 4-5 and chroma 3-4. The texture was silty clay loam to silty loam, few to many, faint or distant, brownish yellow to yellowish brown mottles were present. Few to common, fine to medium diffuse or discrete ferromanganese concretions were present in `B` horizon.

**4.1.1.2.4 Soil mapping units of Sihali Series**

Three mapping units had been identified:

1. Sihali silty loam, very deep, moderately well drained, 0-1% slope, slightly eroded soils (SlfA$_1$) :- these soils were very deep, moderately well drained, occurring on mid upland with 0-1 percent slope. The surface texture was silty loam. It had non to slight limitation and responses well to management.
2. Sihali loam, very deep, moderately well drained, 0-1% slope, slightly eroded soils (SleA1): these soils had similar characteristics to above mapping unit. It differes only in surface textures which was loam in this case. It had non to slight limitation and responses well to management.

3. Sihali loam, very deep, moderately well drained 1-3% slope, slightly eroded soils ($SleB_1$): the soils of this mapping unit had similar characteristics to above mapping unit. It differs only in slope which was 1-3%. It had slight erosion hazard and as such responses well to management particularly for contour bunding and leveling.

**4.1.1.3 Bajgahani Series**

Bajgahani Series was the member of fine silty calcarious mixed, Hyperthermic family of Aeric Halaquepts. These soils were very deep, poorly drained occurring on low land. The slope varies from 0-3%. The surface texture was silty loam, which merges into silty clay loam to clay loam sub soils. The surface colour was light gray and sub surface were very strongly alkaline and calcarious throughout the profile. The water holding capacity of the soil was medium and permeability was very slow. The water table varies 0.5 to 1 mtrs throughout the year.

**4.1.1.3.1Typifying Pedon:** Bajgahani Uncultivated:

**$A_1$(0-3cm):** Light grey (2.5 Y 7/2 D Brownish grey (2.5 Y 6/2 M); silty loam; massive , soft, friable, slightly sticky and slightly plastic; many fine roots; violent effervescence; pH 10.4; abrupt and smooth boundary.

**B1(3-25cm):** White (2.5Y 8/2D); light brownish grey (2.5 Y 6/2 M); silty clay loam; weak, moderate, subangular blocky structure; slightly hard, firm, sticky and plastic; common, very fine roots; many fine interstitial pores; common very fine discontinuos, random simple tubular imped pores; violent effervescense; pH 10.2; abrupt, wavy boundary.

**$B_{21}$(25-55cm):** Pale brown (10 YR 6/3M); silty clay loam, moderate, medium subangular blocky structure; very firm, sticky and plastic; common fine distinct olive yellow (2.5 Y 6/8) mottles; common fine diffused ferromanganese concretions, common very fine roots, common very fine discontinuos random simple, tubular, imped pores, strong effervescence, pH 10.1, abrupt and smooth boundary.

**$B_{22}$(55-78cm):** Pale brown (10 YR 6/3 M); Clay loam, moderate, coarse, subangular blocky structure, firm, sticky and plastic, many medium prominent, olive-yellow (2.5 Y 6/8) mottles, thin patchy of matran, common, medium, diffused ferromanganese concretions, common very fine roots; simple, tubular imped pores, few coarse to very coarse; weakly adhesive, partially filled, orthotubulic, aggrotubules, many, fine interstitial pores, slight effervescence, pH 9.3, abrupt wavy boundary.

**$B_{23}$(78-129cm):** Pale brown (10 YR 6/3 M); Silty Clay loam, moderate coarse, subangular blocky structure, firm sticky and plastic, common, medium distinct, yellowish brown (10 YR 5/6) mottles, common, fine diffused ferromanganese concretions few, very fine roots, few coarse, weakly adhesive, partially filled orthotubulic aggrotubules, many, fine interstitial common, very fine, discontinuos, random simple tubular imped pores strong effervescence, pH 9.3, abrupt wavy boundary.

**$B_{24}$(129-175cm):** Light brownish grey (2.5 Y 6/2 M); silty clay loam, moderate coarse subangular blocky structure, firm sticky and plastic common medium to coarse calcium carbonate concretions, few fine diffused ferromanganese concretions , many medium distinct, yellowish brown (10 YR 5/8) mottles, few very fine roots, many fine, interstitial pores, common very fine to fine, discontinuous random simple, tubular imped pores, few coarse, weakly adhesive partially filled orthotubulic aggrotubules, strongly effervescence, pH 8.4, clear, wavy boundary.

**$B_3$(175-180cm):** Light brownish grey (10 YR 6/2 M);Silty clay loam, massive friable sticky and plastic, many , medium distinct, brownish yellow (10 YR 6/8) mottles , common very coarse calcium carbonate concrete ions, few, medium, dif f used ferromaganese concretions, few, very fine roots, many, very fine to fine interstitial p[ores, slight effervescence, pH 8.2.

**4.1.1.3.2 Type Location**

The pedon was locally situated in Khasra No. 201 of village Chachera , situated at a distance of 3km away from Dewa to Chinhut road in the right side at 9 km from Dewa.

**4.1.1.3.3 Range in Characteristics**

The thickness of the solum was more than 180cm. the MAST was 22.9$^0$C, MSST 30.9$^0$C and MWST was 11.8$^0$C. The moisture control section was saturated for more than 2 months. The \`A\` horizon was only 3cm. thick. The texture was silty loam to silty clay loam. The \`B\` horizon was about 150cm thick. The color was in hue 2.5 Y-10 YR, value 5-6 and chroma 2-6. The texture varies from clay loam to silty clay loam.

**4.1.1.3.4 Soil Mapping Units of Bajghani Series**

Two mapping unit had been identified:

1. Bajghani silty loam, very deep, poorly drained, 0-1% slope, strongly alkaline, none to slightly eroded soils (Bh $fA_1$) : This soils was very deep, poorly drained , occurring on low land with 0-1% slope. The surface texture was silty loam. It had severe limitation of alkalinity and responses well to management, particularly for amendment of alkalinity.
2. Bajgahani Silty clay loam, very deep, poorly drained 1-3% slope, strongly to slightly eroded soils ($BhmBH_1$): the soil of this mapping unit was similar to above mapping unit. It differs only in texture and slope. It responses well to mangament particularly for amendment of alkalinity.

**4.1.1.4 Ukhdi series:**

Ukhdi series was a member of fine silty, mixed hyperthermic family of Natric Ustochrepts. These soils were very deep, moderately well drained occurring on mid land. The slope varies from 0-3%. The surface texture was silty loam which merges into clay loam to silty clay loam subsoil. The surface color was pale yellow to light yellowish brown to light olive brown. These soils were strongly to very strongly alkaline and calcareous throughout the profile. The ground water table fluctuates within 1.5 -3mtr throughout the year. The water holding capacity was medium and permeability was moderately slow.

**4.1.1.4.1 Typifying Pedon**

**$A_{11}$(0-3cm):** Pale yellow (10 YR 8/4 D) to pale yellow (10 YR 7/4 M); silty loam, massive soft loose, slightly sticky and slightly plastic, many very fine roots, many fine interstitial pores, few vesicles, strong effervescence, pH 10.1, abrupt and smooth boundary.

**$B_1$(3-28cm):** Pale yellow (10 YR 7/4 M); silty loam, moderate, medium, subangular blocky structure, friable slightly sticky and slightly plastic, many very fine roots, many fine, discontinuous, random simple, tubular imped pores, few coarse, moderately adhesive , metatubulic aggrotubules, strong effervescence, pH 10.7, clear and smooth boundary.

**$B_{21}$ (28-78cm):** Light gray (10 YR 7/2 M) silty clay loam, moderate coarse, subangular blocky stuucture, firm sticky and plastic common medium distinct light yellowish brown (2.5 Y 6/4) mottles, few fine diffuse ferromanganese, calcium carbonate in amorphous condition, common very fine roots, many fine interstitial common, very fine discontinuous random simple, tubular, imped pores, few coarse orthotubulic , Aggrotubules strong effervescence pH 9.3. abrupt and smooth boundary.

**$B_{22}$ (78-107cm):**Light gray (10 YR 7/2 M); Silty clay loam, moderate, medium, subangular blocky structure, firm sticky and plastic, few fine faint light yellowish brown (2.5 Y 6/4) mottles, few fine diffuse ferromanganese, many splotchy $CaCo_3$ and few , fine, diffuse $CaCo_3$ common , very fine roots, many very fine to fine, interstitial pores, strong effervescence, pH 8.8 abrupt, wavy boundary.

**$B_{31}$(107-149cm):**Pale yellow (10 YR 7/2 M), silty clay loam, massive, broken into weak, fine subangular blocky structure, friable, slightly sticky and slightly plastic, few fine, diffuse ferromanganese, concretions, common, medium, distinct, olive yellow (10yr 6/6) mottles, many, very coarse, irregular, indurated $CaCo_3$, common, very fine roots, many, very fine, discontinuous, random, simple, tubular, imped pores, violent effervescence, pH 8.8, clear, wavy boundary.

**$B_{32}$(149-180cm):**Light gray (10 YR 7/2 M), gravelly silty loam, loam, massive, friable, slightly sticky and slightly plastic, many , medium, faint, yellow (10 YR 7/6) mottles, few, fine, diffuse ferromanganese, many, very coarse, irregular, indurated $CaCo_3$, few, very fine roots, many, fine, interstitial pores, violent effervescence, pH 9.0.

**4.1.1.4.2 Type Location**

Village Ukhdi, tehsil Nawabganj, block Dewa, district Barabanki was situated at the bank of Barabanki branch (Canal) in right hand side at a distance of about 8km. from Dewa and Dewa was 13 km away from Barabanki on Barabanki to Fatehpur Road.

#### 4.1.1.4.3 Range in Characteristics

The thickness of solum was more than 180 cm. the MAST was $22.9^0$C, MSST $30.8^0$C and MWST was $11.8^0$C. The moisture control section was very moist about during the year. The `A` horizon was less than 10cm thick. The color was in hue 10 YR, value 7-8 and chrome 4. The texture was silty loam. The thickness of `B` horizon was about 170cm. the color was in hue 10 YR, value 7 and chroma 2-4. The texture was silty clay loam to silty loam. The surface horizon was ochric and sub surface diagnostic horizon was cambic. Coarse fragments were also present in between about 30-180cm.The $CaCo_3$ were present at a depth of about 100cm. very coarse irregular and indurated splotcgy $CaCo_3$ were found in $B_2$ horizon.

#### 4.1.1.4.4 Soil Mapping Units of Ukhdi Series

Two mapping units had been identified:

1. Ukhdi silty loam, very deep, moderately well drained, 0-11 % slope, very strongly alkaline, slightly eroded soils ($UdfA_{11}$): This soil was very deep, moderately well drained occurring on mid land with 0-1% slope. It had similar morphological characteristics as described for the typifying pedon. The soils of this mapping unit were very strongly alkaline. It responses well to management particularly for amelioration of alkalinity.
2. Ukhdi silty loam, very deep, moderately well drained, 0-1% slope, strongly alkaline, slightly eroded soils, ($UdfA_{12}$) : this mapping unit had similar characteristics to above mapping unit but differs only in alkalinity which was strong. It responses well to management particularly for amelioration of alkalinity.

### 4.1.1.5 Nayagaon series

Nayagaon series was a member of fine clayey, mixed Hyperthermic family of Aeric Haplaquepts. These soils were very deep, poorly drained, occurring on low land depressions. The slope varies from 0-3%. The surface texture was silty clay loam which merges into silty clay. The subsoil was silty clay loam to silty clay. The surface color varies from dark graywash brown to dark gray and sub surface color varies from grayish brown to light brownish gray. They were calcereous insub surface horizon . they remain periodically submerged during monsoon, the ground water table fluctuates within 1.5 mt. throughout the year. The ground water saturates the soil for more than 4 months. The water holding capacity of the soil was high and permeability was slow.

#### 4.1.1.5.1Typifying Pedon- Nayagaon Cultivated

**Ap(0-10cm):**Dark grayish brown (10 YR 4/2 M), silty clay loam, strong, coarse, angular blocky structure, very hard, very firm, very sticky and very plastic, many , fine roots, many very fine to fine, interstitial, many micro and very fine, discontinuous random, simple tubular, imped pores, pH 8.1, clear and smooth boundary.

**$B_1$(10-33cm):** Grayish brown (10 YR 5/2 M), silty clay, strong, coarse, angular blocky structure, very guard, very firm, very sticky and very plastic, common, medium, faint, yellowish brown (10 YR 5/4), mottles, common, fine to very fine roots, fine to medium, interstitial, few, very fine, discontinuous, random, simple, tubular, imped pores, pH 8.4, gradual and smooth boundary.

**$B_2$(33-75cm):** Grayish brown (10 YR 5/2 M), silty clay, strong, medium, angular blocky structure, firm, sticky, plastic, few, fine, faint, yellowish brown, (10 YR 5/4) mottles, few, fine to very fine, diffuse ferromanganese and $CaCo_3$ concretions, few fine to very fine roots, common, fine to medium interstitial and few, fine, discontinuous, random, simple, tubular, imped pores, slight effervescence, pH 8.3 clear and smooth boundary.

**$B_{31}$(75-130cm):**Yellowish brown (10 YR 5/4 M), silty clay loam, moderate, medium, angular blocky structure, firm, sticky and plastic, many, medium, distinct yellow (10 YR 7/6) mottles, few, fine, diffuse ferromanganese concretions and few, very fine $CaCo_3$ (2%) concretions, few very fine roots, few, very fine, discontinuous, random, simple, tubular, imped pores, slightly effervescence , pH 8.4, clear and wavy boundary.

**$B_{32}$(130-180cm):**Light brownish gray (2.5 Y 6/2 M), silty clay loam, moderate, medium, subangular blocky structure, very firm, sticky and plastic, many medium, distinct, yellowish brown (10 YR 5/6 ) mottles, few, fine diffuse/dicrete ferromanganese concretions and common, medium to coarse $CaCo_3$ (15% by volume) concretions, violent effervescence, pH 8.7

**4.1.1.5.2Type location**

The pedon was studied in the village Salarpur in Khadra No. 304 in right side of Barabanki to Fatehpur road situated at about 18 km from Barabanki.

**4.1.1.5.3 Range in Characteristics**

The thickness of solum was more than 180cm. te estimated MAST was $22.9^0$C, MSST $30.8^0$C and the MWST was $11.8^0$C. the moisture control section was very moist for the period more than 9 months during the year. They remain submerged during monsoon. The `A1 horizon was 0-10 cm thick. The color was in hue 10YR, value 4 and chroma 2. The texture was silty clay loam to silty loam. The `B` horizon was more than 160 cm thick, the color was in hue 10 YR , value 5-6 and chroma 2-4, the texture was silty clay to silty clay loam. Few to many , fine to medium, faint to distinct, yellowish brown to yellow mottles were present , few , fine to very fine ferromanganese concretions, few to common, medium to coarse $CaCo_3$ kankars were present in $B_3$ horizon.

**4.1.1.5.4 Soil Mapping Units of Nayagaon Series**

Two mapping units had bveen identified:

1. Nayagaon Silty clay loam, very deep, poorly drained 0-1% slope, moderately alkaline, slightly eroded soils ($NgmA_1$).: the soil of this mapping unit was very deep, poorly drained, occurring on low land and depression with 0-1% slope. The surface texture was silty loam. It had severe limitations of water logging and slow permeability. It responses well to management particularly for drainage.
2. Nayagaon silty loam, very deep, imperfectly drained, 0-1% slope, moderately alkaline , slightly eroded soils, ($NgfA_1$) : All characteristics of this mapping unit were similar as above mapping unit. It differs only in texture which was silty loam. It responses well to management particularly for drainage.

**4.1.1.6 Dadra Series**

Dadra series was member of fine silty, mmixed hyperthermic family of Typic Ustochrepts. These soils were very deep, moderately well drained occurin on midland. The slope varies from 0-5%. The surface texture was loam to silty loam and under lain with silty loam to gravely silty clay loam. The surface colour was grey to grayish brown. The `B` horizon was calcereous. The ground water table fluctuate between 1.5 -3m. throughout the year. Water holding capacity of the soil was medium and permeability was moderate to moderate slow.

**4.1.1.6.1 Typifying Pedon: Dadra Cultivated:**

**Ap(0-10cm):** Gray (10 YR 6-5/1D) and grayish brown (10YR 5/2 M), loam, medium, weak, subangular blocky structure, slightly hard, friable, slightly sticky and slightly plastic, many fine to very fine roots, common, very fine to fine, continuous, simple, tubular, vertical, imped pores, pH 7.5, clear and smooth boundary.

**$B_1$(10-27cm):** Pale brown (10 YR 6/3 M) and dark yellowish brown (10 YR 4/4 M), silty loam, moderate, coarse, sub angular blocky structure (stacked in coarse columns), firm, sticky and plastic, few to many, very fine roots, many, very fine, simple, tubular, continuous pores, pH 7.2, gradual and smooth boundary.

**$B_{21}$(27-65cm):**Brown (10 YR 4/3 M), silty clay loam, moderate, coarse, subangular blocky structure (stacked in coarse columns), very firm, sticky and plastic, few, fine, carbonatic concretions, many, very fine roots, common, very fine, simple, tubular, vertical, exped pores, common, very fine, discontinuous, random, simple tubular, imped pores, strong effervescence, pH 7.1, gradual and smooth boundary.

**$B_{22}$(65-105cm):**Brown (10 YR 4/3 M), gravely silty clay loam, moderate, coarse, sub angular blocky structure, firm, sticky and plastic, common, medium, faint, yellowish brown (10 YR 5/4) mottles, common, very coarse, discrete calcium carbonate, few fine, diffuse ferromanganese concretions, common, very fine roots, many, very fine, discontinuous, random, simple, tubular imped pores, few, very fine, interstitial pores, violent effervescence, pH 7.3, clear and wavy boundary.

**$B_{3Ca}$(105-180cm):**Grayish brown (10 YR 5/2 M), gravelly silty loam, apedal firm, slightly sticky and slightly plastic, many, medium, faint, yellowish brown (10 YR 5/4) mottles, many, medium, diffuse or discrete ferromanganese concretions, many, very coarse, irregular, indured $CaCo_3$ concretions, few, very fine roots, many, very fine interstitial pores, violent effervescence, pH 7.4.

**4.1.1.6.2 Type Location**

The Pedon was studied in the village Dewa at Khadra No 282. Dewa on right side at a distance of about 500mtr.away from proper Dewa village. The distance of Dewa from Barabanki was only 13 km.

**4.1.1.6.3 Range in Characteristics**

The thickness of solum was more than 180 cm. the estimated MAST was 22.9$^{0}$C, MSST 30.8$^{0}$C and MWST 11.8$^{0}$C. the moisture control section was moistre for more than 90 consecutive days but also for more than 90 cumulative days. The `A` horizon was 10-20 cm thick. The color was in hue 10YR, value 4-6 and chroma 2-4. The texture was loam to silty loam, few to many medium, faint or distinct yellowish brown (10 YR 5/4) mottles were present, many irregular, indurated calcium carbonate kankar were also present in `$B_3$` horizon.

**4.1.1.6.4 Soil Mapping Units of Dadra Series:**

Two mapping units had been identified:

1. Dadra silty loam, very deep, moderately well drained 0-1% slope, slightly eroded soils, ($DrfA_1$),:this soil was very deep, moderately well drained occurring on midland with 0-1% slope. The surface texture was silty loam. It had non to slight limitation of erosion and responses well to management.
2. Dadra silty loam, very deep, moderately well drained, 1-3% slope, slightly eroded soils ($DrfB_1$): the soil characteristics of this mapping unit were same as above napping unit. It differs only in slope which was 1-3% with this mapping unit. It had slight limitations of erosion and such as responses well to management for contour bunding and leveling.

### 4.1.1.7 Nigari series:

Nigari series was a member of fine silty, mixed, hyperthermic family of Natric Ustochrepts. These soils were very deep, moderately well drained occurring on mid land. The slope varies from 0-1%. The texture was silty loam which merges into clay loam to silty clay loam subsoil. The surface color was light yellowish brown and sub surface color was light olive brown. These soils were strongly to very strongly alkaline and calcarious throughout the profile. The ground water table fluctuate 1.5 - 3metres throughout the year. The water holding capacity was medium and permeability was moderately slow.

#### 4.1.1.7.1Typifying Pedon : Nigari Uncultivated

**$A_{11}$(0-4cm):**Ligth yellowish brown (2.5 Y 6/4 D), silty loam, massive structure, friable, slightly sticky and slightly plastic, few, very fine roots, many, fine, interstitial pores, violent effervescence, pH 10.3, abrupt and smooth boundary.

**$A_{12}$(4-20cm):** Light olive brown (2.5 Y 5/4 M), silty loam, moderate, medium, sunangular blocky structure, firm, sticky and plastic, few very fine roots, many, fine, interstitial and common, very fine, discontinuous, random, simple, tubular, imped pores, few, medium to coarse, moderately, adhesive, orthotubulic, aggrotubules, violent effervescence, pH 10.3, abrupt and smooth boundary.

**$B_{21}$(20-104cm):**Light yellowish brown (2.5 Y 6/4 M), silty clay loam, moderate, medium, subangular blocky structure, firm, sticky and plastic, many, fine, discrete/ diffuse ferro manganese concretions, many, medium, distinct, yellowish brown (10 YR 5/8) mottles, few, very fine roots, many, very fine, discontinuous, random, simple, tubular, imped pores, few, coarse, moderately adhesive, orthotubulic aggrotubules, violent effervescence, pH 9.6 clear and smooth boundary.

**$B_{22}$(104-133cm):**Light olive brown (2.5 Y 5/4 M), silty clay loam, moderate, medium, subangular blocky structure, firm, sticky and plastic, few, fine, diffuse ferromanganese, few, very fine roots, many, fine interstitial pores, pH 8.6 clear and wavy boundary.

**$B_3$(133-180cm):**Light olive brown (2.5 Y 5/4 M), silty loam, weak, fine, subangular blocky structure, friable, slightly sticky and slightly plastic, few, fine, diffuse, ferromanganese, and common, very coarse, (7%) calcium carbonate concretions, few, very fine roots, many, fine, interstitial and few fine, discontinuous, random, simple, tubular, imped pores, violent effervescence, pH 8.6

**4.1.1.7.2Type Location**

The pedon was situated in Plot No. 228 of village Khijirpur-Inayatpur situated at a distance of 5km from Dewa on the bank of Barabanki branch (Canal).

**4.1.1.7.3 Range in Characteristics**

The thickness of solum was more than 180cm. te estimated MASDT 22.9$^0$C, MSST 30.8$^0$C and MWST was 11.8$^0$C. the moisture control section was dry more than 90 cumulative days and moist for more than 90 consecutive days. "the `A` horizon was more than 15cm thick. Its color was in hue 2.5 Y, value 5-6 and chroma 4-5. Te texture was silty loam. The `B` horizon was about more than 160 cm thick. Its color was in hue 2.5 Y, value 5-6 and chroma 4. Its texture was silty loam to silty clay loam, ferromanganese concretions were present below 20-133 cm. depth and few to very common coarse calcium carbonate kankars were found in `$B_3$` horizon.

**4.1.1.7.4 Soil mapping Units of Nigari Series**

Two mapping units had been identified:

1. Nigari Silty loam, very deep, moderately well drained, 0-1% slope, very strongly alkaline, slightly eroded soils ($NrfA_{1-1}$) : this soil was very deep,

moderately well drained, occurring on mid land with 0-1% slope. It had similar morphological characteristics as described for typifying pedon. It had severe limitations (very strong alkaline) of alkalinity. It responses well to management particularly for amelioration of alkalinity.

2. Nigari Silty loam, very deep, moderately well drainage, 0-1% slope, strongly alkaline, slightly eroded soils. (NrfA$_{1-2}$) : the soils of this mapping unit were similar as above mapping unit. It differs only in alkalinity which was strong alkalinity. It responses well to management particularly for amelioration of alkalinity.

**4.1.1.8 Mahraur Series**

Mahraur series was a member of fine clayey, mixed Hyperthermic family of Aeric Haylaquepts. These soils were very deep, imperfectly drained occurring on low land with 0-1% slope. The surface texture was silty loam to silty clay loam sub soils. The surface color was white. These soils were slightly eroded. The ground water table fluctuate between 1-1.5 mtr throughout the year. The water holding capacity was medium and permeability was moderately slow.

**4.1.1.8.1 Typifying Pedon: Mahraur Uncultivated**

**$A_{11}$(0-2cm):** White (10 YR 8/2 M), silty loam, massive, slightly sticky and slightly plastic, common, very fine roots, many, fine interistitial pores, strong effervescence, pH 10.1, abrupt and smooth boundary.

**$A_{12}$(2-13cm):** Light olive brown (2.5 Y 5/4 M), Silty loam, weak, fine, sunangular blocky structure, friable, slightly sticky and slightly plastic, many, very fine roots, many, fine, interstitial pores, strong effervescence, pH 10.4, clear and smooth boundary.

**$B_{21}$(13-34cm):**Light olive brown (2.5 Y 5/4 M), silty clay loam, moderate, medium, subangular blocky structure, firm, sticky and plastic, many, very fine roots, few, coarse, moderately adhesive, partially filled, orthotubulic aggrotubules and many, fine, interstitial pores, strong effervescence, pH 10.2, clear and smooth boundary.

**$B_{22}$(34-65cm):**Grayish brown (2.5 Y 5/2 M), silty clay, loam, strong, coarse, subangular blocky structure, firm, sticky and plastic, many, medium, distinct, yellow (2.5 Y 8/8) mottles, few, fine, diffuse ferromanganese concretions, common, very fine roots, many, fine, interstitial and common, very fine, continuous, vertical, exped pores, strong effervescence, ph 10.0, clear and smooth boundary.

**$B_{23}$(65-100cm):**Grayish brown (2.5 Y 5/2 M), silty clay loam, moderate, medium, subangular blocky structure, firm , sticky and plastic, many, coarse, distinct, yellow (2.5 Y 7/8) mottles, common, fine to medium, diffuse/ discrete ferromanganese concretions, common very fine roots, many, fine, interstitial and common, very fine, continuous, vertical, exped pores, stress cutan, strong effervescence, pH 9.5, abrupt and smooth boundary.

**C(100-140cm+water):**Graywih brown (2.5 Y 5/2 M), Silty loam, massive, friable, slightly sticky and slightly plastic, many, coarse, prominent, light yellowish brown (10 YR 5/4) mottles, few, fine to medium, discrete $CaCo_3$ concretions, few, fine, interstitial pores, violent effervescence, pH 9.0.

**4.1.1.8.2Type Location**

The pedon was studied in/village Mahraur, block Dewa, district Barabanki, situated at a distance of about 9km. linking with a distance of 2.5 km. on Feeder Canal (Indira Canal) in left side.

**4.1.1.8.3 Range in Characteristics**

The thickness of solum was more than 80cm. the estimated MAST 22.9$^0$C, MSST 30.8$^0$C and MAST was 11.8$^0$C. the moisture control section was moist for more than 9 months during the year. They remain submerged during monsoon.

The \`A\` horizon was less than 20cm. the colour was in hue YR 2.5Y, value 5-8 and chroma 2-4. The texture was silty loam. The \`B\` horizon was more than 80cm thick. The colour was in hue 2.5 Y-10 YR; value 5 and chroma 2-4. The texture was silty clay loam. The water table fluctuate within 1 (one) mtr. During rainy season. $CaCo_3$ Kankar covering a volume of more than 50% was found below a depth 140cm.

**4.1.1.8.4 Soil Mapping Units of Mahraur Series**

1. Mahraur Silty Loam, very deep, imperfectly drained, very strongly alkaline, 0.1%slope, slightly eroded soil ($MrfA_1$): the soils of this mapping unit were very deep, imperfectly drained with 0-1% slope. It had severe limitations of alkalinity. It responses well to management particularly for amelioration of alkalinity and water management practices.
2. Mahraur Silty loam, very deep, imperfectly drained, 1-3% slope, strongly alkaline, slightly eroded soil ($MrfB_1$): the characteristics of the soils of this mapping unit were similar to above mapping unit. It differs only in slope and alkalinity which were 1-3% and strong respectively. It responses well to management for amelioration of alkalinity and water management practices.

**Table 4.05. Guide to soil mapping units of different soil series of Dewa block**

| S. No. | Soil Mapping Unit | Characteristics | L.Uc. Class | Soil Irrigability Classes | Land Irrigability Classes | Paddy Soil group | Hydrological Soil Group |
|---|---|---|---|---|---|---|---|
| **1** | **Gl-d-B1** | Gangauli sandy loam, very deep, well drained, 1-3% slope, slightly eroded soils. | IIe | A | 2t | F | A |
| **2** | **Gl-d-C2** | Gangauli sandy loam, very deep, well drained, 3-5% slope, moderately eroded soils. | IIIe | B | 3t | P | A |
| **3** | **Sl-e-A1** | Sihali loam, very deep, moderately well drained, 0-1% slope, non to slightly eroded soils. | I | A | 1 | F | B |
| **4** | **SlfA1** | Sihali silty loam, very deep, moderately well drained, 0-1% slope, non to slightly eroded soils. | I | A | 1 | F | B |
| **5** | **Sl-e-B1** | Sihali loam, very deep, moderately well drained, 1-3% slope, slightly eroded soils. | IIe | A | 2t | F | B |
| **6** | **Dr-f-A1** | Dadra silty loam, very deep, moderately well drained, 0-1% slope, non to slightly eroded soils. | I | A | 1 | G | C |
| **7** | **Dr-f-B1** | Dadra silty loam, very deep, moderately well drained, 1-3% slope, slightly eroded soils. | IIe | A | 2t | G | C |
| **8** | **Nr-f-A1-1** | Nigari silty loam, very deep, moderately well drained, 0-1% slope, very strongly alkaline, non to slightly eroded soils. | IVs | D | 4s | F | C |
| **9** | **Nr-f-A1-2** | Nigari silty loam, very deep, moderately well drained, 0-1% slope, strongly alkaline, non to | IIIs | C | 3s | F | C |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | slightly eroded soils. | | | | | |
| **10** | **Ud-f-A1-1** | Ukhdi silty loam, very deep, moderately well drained, 0-1% slope, very strongly alkaline, non to slightly eroded soils. | IVs | D | 4s | F | C |
| **11** | **Ud-f-A1-2** | Ukhdi silty loam, very deep, moderately well drained, 0-1% slope, strongly alkaline, non to slightly eroded soils. | IIIs | C | 3s | F | C |
| **12** | **Mr-f-A1** | Mahraur, silty loam, very deep, inperfectly drained, 0-1% slope, very strongly alkaline, non to slightly eroded soils. | IVsw | D | 4sd | G | 8D |
| **13** | **Mr-f-B1** | Mahraur silty loam, very deep, imperfectly drained, 1-3% slope, strongly alkaline, slightly eroded soils. | IIIsw2 | C | $3sd_2$ | G | D |
| **14** | **Bh-f-A1** | Bajgahani silty loam, very deep, poorly drained, 0-1% slope,very strongly alkaline, non to slightly eroded soils. | IVsw | D | 4sd | G | D |
| **15** | **Bh-m-A1** | Bajgahani silty clay loam, very deep, poorly drained, 0-1% slope, strongly alkaline, non to slightly eroded soils. | IIIsw | C | $3sd_1$ | G | D |
| **16** | **Ng-m-A1** | Nayagaon silty clay loam, very deep, poorly drained, 0-1% slope, moderatley alkaline, non to slightly eroded soils. | IIIws | C | 3ds | VG | D |
| **17** | **Ng-f-A1** | Nayagaon silty loam, very deep, imperfectly drained, 0-1% slope, moderately alkaline, non to slightly eroded soils. | IIws | B | 2ds | VG | D |

**Table 4.06: Differentiating morphological chracteristics of identified Soil Series of Dewa block, Barabanki**

| **S. No.** | **Soil Series and Symbol** | **Gangauli (G1)** | **Sihali (Sl)** | **Dadara (Dr)** | **Nigari (Nr)** | **Ukhadi (Ud)** | **Mahraur (Mr)** | **Bajgahani (Bh)** | **Nayagaon (Ng)** |
|---|---|---|---|---|---|---|---|---|---|
| **1** | Differentiating Characteristics | Moderately slopy old alluvial upland well drained | Nearly plains old alluvial mid upland moderately well drained | Nearly plains old alluvial mid land moderately well drained | Nearly plains old alluvial mid land moderately well drained | Nearly plains old alluvial mid land moderately well drained | Nearly plains but temporarily water logged lowland Imperfectely to poorly drained | Gently slopy old alluvial low land poorly to imperfectely drained | Nearly plains but temporarily water logged, concave topography,lowland poorly drained |
| **2** | Texture surface | Sl | Sil to 1 | Sil | Sil | Sil | Sil | Sil to Sicl | Sil to Sicl |
| | Sub surface | 1 to sl | Sil to Sicl | Sil to Sicl | 1 to Sicl | Sil to Sicl | Sicl to cl | Sicl to cl | Sicl to Sic |
| **3** | Structure Surface | Subangular blocky | Subangular blocky | Subanular blocky | Massive | Massive | Massive | Massive | Subangular blocky |
| | Sub surface | Subangular blocky | Subangular blocky | Subangular blocky | Subangular blocky | Subangular blocky | Subangular blocky | Subangular blocky | angular blocky |
| **4** | **Soil Colour** Surface | 10YR 5/4 | 10YR5/3 | 10YR4/2 | 2.5Y6/4 | 10YR7/4 | 10YR8/2 | 2.5Y6/2 | 10YR4/2 |
| | Sub Surface | 10YR4/4 to 5/6 | 10YR5/3 to 5/4 | 10YR4/3 to 6/3 | 2.5Y5/4 t0 6/4 | 10YR7/2 to 7/4 | 2.5 Y5/2 to 5/4 | 2.5 Y6/2 to 6/3 | 10YR5/2 to 6/2 |
| **5** | **Diagnostichorizon-** surface | Ochric | Ochric | Ochric | Ochric | Ochric | Ochric | Ochric | Ochric |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sub surface | Cambic | Cambic | Cambic | Cambic & calcic | Cambic & calcic | Cambic | Cambic & calcic | Cambic & calcic |
| **6** | **Glaebules-** Ferromagnetic | After 95cm | After 65 cm | After65cm | After20cm | After28cm | After34cm | After25cm | After12cm |
| | Carbonatic | - | - | After27cm | After133cm | After28cm | After100cm | After175cm | After12cm |
| **7.** | Mottling have chroma 2 or less | - | - | After105 cm | - | - | After34cm | After25cm | After10cm |
| **8** | **Soil pH –** surface | 7.3-7.5 | 7.5 | 7.5 | 10.3 | 10.2 | 10.1 | 10.4 | 7.8-8.2 |
| | Sub surface | 7.5 | 7.3-7.7 | 7.2-7.4 | 8.6-10.3 | 8.4-10.4 | 9.0-10.4 | 8.4-10.2 | 7.8-8.2 |
| **9** | Faunal Activities | After 12cm | After65cm | - | After20cm | After3cm | After30cm | After55cm | - |
| **10** | Particle size classes | Coarse loamy | Fine loamy | Fine silty | Fine silty | Fine silty | Fine clayey | Fine silty | Fine clayey |
| **11** | Calcarious in control section | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| **12** | Encrustation of salt on te surface | No | No | No | Yes | Yes | Yes | Yes | No |

**Table . 4.07: Analytical results of identified soils of Block Dewa District Barabanki**

| S. No. | Name of Series | Horizon | Depth in cm | Particulars Classes (dia in mm) | | | Textural classes | Coarse Fragments | Organic carbons % | Carbonates $CaCO_3$ | WHC% | pH value 1:2:5 | EC mm hos/cm | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Sand (2-.05) | Silt (0.5-.002) | Clay (.002) | | | | | | | 1:2:5 soil water | Saturation extract |
| 1 | Gangauli | Ap | 0-12 | 68.0 | 18.0 | 14.0 | Sl | - | 0.47 | - | 38.6 | 7.5 | 0.17 | 0.68 |
| 2 | | B1/A3 | 12-40 | 50.0 | 36.0 | 14.0 | l | - | 0.20 | - | 38.4 | 7.4 | 0.14 | 0.56 |
| | | B2 | 40-98 | 44 | 38 | 18 | l | - | 0.12 | - | 39.6 | 7.5 | 0.15 | 0.60 |
| | | B3 | 98-150 | 66 | 22 | 12 | Sl | - | 0.07 | - | 40.2 | 7.5 | 0.14 | 0.56 |
| | | C | 150-180 | 72 | 18 | 10 | Sl | - | 0.05 | - | 38.6 | 7.3 | 0.15 | 0.60 |
| 2 | Sihali | Ap | 0-12 | 30 | 52 | 18 | Sil | - | 0.290 | - | 47.2 | 7.5 | 0.14 | 0.56 |
| | | B1/A3 | 12-65 | 26 | 50 | 24 | Sil | - | 0.190 | - | 47.3 | 7.7 | 0.16 | 0.64 |
| | | B21 | 65-105 | 24 | 46 | 30 | Sicl | - | 0.160 | - | 50.5 | 7.6 | 0.15 | 0.60 |
| | | B22 | 105-145 | 18 | 50 | 32 | Sicl | - | 0.090 | - | 55.7 | 7.5 | 0.15 | 0.60 |
| | | B3 | 145-180 | 20 | 56 | 24 | Sil | - | 0.070 | - | 52.2 | 7.3 | 0.18 | 0.72 |
| 3. | Dadara | Ap | 0-10 | 45 | 32 | 23 | l | - | 0.44 | - | 43.4 | 7.5 | 0.25 | 1.0 |
| | | A3/B1 | 10-27 | 27 | 56 | 27 | Sil/Sicl | - | 0.17 | 1.0 | 48.8 | 7.2 | 0.21 | 0.84 |
| | | B21 | 27-65 | 19 | 47 | 34 | Sicl | - | 0.17 | 2 | 55.3 | 7.1 | 0.19 | 0.76 |
| | | B22 | 65-105 | 17 | 48 | 35 | Sicl | - | 0.17 | 7.5 | 62.1 | 7.3 | 0.22 | 0.88 |
| | | B3(Ca) | 105-180 | 27 | 50 | 23 | Sil | - | 0.06 | 22 | 55.8 | 7.4 | 0.22 | 0.88 |
| 4 | Nigari | A11 | 0-4 | 46 | 52 | 2 | Sil | - | 0.136 | 6 | 42.89 | 10.3 | 1.0 | 4.0 |
| | | A12 | 4-20 | 22 | 55 | 23 | Sil | - | 0.109 | 4 | 42.89 | 10.3 | 0.83 | 3.73 |
| | | B21 | 20-104 | 18 | 53 | 29 | Sicl | - | 0.068 | 2.5 | 47.14 | 9.6 | 0.40 | 1.60 |
| | | B22 | 104-133 | 17 | 51 | 32 | Sicl | - | 0.014 | 3 | 47.97 | 8.6 | 0.23 | 0.92 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | B3/C | 133-180 | 24 | 51 | 25 | Sil | - | 0.014 | 1 | 55.24 | 8.6 | 0.18 | 0.72 |
| 5 | Ukhadi | A11 | 0-3 | 22.6 | 55 | 22.4 | Sil | - | 0.267 | 1.5 | 44.50 | 10.1 | 1.2 | 4.8 |
| | | B1 | 3-28 | 22.6 | 55 | 22.4 | Sil | - | 0.114 | 3.0 | 43.96 | 10.7 | 0.45 | 1.8 |
| | | B21 | 28-78 | 20.1 | 52.5 | 27.4 | Sicl | - | 0.05 | 1.5 | 46.64 | 9.3 | 0.5 | 2.0 |
| | | B22 | 78-107 | 12.6 | 50 | 37.4 | Sicl | - | 0.121 | 3.5 | 54.78 | 8.8 | 0.30 | 1.2 |
| | | B31 | 107-149 | 17.6 | 55 | 27.4 | Sicl | - | 0.114 | 9.5 | 47.59 | 8.8 | 0.25 | 1.0 |
| | | B32 | 149-180 | 13.1 | 60 | 26.9 | Sil | - | 0.089 | 14.5 | 54.10 | 9.0 | 0.25 | 1.0 |
| 6 | Mahraur | A11 | 0-2 | 17 | 61.1 | 21.8 | Sil | - | 0.066 | 31.5 | 38.17 | 10.1 | 1.7 | 6.8 |
| | | A12 | 2-13 | 20.7 | 52.5 | 26.8 | Sil | - | 0.092 | 33 | 39.81 | 10.4 | 3.4 | 13.6 |
| | | B21 | 13-34 | 15.7 | 50 | 34.3 | Sicl | - | 0.066 | 32.5 | 47.51 | 10.2 | 1.85 | 7.4 |
| | | B22 | 34-65 | 15.7 | 42.5 | 41.8 | Sicl | - | 0.092 | 24 | 56.5 | 10 | 1.2 | 4.8 |
| | | B23 | 65-100 | 15.7 | 47.5 | 36.8 | Sicl | - | 0.026 | 26 | 57.38 | 9.5 | 0.4 | 1.6 |
| | | C | 100-140 | 17.2 | 63.5 | 19.3 | Sil | - | 0.066 | 24 | 46.3 | 9 | 0.18 | 0.72 |
| 7 | Bajgahani | A1 | 0-3 | 16 | 68 | 17 | Sil | - | 0.11 | 1 | 36.9 | 10.4 | 6.7 | 33.5 |
| | | B1 | 3-25 | 18 | 52 | 30 | Sicl | - | 0.11 | 0.5 | 42.7 | 10.2 | 1.6 | 8 |
| | | B21 | 25-55 | 20 | 52 | 28 | Sicl | - | 0.07 | - | 36.6 | 10.1 | 1.4 | 7 |
| | | B22 | 55-78 | 22 | 44 | 34 | CR | - | 0.07 | - | 44.9 | 9.3 | 0.59 | 2.36 |
| | | B23 | 78-129 | 18 | 50 | 32 | Sicl | - | 0.04 | 1.5 | 44.3 | 9.3 | 0.41 | 1.64 |
| | | B24 | 129-175 | 8 | 54 | 38 | Sicl | 15 | 0.03 | - | 44.5 | 8.4 | 0.21 | 0.84 |
| | | B3 | 175-180 | 12 | 60 | 28 | Sicl | 10 | 0.03 | 1.0 | 53.6 | 8.2 | 0.24 | 0.96 |
| 8 | Nayagaon | Ap | 0-10 | 19 | 52 | 29 | Sicl | - | 0.39 | - | 51.7 | 8.1 | 0.19 | 0.76 |
| | | B21 | 10-33 | 14 | 46 | 40 | Sicl | - | 0.190 | - | 50.3 | 8.4 | 0.26 | 1.04 |
| | | B22 | 33-75 | 11 | 46 | 43 | Sic | - | 0.140 | - | 52.7 | 8.3 | 0.25 | 1 |
| | | B23Ca | 75-130 | 18 | 42 | 40 | Sicl | - | 0.170 | - | 58.1 | 8.4 | 0.19 | 0.76 |
| | | B3Ca | 130-180 | 15 | 54 | 31 | Sicl | - | 0.08 | 4.5 | 60.4 | 8.7 | 0.18 | 0.72 |

## 4.2 Carbon Sequestration Potential in Different Land Use of Different Soil Series, Dewa Block, Barabanki.

### 4.2.1 Gangauli Soil Series (Pavaiya Viran)

#### 4.2.1.1 Soil pH in different Land use

Result indicated that soil pH of surface (0-15cm) was significantly increases in uncultivated land than forested and cultivated land. The pH was 8.77 in uncultivated soil which showed alkali in nature while in forested (pH 7.37) and cultivated (pH 7.73) it was normal. While in subsurface soil (15-30cm depth) soil pH was slightly higher in comparison to surface soil. Similar trend was observed in subsurface soil as well as in surface soil or top soil. It was also significantly increases in uncultivated soil than the forested soil and cultivated soil ( Table 4.08).

#### 4.2.1.2 Soil Bulk Density in different Land use:

Result indicate that bulk density in surface soil was significantly higher in cultivated and uncultivated land than the forested land while in subsurface soil (15-30cm depth) bulk density was significantly vary in uncultivated and cultivated soil than the forested soil (Table 4.08).

#### 4.2.1.3 Organic Carbon in different Land use:

Organic Carbon percentage in surface soil was ranged from 0.4 % to 0.88% while in subsurface soil 0.29% to 0.70%. Organic Carbon in surface soil was significantly decreased in uncultivated soil than forested and cultivated soil. Maximum organic carbon was observed in forested soil (0.88%) which was very high level while in cultivated it was high level (0.65%) and in uncultivated it was low level (0.4%) in surface soil. Similar trend was also observed in subsurface soil i.e., forested soil was high Organic Carbon level (0.7%) and cultivated soil was medium organic carbon (0.48%) and in uncultivated it was very low (0.29%). In subsurface soil organic Carbon significantly decreased in uncultivated and cultivated soil than the forested soil (Table 4.08).

#### 4.2.1.4 SOC Stock in different Land use

SOC stock in surface soil was ranged from 9.32 to 19.84 Mt $ha^{-1}$ while in subsurface soil 6.80 to 16.11 Mt $ha^{-1}$. SOC stock in surface soil was significantly decreased in uncultivated soil than forested and cultivated soil. Maximum SOC stock was observed in forested soil (19.84 M t $ha^{-1}$) while in cultivated it was 15.01 M t $ha^{-1}$ and in uncultivated it was low level (9.93Mt $ha^{-1}$) in surface soil. Similar trend was also observed in subsurface soil i.e., forested soil was high SOC stock (16.11 Mt $ha^{-1}$) and cultivated soil was medium organic carbon (11.27 M t $ha^{-1}$) and in uncultivated it was very low (6.8 Mt $ha^{-1}$). In subsurface soil SOC stock significantly decreased than the surface soil in all land use i.e. forested, cultivated and uncultivated soil (Table 4.08).

#### 4.2.1.5 Carbon Sequestration Potential in different Landuse

Carbon Sequestration Potential in surface soil was ranged from 59.52 to 77.79 Mt $CO_2$Equivalent $ha^{-1}$ while in subsurface soil 59.43 to 82.95 Mt $CO_2$ Equivalent $ha^{-1}$. Carbon Sequestration Potential in surface soil was significantly decreased in cultivated soil than forested and uncultivated soil. Maximum Carbon Sequestration Potential was observed in forested soil (77.79 Mt $CO_2$Equivalent $ha^{-1}$) while in uncultivated it was 76.26 Mt $CO_2$ Equivalent $ha^{-1}$ and in cultivated it was low level (59.52 Mt $CO_2$ Equivalent $ha^{-1}$) in surface soil. A very little variation was observed in subsurface soil i.e., uncultivated soil was high Carbon Sequestration Potential (82.95 $CO_2$ Mt Equivalent $ha^{-1}$) and forested soil was medium Carbon Sequestration Potential (78.81 $CO_2$ Mt Equivalent $ha^{-1}$) and in cultivated it was very low (59.43 $CO_2$ Mt Equivalent $ha^{-1}$). In subsurface soil Carbon Sequestration Potential significantly increased than the surface soil in forested and uncultivated land use systems while decreased in cultivated soil (Table4.08).

**Table 4.08: Soil pH, bulk density, organic carbon, SOC stock and carbon sequestration potential, Gangauli Soil Series (Pavaiya viran) of Dewa Block in different land use of Dewa Block, District Barabanki**

| Soil Properties | Soil Depth (cm) | Different Land use | | | Mean | LSD (α=0.05) |
|---|---|---|---|---|---|---|
| | | Forested | Cultivated | Uncultivated | | |
| **Soil pH** (1 : 2.5 soil water) | 0-15 | 7.37±0.19 | 7.73 ± 0.12 | 8.77 ± 0.175 | 7.95 | 0.530 |
| | 15-30 | 7.67 ± 0.16 | 8.0 ± 0.085 | 8.8 ± 0.23 | 8.15 | 0.541 |
| **Soil Bulk density** (g $ml^{-3}$) | 0-15 | 1.51 ± 0.02 | 1.54 ± 0.01 | 1.57 ± 0.005 | 1.53 | 0.0423 |
| | 15-30 | 1.53 ±0.005 | 1.57±0.006 | 1.59±0.0075 | 1.56 | 0.02 |
| **Soil Org. C** (%) | 0-15 | 0.88± 0.13 | 0.65±0.06 | 0.4±0.03 | 0.647 | 0.27 |
| | 15-30 | 0.7 ± 0.025 | 0.48 ± 0.015 | 0.29 ± 0.005 | 0.488 | 0.054 |
| **SOC Stock** (M t $ha^{-1}$) | 0-15 | 19.84 ± 2.67 | 15.01 ± 1.36 | 9.3 ± 0.73 | 14.71 | 5.7 |
| | 15-30 | 16.11 ±0.49 | 11.27 ± 0.29 | 6.80 ± 0.16 | 11.39 | 1.10 |
| **Carbon Sequestration Potential** ($CO_2$ Mt Equivalent $ha^{-1}$) | 0-15 | 72.73 ±9.79 | 55.02 ±5.0 | 34.1 ± 2.675 | 53.95 | 20.897 |
| | 15-30 | 59.05 ±1.80 | 41.34 ±1.06 | 24.93 ±0.59 | 41.77 | 4.021 |

### 4.2.2 Bajgahani Soil Series (Chachera Village)

#### 4.2.2.1 Soil pH in different Land use

Result indicated that soil pH of top soil (0-15cm) was significantly increases in cultivated land than forested and uncultivated land. The pH was 8.5 in cultivated soil which showed alkali in nature while in forested (pH 7.67) and uncultivated (pH 7.6) it was normal. While in subsurface soil (15-30cm depth) soil pH was slightly lower in comparison to surface soil. Similar trend was observed in subsurface soil as in surface soil or top soil. It was also significantly increases in cultivated soil (pH 8.03) than the forested soil (pH7.77) and uncultivated soil (pH 7.67) (Table 4.09).

#### 4.2.2.2 Soil Bulk Density in different Land use

Result indicated that bulk density in surface soil was significantly higher in cultivated (1.54 g ml$^{-3)}$ than uncultivated land (1.51 g ml$^{-3)}$ and the forested land (1.5 g ml$^{-3)}$while in subsurface soil (15-30cm depth) bulk density was significantly vary in cultivated land (1.54 g ml$^{-3)}$ than uncultivated soil (1.49 g ml$^{-3)}$ and the forested soil (1.49 g ml$^{-3)}$ (Table 4.09).

#### 4.2.2.3 Organic Carbon in different Land use

Organic Carbon percentage in surface soil was ranged from 0.71 % to 0.95% while in subsurface soil 0.71% to 1.01%. Organic Carbon in surface soil was significantly decreased in cultivated soil than forested and uncultivated soil. Maximum organic carbon was observed in forested soil (0.95%) which was very high level while in uncultivated it was high level (0.92%) and in cultivated it was low level (0.71%) in surface soil. Little variation was observed in subsurface soil i.e., uncultivated soil was high Organic Carbon level (1.01%) and forested soil was medium organic carbon (0.96%) and in cultivated it was very low (0.71%). In subsurface soil organic Carbon significantly increased in uncultivated and forested soil than the cultivated soil (Table 4.09).

#### 4.2.2.4 SOC Stock in different Land use:

SOC stock in surface soil was ranged from 16.23 to 21.22 M t ha$^{-1}$ while in subsurface soil 16.21 to 22.62 M t ha$^{-1}$. SOC stock in surface soil was significantly decreased in cultivated soil than forested and uncultivated soil. Maximum SOC stock was observed in forested soil (21.22 M t ha$^{-1}$) while in uncultivated it was 20.8 M t ha$^{-1}$ and in cultivated it was low level (16.23M t ha$^{-1}$) in surface soil. Minute variation was observed in subsurface soil i.e., uncultivated soil was high SOC stock (22.62 M t ha$^{-1}$) and forested soil was medium organic carbon (21.49 M t ha$^{-1}$) and in cultivated it was very low (16.21 M t ha$^{-1}$). In subsurface soil SOC stock significantly increased than the surface soil in forested and uncultivated while decreased in cultivated soil (Table 4.09).

#### 4.2.2.5 Carbon Sequestration Potential in different Landuse

Carbon Sequestration Potential in surface soil was ranged from 59.52 to 77.79 $CO_2$ Mt Equivalent ha$^{-1}$while in subsurface soil 59.43 to 82.95 $CO_2$ Mt Equivalent ha$^{-1}$. Carbon Sequestration Potential in surface soil was significantly decreased in cultivated soil than forested and uncultivated soil. Maximum Carbon Sequestration Potential was observed in forested soil (77.79 $CO_2$ Mt Equivalent ha$^{-1}$) while in uncultivated it was 76.26 $CO_2$ Mt Equivalent ha$^{-1}$ and in cultivated it was low level (59.52 $CO_2$ Mt Equivalent ha$^{-1}$) in surface soil. A very little variation was observed in subsurface soil i.e., uncultivated soil was high Carbon Sequestration Potential (82.95 $CO_2$ Mt Equivalent ha$^{-1}$) and forested soil was medium Carbon Sequestration Potential (78.81 $CO_2$ Mt Equivalent ha$^{-1}$) and in cultivated it was very low (59.43 $CO_2$ Mt Equivalent ha$^{-1}$). In subsurface soil Carbon Sequestration Potential significantly increased than the surface soil in forested and uncultivated land use systems while decreased in cultivated soil (Table 4.09).

**Table 4.09: Soil pH, bulk density, organic carbon, SOC stock and carbon sequestration potential of Bajghani Soil Series (Chachera Village) of Dewa Block in different land use of Dewa Block, District Barabanki**

| Soil Properties | Soil Depth (cm) | Different Land use | | | Mean | LSD (α=0.05) |
|---|---|---|---|---|---|---|
| | | Forested | Cultivated | Uncultivated | | |
| **Soil pH** (1 : 2.5 soil water) | 0-15 | 7.67 ± 0.06 | 8.5± 0.05 | 7.6 ± 0.05 | 7.922 | 0.171 |
| | 15-30 | 7.77 ±0.03 | 8.03 ± 0.075 | 7.67 ± 0.075 | 7.822 | 0.204 |
| **Soil Bulk density** (g $ml^{-3}$) | 0-15 | 1.5 ± 0.015 | 1.54 ± 0.005 | 1.51 ± 0.005 | 1.51 | 0.0306 |
| | 15-30 | 1.49 ± 0.01 | 1.54 ± 0.01 | 1.49 ± 0.005 | 1.50 | 0.0277 |
| **Soil Org. C** (%) | 0-15 | 0.95 ± 0.075 | 0.71 ± 0.05 | 0.92 ± 0.04 | 0.85 | 0.182 |
| | 15-30 | 0.96 ± 0.08 | 0.71 ± 0.07 | 1.01 ± 0.015 | 0.89 | 0.198 |
| **SOC Stock** (M t $ha^{-1}$) | 0-15 | 21.22 ± 1.6 | 16.23 ± 1.065 | 20.8 ± 0.88 | 19.41 | 3.904 |
| | 15-30 | 21.49 ± 1.725 | 16.21 ± 1.575 | 22.62 ± 0.34 | 20.10 | 4.360 |
| **Carbon Sequestration Potential** ($CO_2$ Mt Equivalent $ha^{-1}$) | 0-15 | 77.79 ± 5.0 | 59.52 ± 3.9 | 76.26 ± 3.225 | 71.191 | 13.140 |
| | 15-30 | 78.81 ± 5.95 | 59.43 ± 5.765 | 82.95 ± 1.245 | 73.729 | 15.474 |

### 4.2.3 Sihali Soil Series of Khajurpur Gaon

#### 4.2.3.1 Soil pH in different Land use

Result indicated that soil pH of top soil (0-15cm) was significantly increases in uncultivated land than forested and cultivated land. The pH was 8.23 in uncultivated soil which showed alkali in nature while in cultivated (pH 7.93) and forested (pH 6.83) it was normal. While in subsurface soil (15-30cm depth) soil pH was slightly increased in comparison to surface soil. Similar trend was observed in subsurface soil as in surface soil or top soil. It was also significantly increased in uncultivated soil (pH 8.4) than the cultivated soil (pH8.0) and forested soil (pH 7.2) (Table 4.10).

#### 4.2.3.2 Soil Bulk Density in different Land use

Result indicated that bulk density in surface soil was significantly higher in cultivated (1.56 g $ml^{-3)}$ than uncultivated land (1.55 g $ml^{-3)}$ and the forested land (1.5 g $ml^{-3)}$while in subsurface soil (15-30cm depth) bulk density was significantly vary in cultivated land (1.56 g $ml^{-3)}$ than uncultivated soil (1.54 g $ml^{-3)}$ and the forested soil (1.49 g $ml^{-3)}$ (Table 4.10).

#### 4.2.3.3 Organic Carbon in different Land use

Organic Carbon percentage in surface soil was ranged from 0.5 % to 0.97% while in subsurface soil 0.48% to 0.99%. Organic Carbon in surface soil was significantly decreased in cultivated soil than forested and uncultivated soil. Maximum organic carbon was observed in forested soil (0.97%) which was very high level while in uncultivated it was high level (0.65%) and in cultivated it was low level (0.5%) in surface soil. Similar trend was observed in subsurface soil i.e., forestedted soil was high Organic Carbon level (0.99%) and uncultivated soil was medium organic carbon (0.66%) and in cultivated it was very low (0.48%). In subsurface soil organic Carbon significantly increased in uncultivated and forested soil than the cultivated soil (Table 4.10).

**4.2.3.4 SOC Stock in different Land use:**

SOC stock in surface soil was ranged from 11.68 to 21.62 M t $ha^{-1}$ while in subsurface soil 11.13 to 22.01 M t $ha^{-1}$. SOC stock in surface soil was significantly decreased in cultivated soil than forested and uncultivated soil. Maximum SOC stock was observed in forested soil (21.62 M t $ha^{-1}$) while in uncultivated it was 14.9 M t $ha^{-1}$ and in cultivated it was low level (11.68M t $ha^{-1}$) in surface soil. Similar trend was observed in subsurface soil i.e., forested soil was high SOC stock (22.01 M t $ha^{-1}$) and uncultivated soil was medium organic carbon (15.14 M t $ha^{-1}$) and in cultivated it was very low (11.13 M t $ha^{-1}$). In subsurface soil SOC stock significantly increased than the surface soil in forested and uncultivated while decreased in cultivated soil (Table 4.10).

**4.2.3.5 Carbon Sequestration Potential in different Landuse**

Carbon Sequestration Potential in surface soil was ranged from 42.84 to 79.29 $CO_2$ Mt Equivalent $ha^{-1}$ while in subsurface soil 40.83 to 80.7 $CO_2$ Mt Equivalent $ha^{-1}$. Carbon Sequestration Potential in surface soil was significantly decreased in cultivated soil than forested and uncultivated soil. Maximum Carbon Sequestration Potential was observed in forested soil (79.29 $CO_2$ Mt Equivalent $ha^{-1}$) while in uncultivated it was 54.63 $CO_2$ Mt Equivalent $ha^{-1}$ and in cultivated it was low level (42.84 $CO_2$ Mt Equivalent $ha^{-1}$) in surface soil. A very similar trend was observed in subsurface soil i.e., forested soil was high Carbon Sequestration Potential (80.7 $CO_2$ Mt Equivalent $ha^{-1}$) and uncultivated soil was medium Carbon Sequestration Potential (55.51 $CO_2$ Mt Equivalent $ha^{-1}$) and in cultivated it was very low (40.83 $CO_2$ Mt Equivalent $ha^{-1}$). In subsurface soil Carbon Sequestration Potential significantly increased than the surface soil in forested and uncultivated land use systems while decreased in cultivated soil (Table 4.10).

**Table 4.10: Soil pH, bulk density, organic carbon, SOC stock and carbon sequestration potential of Sihali Soil Series (Khajurpur Gaon) of Dewa Block in different land use of Dewa Block, District Barabanki**

| Soil Properties | Soil Depth (cm) | Different Land use | | | Mean | LSD (α=0.05) |
|---|---|---|---|---|---|---|
| | | Forested | Cultivated | Uncultivated | | |
| **Soil pH** (1 : 2.5 soil water) | 0-15 | 6.83 ± 0.275 | 7.93 ± 0.075 | 8.23 ± 0.125 | 7.66 | 0.575 |
| | 15-30 | 7.2 ± 0.175 | 8.0 ± 0.005 | 8.4 ± 0.005 | 7.86 | 0.323 |
| **Soil Bulk density** (g $ml^{-3}$) | 0-15 | 1.5 ± 0.015 | 1.56 ± 0.005 | 1.55 ± 0.02 | 1.53 | 0.0471 |
| | 15-30 | 1.49 ± 0.005 | 1.56 ± 0.0055 | 1.54 ± 0.015 | 1.530 | 0.0309 |
| **Soil Org. C** (%) | 0-15 | 0.97 ± 0.08 | 0.5 ± 0.01 | 0.65 ± 0.15 | 0.703 | 0.319 |
| | 15-30 | 0.99 ± 0.05 | 0.48 ± 0.03 | 0.66 ± 0.125 | 0.706 | 0.255 |
| **SOC Stock** (M t $ha^{-1}$) | 0-15 | 21.62 ± 2.25 | 11.68 ± 0.225 | 14.9 ± 3.315 | 16.068 | 7.412 |
| | 15-30 | 22.01 ± 1.02 | 11.13 ± 0.645 | 15.14 ± 2.65 | 16.093 | 5.378 |
| **Carbon Sequestration Potential** ($CO_2$ Mt Equivalent $ha^{-1}$) | 0-15 | 79.29 ± 5.815 | 42.84 ±0.83 | 54.63 ± 12.15 | 58.91922 | 24.927 |
| | 15-30 | 80.7 ± 3.73 | 40.83 ± 2.36 | 55.51 ± 9.71 | 59.010 | 19.701 |

### 4.2.4 Ukhdi Soil Series of Ukhdi Gaon

#### 4.2.4.1Soil pH in different Land use

Result indicated that soil pH of top soil (0-15cm) was significantly increases in uncultivated land than forested and cultivated land. The pH was 8.47 in uncultivated soil which showed alkali in nature while in cultivated (pH 7.63) and forested (pH 7.57) it was normal. While in subsurface soil (15-30cm depth) soil pH was slightly increased in comparison to surface soil. Similar trend was observed in subsurface soil as in surface soil or top soil. It was also significantly increased in uncultivated soil (pH 8.63) than the cultivated soil (pH 7.63) and forested soil (pH 7.53) (Table 4.11).

#### 4.2.4.2Soil Bulk Density in different Land use:

Result indicated that bulk density in surface soil was significantly higher in cultivated (1.53 g $ml^{-3)}$ than uncultivated land (1.52 g $ml^{-3)}$ and the forested land (1.49 g $ml^{-3)}$while in subsurface soil (15-30cm depth) bulk density was significantly vary in forested land (1.5 g $ml^{-3)}$ than cultivated soil (1.54 g $ml^{-3)}$ and the uncultivated soil (1.53 g $ml^{-3)}$ (Table 4.11).

#### 4.2.4.3Organic Carbon in different Land use:

Organic Carbon percentage in surface soil was ranged from 0.73 % to 1.04% while in subsurface soil 0.68% to 0.95%. Organic Carbon in surface soil was significantly decreased in cultivated soil than forested and uncultivated soil. Maximum organic carbon was observed in forested soil (1.04%) which was very high level while in uncultivated it was high level (0.75%) and in cultivated it was low level (0.73%) in surface soil. Similar trend was observed in subsurface soil i.e., forested soil was high Organic Carbon level (0.95%) and uncultivated soil was medium organic carbon (0.77%) and in cultivated it was very low (0.68%). In subsurface soil organic Carbon significantly increased in uncultivated and forested soil than the cultivated soil (Table 4.11).

#### 4.2.4.4 SOC Stock in different Land use

SOC stock in surface soil was ranged from 16.73 to 23.18 M t $ha^{-1}$ while in subsurface soil 15.66 to 21.19 M t $ha^{-1}$. SOC stock in surface soil was significantly decreased in cultivated soil than forested and uncultivated soil. Maximum SOC stock was observed in forested soil (23.18 M t $ha^{-1}$) while in uncultivated it was 17.12 M t $ha^{-1}$ and in cultivated it was low level (16.73M t $ha^{-1}$) in surface soil. Similar trend was observed in subsurface soil i.e., forested soil was high SOC stock (21.19 M t $ha^{-1}$) and uncultivated soil was medium organic carbon (17.48 M t $ha^{-1}$) and in cultivated it was very low (15.66 M t $ha^{-1}$). In subsurface soil SOC stock significantly decreased than the surface soil in forested and cultivated while increased in uncultivated soil (Table 4.11).

#### 4.2.4.5 Carbon Sequestration Potential in different Landuse

Carbon Sequestration Potential in surface soil was ranged from 61.34 to 85.0 $CO_2$ Mt Equivalent $ha^{-1}$while in subsurface soil 57.43 to 77.69 $CO_2$ Mt Equivalent $ha^{-1}$. Carbon Sequestration Potential in surface soil was significantly decreased in cultivated soil than forested and uncultivated soil. Maximum Carbon Sequestration Potential was observed in forested soil (85.0 $CO_2$ Mt Equivalent $ha^{-1}$) while in uncultivated it was 62.78 $CO_2$ Mt Equivalent $ha^{-1}$ and in cultivated it was low level (61.34 $CO_2$ Mt Equivalent $ha^{-1}$) in surface soil. A very similar trend was observed in subsurface soil i.e., forested soil was high Carbon Sequestration Potential (77.69 $CO_2$ Mt Equivalent $ha^{-1}$) and uncultivated soil was medium Carbon Sequestration Potential (64.09 $CO_2$ Mt Equivalent $ha^{-1}$) and in cultivated it was very low (57.43 $CO_2$ Mt Equivalent $ha^{-1}$). In subsurface soil Carbon Sequestration Potential significantly decreased than the surface soil in forested and cultivated land use systems while increased in uncultivated soil (Table 4.11).

**Table 4.11: Soil pH, bulk density, organic carbon, SOC stock and carbon sequestration potential of Ukhdi Soil Series (Ukhdi Gaon) of Dewa Block in different land use of Dewa Block, District Barabanki**

| Soil Properties | Soil Depth (cm) | Different Land use | | | Mean | LSD (α=0.05) |
|---|---|---|---|---|---|---|
| | | Forested | Cultivated | Uncultivated | | |
| **Soil pH** (1 : 2.5 soil water) | 0-15 | 7.57 ± 0.075 | 7.63 ± 0.225 | 8.47 ± 0.1 | 7.88 | 0.475 |
| | 15-30 | 7.53 ± 0.125 | 7.63 ± 0.21 | 8.63 ± 0.35 | 7.933 | 0.788 |
| **Soil Bulk density** (g $ml^{-3}$) | 0-15 | 1.49 ± 0.01 | 1.53 ± 0.005 | 1.53 ± 0.015 | 1.514 | 0.0346 |
| | 15-30 | 1.5 ± 0.01 | 1.54 ± 0.005 | 1.53 ± 0.01 | 1.52 | 0.0277 |
| **Soil Org. C** (%) | 0-15 | 1.04 ± 0.07 | 0.73 ± 0.07 | 0.75 ± 0.105 | 0.84 | 0.267 |
| | 15-30 | 0.95 ± 0.05 | 0.68 ± 0.045 | 0.77 ± 0.06 | 0.796 | 0.166 |
| **SOC Stock** (M t $ha^{-1}$) | 0-15 | 23.18 ± 1.37 | 16.73 ± 1.445 | 17.12 ± 2.25 | 19.01 | 5.55 |
| | 15-30 | 21.19 ± 1.0 | 15.66 ± 1.075 | 17.48 ± 1.3 | 18.10 | 3.622 |
| **Carbon Sequestration Potential** ($CO_2$ Mt Equivalent $ha^{-1}$) | 0-15 | 85.0 ± 5.025 | 61.34 ± 5.305 | 62.78 ± 8.245 | 69.703 | 20.349 |
| | 15-30 | 77.69±3.0 | 57.43 ± 3.935 | 64.09±4.77 | 66.40 | 12.695 |

### 4.2.5 Dadra Soil Series of Dewa Village

#### 4.2.5.1 Soil pH in different Land use

Result indicated that soil pH of top soil (0-15cm) was significantly increases in uncultivated land than forested and cultivated land. The pH was 7.87 in uncultivated soil which showed alkali in nature while in cultivated (pH 7.57) and forested (pH 7.23) it was normal. While in subsurface soil (15-30cm depth) soil pH was slightly increased in comparison to surface soil. Little variations were observed in subsurface soil as in surface soil or top soil. It was significantly decreased in forested soil (pH 7.3) than the cultivated soil (pH 7.67) and uncultivated soil (pH 7.43) (Table 4.12).

#### 4.2.5.2 Soil Bulk Density in different Land use:

Result indicated that bulk density in surface soil was significantly higher in cultivated (1.53 g ml$^{-3}$) than forested land (1.5 g ml$^{-3}$) and the uncultivated land (1.46 g ml$^{-3}$)while in subsurface soil (15-30cm depth) bulk density was significantly vary in forested land (1.5 g ml$^{-3}$) than cultivated soil (1.53 g ml$^{-3}$) and the uncultivated soil (1.47 g ml$^{-3}$) (Table 4.12).

#### 4.2.5.3 Organic Carbon in different Land use:

Organic Carbon percentage in surface soil was ranged from 0.73 % to 1.26% while in subsurface soil 0.74% to 1.17%. Organic Carbon in surface soil was significantly increased in cultivated soil and forested than uncultivated soil. Maximum organic carbon was observed in uncultivated soil (1.26%) which was very high level while in forested it was high level (0.92%) and in cultivated it was low level (0.73%) in surface soil. Similar trend was observed in subsurface soil i.e., uncultivated soil was high Organic Carbon level (1.17%) and forested soil was medium organic carbon (0.95%) and in cultivated it was very low (0.74%). In subsurface soil organic Carbon significantly increased in forested soil and cultivated soil than the uncultivated soil (Table 4.12).

**4.2.5.4 SOC Stock in different Land use**

SOC stock in surface soil was ranged from 16.75 to 27.57 M t ha$^{-1}$ while in subsurface soil 16.85 to 25.8 M t ha$^{-1}$. SOC stock in surface soil was significantly decreased in cultivated soil than forested and uncultivated soil. Maximum SOC stock was observed in uncultivated soil (27.57 M t ha$^{-1}$) while in forested it was 20.64 M t ha$^{-1}$ and in cultivated it was low level (16.75M t ha$^{-1}$) in surface soil. Similar trend was observed in subsurface soil i.e., uncultivated soil was high SOC stock (25.8 M t ha$^{-1}$) and forested soil was medium organic carbon (21.26 M t ha$^{-1}$) and in cultivated it was very low (16.85M t ha$^{-1}$). In subsurface soil SOC stock significantly decreased than the surface soil in uncultivated while increased in forested and cultivated soil (Table 4.12).

**4.2.5.5 Carbon Sequestration Potential in different Landuse**

Carbon Sequestration Potential in surface soil was ranged from 61.41 to 101.09 $CO_2$ Mt Equivalent ha$^{-1}$while in subsurface soil 61.8 to 94.61 $CO_2$ Mt Equivalent ha$^{-1}$. Carbon Sequestration Potential in surface soil was significantly decreased in cultivated soil than forested and uncultivated soil. Maximum Carbon Sequestration Potential was observed in uncultivated soil (101.09 $CO_2$ Mt Equivalent ha$^{-1}$) while in forested it was 75.69 $CO_2$ Mt Equivalent ha$^{-1}$ and in cultivated it was low level (61.41 $CO_2$ Mt Equivalent ha$^{-1}$) in surface soil. A very similar trend was observed in subsurface soil i.e., uncultivated soil was high Carbon Sequestration Potential (94.61 $CO_2$ Mt Equivalent ha$^{-1}$) and forested soil was medium Carbon Sequestration Potential (77.95 $CO_2$ Mt Equivalent ha$^{-1}$) and in cultivated it was very low (61.8 $CO_2$ Mt Equivalent ha$^{-1}$). In subsurface soil Carbon Sequestration Potential significantly decreased than the surface soil in uncultivated soil while increased in forested and cultivated land use systems (Table 4.12).

**Table 4.12: Soil pH, bulk density, organic carbon, SOC stock and carbon sequestration potential of Dadra Soil Series (Dewa Village) of Dewa Block in different land use of Dewa Block, District Barabanki**

| Soil Properties | Soil Depth (cm) | Different Land use | | | Mean | LSD (α=0.05) |
|---|---|---|---|---|---|---|
| | | Forested | Cultivated | Uncultivated | | |
| **Soil pH** (1 : 2.5 soil water) | 0-15 | 7.23 ± 0.115 | 7.57 ± 0.175 | 7.87 ± 0.125 | 7.55 | 0.450 |
| | 15-30 | 7.3 ± 0.115 | 7.67 ± 0.2 | 7.43 ± 0.125 | 7.5 | - |
| **Soil Bulk density** (g $ml^{-3}$) | 0-15 | 1.5 ± 0.005 | 1.53 ± 0.005 | 1.46 ± 0.005 | 1.498 | 0.016 |
| | 15-30 | 1.5 ± 0.005 | 1.53 ± 0.005 | 1.47 ± 0.005 | 1.499 | 0.016 |
| **Soil Org. C** (%) | 0-15 | 0.92 ± 0.025 | 0.73 ± 0.025 | 1.26 ± 0.015 | 0.96 | 0.0709 |
| | 15-30 | 0.95 ± 0.035 | 0.74 ± 0.025 | 1.17 ± 0.02 | 0.95 | 0.0876 |
| **SOC Stock** (M t $ha^{-1}$) | 0-15 | 20.64 ± 0.56 | 16.75 ± 0.515 | 27.57 ± 0.255 | 21.65 | 1.482 |
| | 15-30 | 21.26 ± 0.675 | 16.85 ± 0.575 | 25.8 ± 0.395 | 21.30 | 1.793 |
| **Carbon Sequestration Potential** ($CO_2$ Mt Equivalent $ha^{-1}$) | 0-15 | 75.69 ± 2.055 | 61.41 ± 1.895 | 101.09± 0.93 | 79.39 | 5.441 |
| | 15-30 | 77.95 ± 2.475 | 61.8 ± 2.115 | 94.61 ± 1.44 | 78.12 | 6.575 |

### 4.2.6 Nayagaon Soil Series of Salarpur Village

#### 4.2.6.1 Soil pH in different Land use

Result indicated that soil pH of top soil (0-15cm) was significantly increases in uncultivated land than forested and cultivated land. The pH was 8.17 in uncultivated soil which showed alkali in nature while in cultivated (pH 8.07) and forested (pH 8.07) it was normal. While in subsurface soil (15-30cm depth) soil pH was slightly increased in comparison to surface soil. Little variations were observed in subsurface soil as in surface soil or top soil. It was significantly decreased in forested soil (pH 8.1) than the cultivated soil (pH 8.17) and uncultivated soil (pH 8.3) (Table 4.13).

#### 4.2.6.2 Soil Bulk Density in different Land use

Result indicated that bulk density in surface soil was significantly higher in cultivated (1.54 g $ml^{-3)}$ and forested land (1.54 g $ml^{-3)}$ than the uncultivated land (1.47 g $ml^{-3)}$while in subsurface soil (15-30cm depth) bulk density was significantly vary in forested land (1.53 g $ml^{-3)}$ than cultivated soil (1.52 g $ml^{-3)}$ and the uncultivated soil (1.47 g $ml^{-3)}$ (Table 4.13).

#### 4.2.6.3 Organic Carbon in different Land use

Organic Carbon percentage in surface soil was ranged from 0.65 % to 1.19% while in subsurface soil 0.77% to 1.19%. Organic Carbon in surface soil was significantly increased in uncultivated soil than forested and cultivated soil. Maximum organic carbon was observed in uncultivated soil (1.19%) which was very high level while in cultivated it was high level (0.67%) and in forested it was low level (0.65%) in surface soil. Similar trend was observed in subsurface soil i.e., uncultivated soil was high Organic Carbon level (1.19%) and cultivated soil was medium organic carbon (0.82%) and in forested it was very low (0.77%). In subsurface soil organic Carbon significantly increased in forested soil and cultivated soil than the uncultivated soil (Table 4.13).

**4.2.6.4 SOC Stock in different Land use:**

SOC stock in surface soil was ranged from 14.89 to 26.08 M t $ha^{-1}$ while in subsurface soil 18.5 to 26.05 M t $ha^{-1}$. SOC stock in surface soil was significantly decreased in forested soil than cultivated and uncultivated soil. Maximum SOC stock was observed in uncultivated soil (26.08 M t $ha^{-1}$) while in cultivated it was 15.45 M t $ha^{-1}$ and in forested it was low level (14.89M t $ha^{-1}$) in surface soil. Similar trend was observed in subsurface soil i.e., uncultivated soil was high SOC stock (26.05 M t $ha^{-1}$) and cultivated soil was medium organic carbon (18.5 M t $ha^{-1}$) and in forested it was very low (17.45M t $ha^{-1}$). In subsurface soil SOC stock significantly increased than the surface soil in cultivated and forested while decreased in uncultivated soil (Table 4.13).

**4.2.6.5 Carbon Sequestration Potential in different Landuse**

Carbon Sequestration Potential in surface soil was ranged from 54.61 to 95.63 $CO_2$ Mt Equivalent $ha^{-1}$while in subsurface soil 64.0 to 95.53 $CO_2$ Mt Equivalent $ha^{-1}$. Carbon Sequestration Potential in surface soil was significantly decreased in forested land than cultivated and uncultivated soil. Maximum Carbon Sequestration Potential was observed in uncultivated soil (95.63 $CO_2$ Mt Equivalent $ha^{-1}$) while in cultivated it was 56.66 $CO_2$ Mt Equivalent $ha^{-1}$ and in forested it was low level (54.61 $CO_2$ Mt Equivalent $ha^{-1}$) in surface soil. A very similar trend was observed in subsurface soil i.e., uncultivated soil was high Carbon Sequestration Potential (95.53 $CO_2$ Mt Equivalent $ha^{-1}$) and cultivated soil was medium Carbon Sequestration Potential (67.84 $CO_2$ Mt Equivalent $ha^{-1}$) and forested it was very low (64.0 $CO_2$ Mt Equivalent $ha^{-1}$). In subsurface soil Carbon Sequestration Potential significantly decreased than the surface soil in uncultivated soil while increased in forested and cultivated land use systems (Table 4.13).

**Table 4.13: Soil pH, bulk density, organic carbon, SOC stock and carbon sequestration potential of Nayagaon Soil Series (Salarpur Village) of Dewa Block in different land use of Dewa Block, District Barabanki**

| Soil Properties | Soil Depth (cm) | Different Land use | | | Mean | LSD (α=0.05) |
|---|---|---|---|---|---|---|
| | | Forested | Cultivated | Uncultivated | | |
| **Soil pH** (1 : 2.5 soil water) | 0-15 | 8.07± 0.85 | 8.07 ± 0.06 | 8.17 ± 0.125 | 8.1 | - |
| | 15-30 | 8.1 ± 0.05 | 8.17 ± 0.155 | 8.3 ± 0.18 | 8.188 | - |
| **Soil Bulk density** (g $ml^{-3}$) | 0-15 | 1.54 ± 0.01 | 1.54 ± 0.005 | 1.47 ± 0.01 | 1.51 | 0.0277 |
| | 15-30 | 1.53 ± 0.015 | 1.52 ± 0.015 | 1.47 ± 0.015 | 1.50 | 0.048 |
| **Soil Org. C** (%) | 0-15 | 0.65 ± 0.07 | 0.67 ± 0.035 | 1.19 ± 0.065 | 0.83 | 0.188 |
| | 15-30 | 0.77 ± 0.09 | 0.82 ± 0.105 | 1.19 ± 0.10 | 0.92 | 0.315 |
| **SOC Stock** (M t $ha^{-1}$) | 0-15 | 14.89 ± 1.495 | 15.45 ± 0.805 | 26.08 ± 1.31 | 18.80 | 3.961 |
| | 15-30 | 17.45 ± 1.945 | 18.5 ± 2.2 | 26.05 ± 1.94 | 20.67 | 6.501 |
| **Carbon Sequestration Potential** ($CO_2$ Mt Equivalent $ha^{-1}$) | 0-15 | 54.61 ± 5.385 | 56.66 ± 2.945 | 95.63 ± 4.795 | 68.96 | 14.386 |
| | 15-30 | 64.0 ± 7.13 | 67.84 ± 8.06 | 95.53 ± 7.115 | 75.79 | 23.828 |

### 4.2.7 Inayatpur Soil Series of Nigari Village

#### 4.2.7.1 Soil pH in different Land use

Result indicated that soil pH of top soil (0-15cm) was significantly increases in uncultivated land than forested and cultivated land. The pH was 8.87 in uncultivated soil which showed alkali in nature while in cultivated (pH 8.3) and forested (pH 7.9) it was normal. While in subsurface soil (15-30cm depth) soil pH was slightly decreased in comparison to surface soil. Similar trend were observed in subsurface soil as in surface soil or top soil. It was significantly decreased in forested soil (pH 7.87) than the cultivated soil (pH 8.2) and uncultivated soil (pH 8.77) (Table 4.14).

#### 4.2.7.2 Soil Bulk Density in different Land use

Result indicated that bulk density in surface soil was significantly higher in uncultivated (1.58 g $ml^{-3)}$ and cultivated land (1.54 g $ml^{-3)}$ than the forested land (1.51 g $ml^{-3)}$while in subsurface soil (15-30cm depth) bulk density was significantly similar in forested land (1.51 g $ml^{-3}$ ) and cultivated soil (1.54 g $ml^{-3)}$ than the uncultivated soil (1.57 g $ml^{-3)}$ where it decreased from surface soil (Table 4.14).

#### 4.2.7.3 Organic Carbon in different Land use

Organic Carbon percentage in surface soil was ranged from 0.41 % to 0.9% while in subsurface soil 0.43% to 0.85%. Organic Carbon in surface soil was significantly increased in forested soil than cultivated and uncultivated soil. Maximum organic carbon was observed in forested soil (0.9%) which was very high level while in cultivated it was high level (0.68%) and in uncultivated it was low level (0.41%) in surface soil. Similar trend was observed in subsurface soil i.e., forested soil was high Organic Carbon level (0.85%) and cultivated soil was medium organic carbon (0.7%) and in uncultivated it was very low (0.43%). In subsurface soil organic Carbon significantly increased in uncultivated soil and cultivated soil than the forested soil (Table 4.14).

**4.2.7.4 SOC Stock in different Land use:**

SOC stock in surface soil was ranged from 9.69 to 20.2 M t $ha^{-1}$ while in subsurface soil 10.03 to 19.28 M t $ha^{-1}$. SOC stock in surface soil was significantly increased in forested soil than cultivated and uncultivated soil. Maximum SOC stock was observed in forested soil (20.2 M t $ha^{-1}$) while in cultivated it was 15.67 M t $ha^{-1}$ and in uncultivated it was low level (9.69M t $ha^{-1}$) in surface soil. Similar trend was observed in subsurface soil i.e., forested soil was high SOC stock (19.28 M t $ha^{-1}$) and cultivated soil was medium organic carbon (15.94 M t $ha^{-1}$) and in uncultivated it was very low (10.03M t $ha^{-1}$). In subsurface soil SOC stock significantly increased than the surface soil in cultivated and uncultivated while decreased in forested soil (Table 4.14).

**4.2.7.5 Carbon Sequestration Potential in different Landuse**

Carbon Sequestration Potential in surface soil was ranged from 35.53 to 74.06 $CO_2$ Mt Equivalent $ha^{-1}$while in subsurface soil 36.79 to 70.69 $CO_2$ Mt Equivalent $ha^{-1}$. Carbon Sequestration Potential in surface soil was significantly decreased in uncultivated land than cultivated and forested soil. Maximum Carbon Sequestration Potential was observed in forested soil (74.06 $CO_2$ Mt Equivalent $ha^{-1}$) while in cultivated it was 57.47 $CO_2$ Mt Equivalent $ha^{-1}$ and in uncultivated it was low level (35.53 $CO_2$ Mt Equivalent $ha^{-1}$) in surface soil. A very similar trend was observed in subsurface soil i.e., forested soil was high Carbon Sequestration Potential (70.69 $CO_2$ Mt Equivalent $ha^{-1}$) and cultivated soil was medium Carbon Sequestration Potential (58.44 $CO_2$ Mt Equivalent $ha^{-1}$) and uncultivated it was very low (36.79 $CO_2$ Mt Equivalent $ha^{-1}$). In subsurface soil Carbon Sequestration Potential significantly decreased than the surface soil in forested while increased in uncultivated soil and cultivated land use systems (**Table 4.14).**

**Table 4.14: Soil pH, bulk density, organic carbon, SOC stock and carbon sequestration potential of Inayatpur Soil Series (Nigari Village) of Dewa Block in different land use of Dewa Block, District Barabanki**

| Soil Properties | Soil Depth (cm) | Different Land use | | | Mean | LSD (α=0.05) |
|---|---|---|---|---|---|---|
| | | Forested | Cultivated | Uncultivated | | |
| **Soil pH** (1 : 2.5 soil water) | 0-15 | 7.9 ±0.13 | 8.3 ± 0.28 | 8.87 ± 0.5 | 8.35 | - |
| | 15-30 | 7.87 ± 0.125 | 8.2 ± 0.28 | 8.77 ± 0.04 | 8.27 | 0.571 |
| **Soil Bulk density** (g $ml^{-3}$) | 0-15 | 1.51 ± 0.01 | 1.54 ± 0.005 | 1.58 ± 0.005 | 1.54 | 0.0226 |
| | 15-30 | 1.51 ± 0.005 | 1.54 ± 0.015 | 1.57 ± 0.005 | 1.54 | 0.0306 |
| **Soil Org. C** (%) | 0-15 | 0.9 ± 0.08 | 0.68 ± 0.025 | 0.41 ± 0.03 | 0.66 | 0.164 |
| | 15-30 | 0.85 ± 0.05 | 0.7 ± 0.11 | 0.43 ± 0.015 | 0.65 | 0.225 |
| **SOC Stock** (M t $ha^{-1}$) | 0-15 | 20.2 ± 1.67 | 15.67 ± 0.57 | 9.69 ± 0.69 | 15.18 | 3.5 |
| | 15-30 | 19.28 ± 1.05 | 15.94 ± 2.33 | 10.03 ± 0.355 | 15.08 | 4.766 |
| **Carbon Sequestration Potential** ($CO_2$ Mt Equivalent $ha^{-1}$) | 0-15 | 74.06 ± 6.45 | 57.47 ± 2.085 | 35.53 ± 2.53 | 55.68 | 12.816 |
| | 15-30 | 70.69 ± 3.855 | 58.44 ± 8.545 | 36.79 ± 1.3 | 55.30 | 17.480 |

### 4.2.8 Mahraur Soil Series of Mahraur Village

#### 4.2.8.1 Soil pH in different Land use

Result indicated that soil pH of top soil (0-15cm) was significantly increases in uncultivated land than forested and cultivated land. The pH was 7.87 in uncultivated soil which showed alkali in nature while in forested (pH 7.6) and cultivated (pH 7.57) it was normal. While in subsurface soil (15-30cm depth) soil pH was slightly increased in comparison to surface soil. Little variations were observed in subsurface soil as in surface soil or top soil. It was significantly decreased in cultivated soil (pH 7.6) than the forested soil (pH 7.7) and uncultivated soil (pH 7.9) (Table 4.15).

#### 4.2.8.2 Soil Bulk Density in different Land use

Result indicated that bulk density in surface soil was significantly higher in cultivated (1.54 g $ml^{-3)}$ and uncultivated land (1.52 g $ml^{-3)}$ than the forested land (1.5 g $ml^{-3)}$while in subsurface soil (15-30cm depth) bulk density was significantly vary in cultivated land (1.55 g $ml^{-3)}$ than forested soil (1.5 g $ml^{-3)}$ and the uncultivated soil (1.52 g $ml^{-3)}$ which remained similar to surface soil bulk density (Table 4.15).

#### 4.2.8.3 Organic Carbon in different Land use

Organic Carbon percentage in surface soil was ranged from 0.66 % to 0.98% while in subsurface soil 0.67% to 0.94%. Organic Carbon in surface soil was significantly increased in forested soil than uncultivated and cultivated soil. Maximum organic carbon was observed in forested soil (0.98%) which was very high level while in uncultivated it was high level (0.8%) and in cultivated it was low level (0.66%) in surface soil. Similar trend was observed in subsurface soil i.e., forested soil was high Organic Carbon level (0.94%) and uncultivated soil was medium organic carbon (0.82%) and in cultivated it was very low (0.67%). In subsurface soil organic Carbon significantly increased in uncultivated soil and cultivated soil than the forested soil (Table 4.15).

#### 4.2.8.4 SOC Stock in different Land use

SOC stock in surface soil was ranged from 15.13 to 21.86 M t $ha^{-1}$ while in subsurface soil 15.45 to 21.12 M t $ha^{-1}$. SOC stock in surface soil was significantly increased in forested soil than cultivated and uncultivated soil. Maximum SOC stock was observed in forested soil (21.86 M t $ha^{-1}$) while in uncultivated it was 18.18 M t $ha^{-1}$ and in cultivated it was low level (15.13M t $ha^{-1}$) in surface soil. Similar trend was observed in subsurface soil i.e., forested soil was high SOC stock (21.12 M t $ha^{-1}$) and uncultivated soil was medium organic carbon (18.59 M t $ha^{-1}$) and in cultivated it was very low (15.45M t $ha^{-1}$). In subsurface soil SOC stock significantly increased than the surface soil in cultivated and uncultivated while decreased in forested soil (Table 4.15).

#### 4.2.8.5 Carbon Sequestration Potential in different Landuse

Carbon Sequestration Potential in surface soil was ranged from 55.47 to 80.17 $CO_2$ Mt Equivalent $ha^{-1}$while in subsurface soil 55.67 to 77.46 $CO_2$ Mt Equivalent $ha^{-1}$. Carbon Sequestration Potential in surface soil was significantly increased in forested land than cultivated and uncultivated soil. Maximum Carbon Sequestration Potential was observed in forested soil (80.17 $CO_2$ Mt Equivalent $ha^{-1}$) while in uncultivated it was 66.67 $CO_2$ Mt Equivalent $ha^{-1}$ and in cultivated it was low level (55.47 $CO_2$ Mt Equivalent $ha^{-1}$) in surface soil. A very similar trend was observed in subsurface soil i.e., forested soil was high Carbon Sequestration Potential (77.46 $CO_2$ Mt Equivalent $ha^{-1}$) and uncultivated soil was medium Carbon Sequestration Potential (68.18 $CO_2$ Mt Equivalent $ha^{-1}$) and cultivated it was very low (55.67 $CO_2$ Mt Equivalent $ha^{-1}$). In subsurface soil Carbon Sequestration Potential significantly increased than the surface soil in uncultivated soil and cultivated land use systems while decreased in forested land use system (Table 4.15).

**Table 4.15: Soil pH, bulk density, organic carbon, SOC stock and carbon sequestration potential of Mahraur Soil Series (Mahraur Village) of Dewa Block in different land use of Dewa Block, District Barabanki**

| Soil Properties | Soil Depth (cm) | Different Land use | | | Mean | LSD (α=0.05) |
|---|---|---|---|---|---|---|
| | | Forested | Cultivated | Uncultivated | | |
| **Soil pH** (1 : 2.5 soil water) | 0-15 | 7.6 ± 0.075 | 7.57 ± 0.03 | 7.87 ± 0.075 | 7.67 | 0.204 |
| | 15-30 | 7.7 ± 0.07 | 7.6 ± 0.05 | 7.9 ± 0.08 | 7.733 | 0.229 |
| **Soil Bulk density** (g $ml^{-3}$) | 0-15 | 1.5 ± 0.01 | 1.54 ± 0.005 | 1.52 ± 0.015 | 1.52 | - |
| | 15-30 | 1.5 ± 0.01 | 1.55 ± 0.01 | 1.52 ± 0.015 | 1.52 | 0.0381 |
| **Soil Org. C** (%) | 0-15 | 0.98 ± 0.06 | 0.66 ± 0.035 | 0.8 ± 0.105 | 0.81 | 0.233 |
| | 15-30 | 0.94 ± 0.085 | 0.67 ± 0.035 | 0.82 ± 0.06 | 0.81 | 0.203 |
| **SOC Stock** (M t $ha^{-1}$) | 0-15 | 21.86 ± 1.215 | 15.13 ± 0.805 | 18.18 ± 2.22 | 18.39 | 4.905 |
| | 15-30 | 21.12 ± 1.785 | 15.45 ± 0.735 | 18.59 ± 1.935 | 18.39 | - |
| **Carbon Sequestration Potential** ($CO_2$ Mt Equivalent $ha^{-1}$) | 0-15 | 80.17 ± 4.445 | 55.47 ± 2.955 | 66.67 ± 8.145 | 67.43 | 17.987 |
| | 15-30 | 77.46 ± 6.545 | 55.67 ± 2.685 | 68.18 ± 8.92 | 67.43 | - |

## 4.3 Comparative studies of soil properties and soil carbon sequestration potential in different Soil Series of Dewa Block

### 4.3.1 Soil pH of different soil series

The comparative studies of different soil series showed that pH of soil in surface soil were ranged from 6.85 – 8.05 in forested land while in subsurface soil ranged from 7.3 – 8.15 that was slightly higher than surface soil. Maximum soil pH in surface soil was observed in Nayagaon Soil Series (8.05) while minimum in Sihali soil series (6.85) which was slightly acidic in nature which may be due to high humus content (Fig. 4.06).

The soil pH of cultivated soil were ranged from 7.40 – 8.5 in surface soil while in subsurface soil were ranged 7.45 – 8.25. The maximum pH was observed in surface soil of Bajghani Soil Series (8.5) while minimum in Dadra soil series (7.40) but in subsurface soil maximum pH was observed in Nigari soil series(8.25) that was slightly less than surface soil in cultivated land which may be due to agricultural practice adopted by farmers (Fig 4.06.).

The soil pH of uncultivated soil were ranged from 7.35 – 8.95 in surface soil while in subsurface soil these were ranged from 7.25 – 8.85. Thus maximum soil pH was observed both in surface and subsurface soil of Nigari Soil Series that was sodic in nature. Although Gangauli and Ukhdi Soil Series were also showed alkaline (sodic) in nature (Fig 4.06).

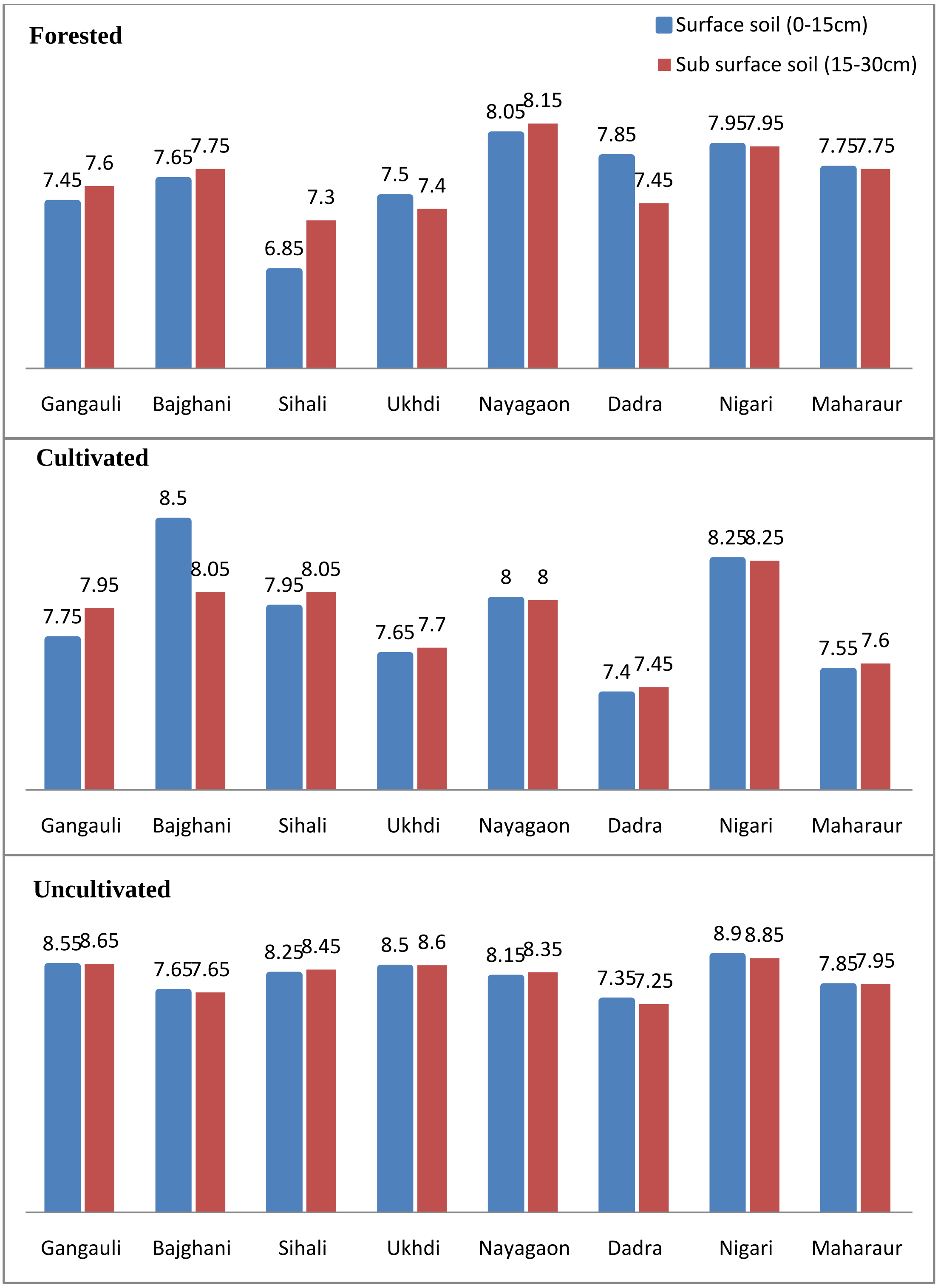


**Fig 4.06**: Comparative studies of soil pH in different landuse i.e., forested, cultivated and uncultivated land of different soil series of Dewa block, Barabanki.

### 4.3.2 Bulk Density in different soil series

The comparative studies of different soil series showed that bulk density of soil in surface soil were ranged from 1.48 – 1.55 g $cm^{-3}$ in forested land while in subsurface soil ranged from 1.49 – 1.53 g $cm^{-3}$ that was slightly lower than surface soil. Maximum soil bulk density in surface soil was observed in Nayagaon Soil Series (1.55 g $cm^{-3}$) while minimum in Ukhdi soil series (1.48g $cm^{-3}$) which was slightly acidic in nature which may be due to high humus content (Fig. 4.07).

The soil bulk density of cultivated soil were ranged from 1.53 – 1.57 g $cm^{-3}$ in surface soil while in subsurface soil were ranged 1.51 – 1.57 g $cm^{-3}$. The maximum bulk density was observed in surface soil of Sihali Soil Series (1.57 g $cm^{-3}$) while minimum in Ukhdi soil series (1.53 g $cm^{-3}$) but in subsurface soil maximum bulk density was observed in Gangauli soil series (1.57g $cm^{-3}$) that was nearly similar to surface soil in cultivated land which may be due to agricultural practice adopted by farmers (Fig. 4.07).

The soil bulk density of uncultivated soil were ranged from 1.46 –1.58 g $cm^{-3}$ in surface soil while in subsurface soil these were ranged from 1.465 – 1.57 g $cm^{-3}$. Thus maximum soil bulk density was observed in surface soil of Nigari Soil Series (1.58 g $cm^{-3}$) while minimum bulk density in uncultivated soil was seen in surface soil of Nayagaon soil series (1.46 g $cm^{-3}$) (Fig. 4.07).

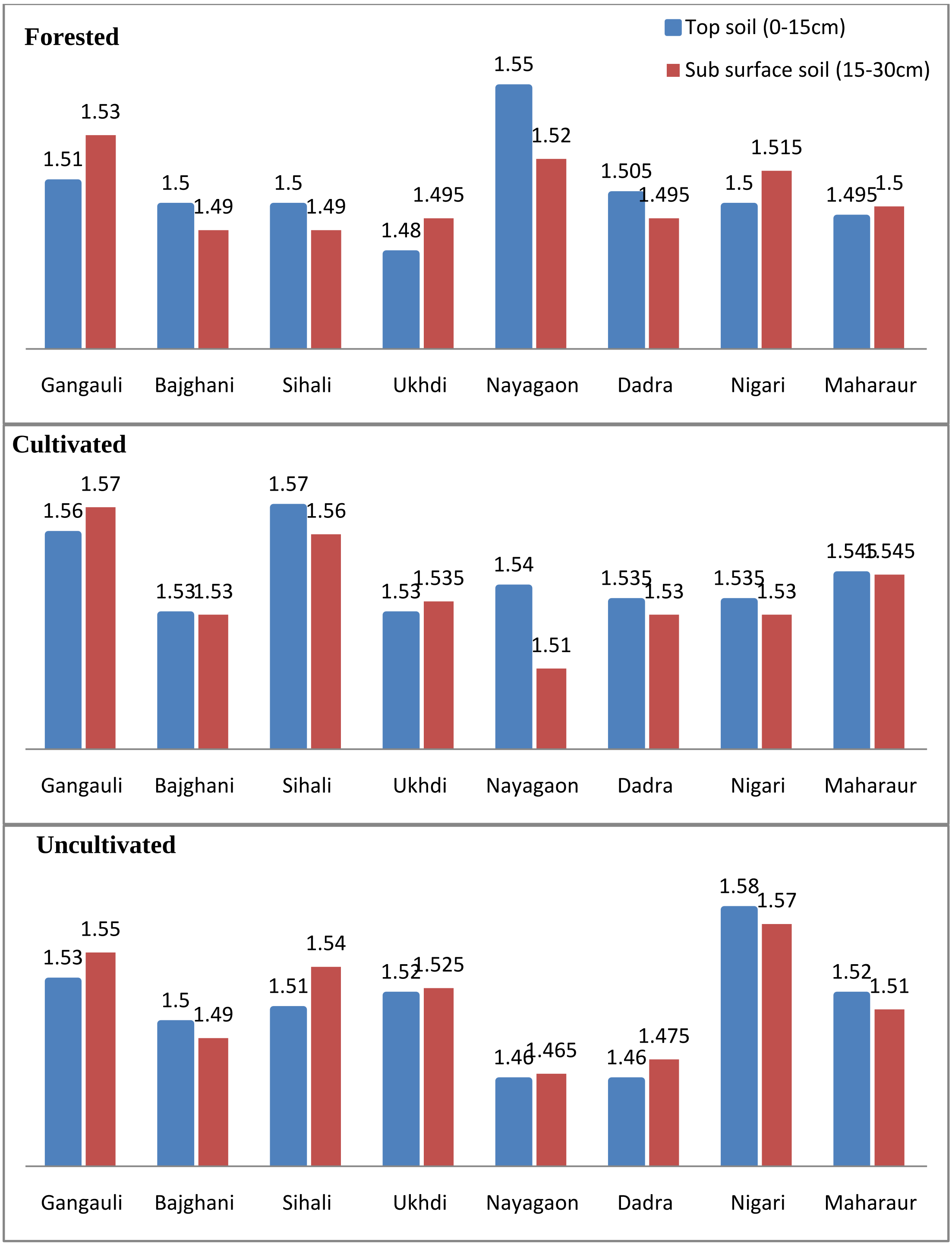


**Fig. 4.07. Comparative studies of bulk density in different landuse i.e., forested, cultivated and uncultivated land of different soil series of Dewa block, Barabanki.**

### 4.3.3 Organic Carbon in different soil series

The comparative studies of different soil series showed that Organic Carbon of soil in surface soil were ranged from 0.5775% – 1.11% in forested land while in subsurface soil ranged from 0.65% – 0.99% that was slightly lower than surface soil. Maximum soil Organic Carbon in surface soil was observed in Ukhdi Soil Series (1.11%) while minimum in Nayagaon soil series (0.5775%) (Fig. 4.08).

The soil Organic Carbon of cultivated soil were ranged from 0.55% – 0.735% in surface soil while in subsurface soil were ranged 0.35% – 0.9%. The maximum Organic Carbon was observed in surface soil of Ukhdi Soil Series (0.735%) while minimum in soil series (0.55%) but in subsurface soil maximum Organic Carbon was observed in Nayagaon soil series (0.9%) that was slightly more than surface soil in cultivated land which may be due to agricultural practice adopted by farmers (Fig. 4.08).

The soil Organic Carbon of uncultivated soil were ranged from 0.405% – 1.275% in surface soil while in subsurface soil these were ranged from 0.44% – 1.22%. Thus maximum soil Organic Carbon was observed in surface soil of Dadra Soil Series (1.275%) while minimum Organic Carbon in uncultivated soil was seen in surface soil of Nigari soil series (0.405%) (Fig. 4.08).

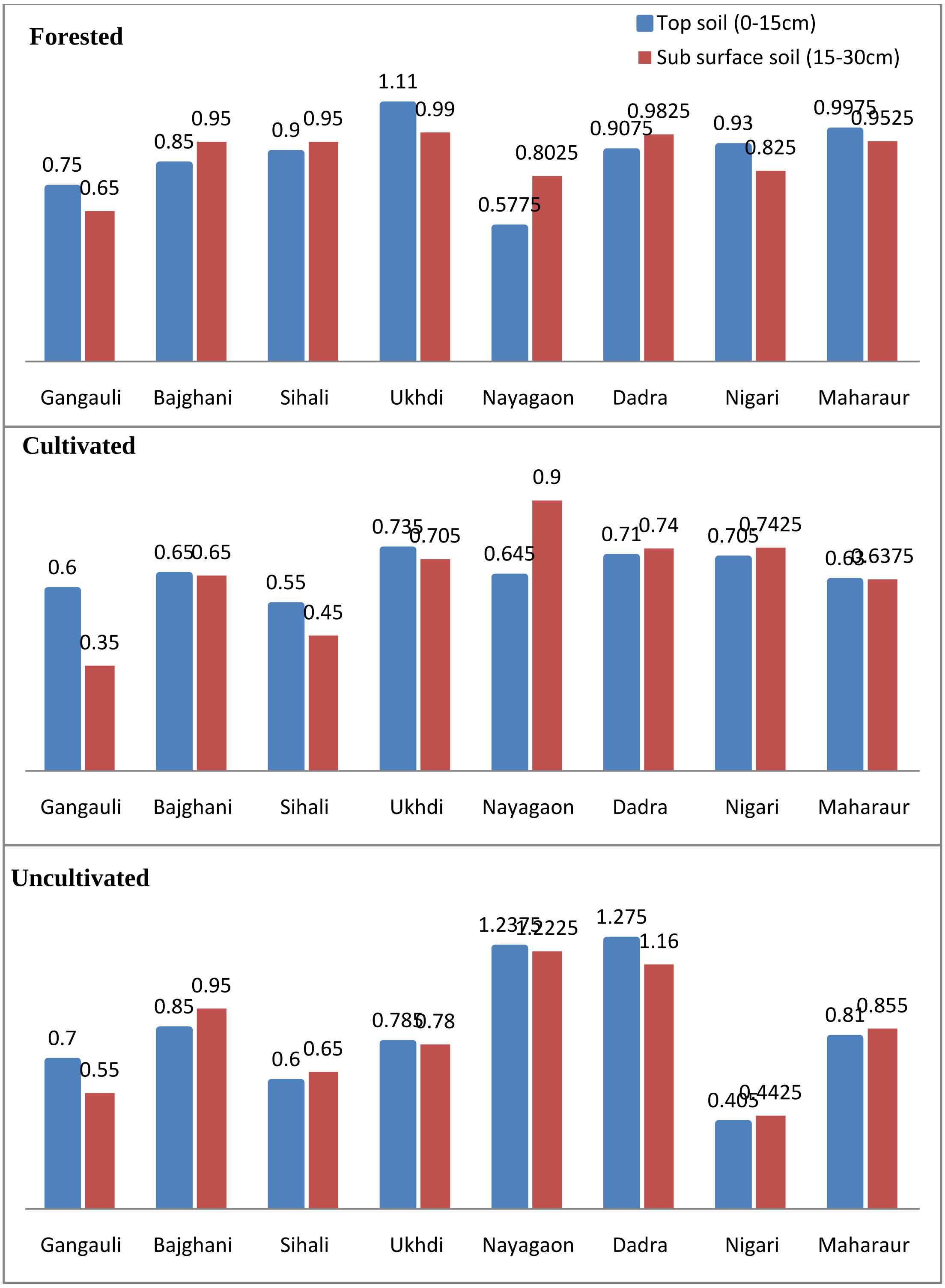


**Fig. 4.08. Comparative studies of organic carbon in different landuse i.e., forested, cultivated and uncultivated land of different soil series of Dewa block, Barabanki.**

### 4.3.4 Soil Organic Carbon Stock in different soil series

The comparative studies of different soil series showed that Soil Organic Carbon Stock of soil in surface soil were ranged from 12.5 – 24 M t $ha^{-1}$ in forested land while in subsurface soil ranged from 16 – 22.5 M t $ha^{-1}$ that was slightly lower than surface soil. Maximum Soil Organic Carbon Stock in surface soil was observed in Ukhdi Soil Series (24 M t $ha^{-1}$) while minimum in Nayagaon soil series (12.5 M t $ha^{-1}$) (Fig. 4.09).

The Soil Organic Carbon Stock of cultivated soil were ranged from 11.5 – 16 M t $ha^{-1}$ in surface soil while in subsurface soil were ranged 9 – 20 M t $ha^{-1}$. The maximum Soil Organic Carbon Stock was observed in surface soil of Ukhdi and similarly in Dadra Soil Series (16 M t $ha^{-1}$) while minimum in soil series Sihali (11.5 M t $ha^{-1}$) but in subsurface soil maximum Soil Organic Carbon Stock was observed in Nayagaon soil series (20 M t $ha^{-1}$) that was slightly more than surface soil in cultivated land which may be due to agricultural practice adopted by farmers (Fig. 4.09).

The soil Soil Organic Carbon Stock of uncultivated soil were ranged from 9.5 to 27 M t $ha^{-1}$ in surface soil while in subsurface soil these were ranged from 10.5 to 26.5 M t $ha^{-1}$. Thus maximum Soil Organic Carbon Stock was observed in surface soil of Dadra and Nayagaon Soil Series (27 M t $ha^{-1}$) while minimum Soil Organic Carbon Stock in uncultivated soil was seen in surface soil of Nigari soil series (9.5 M t $ha^{-1}$) (Fig. 4.09).

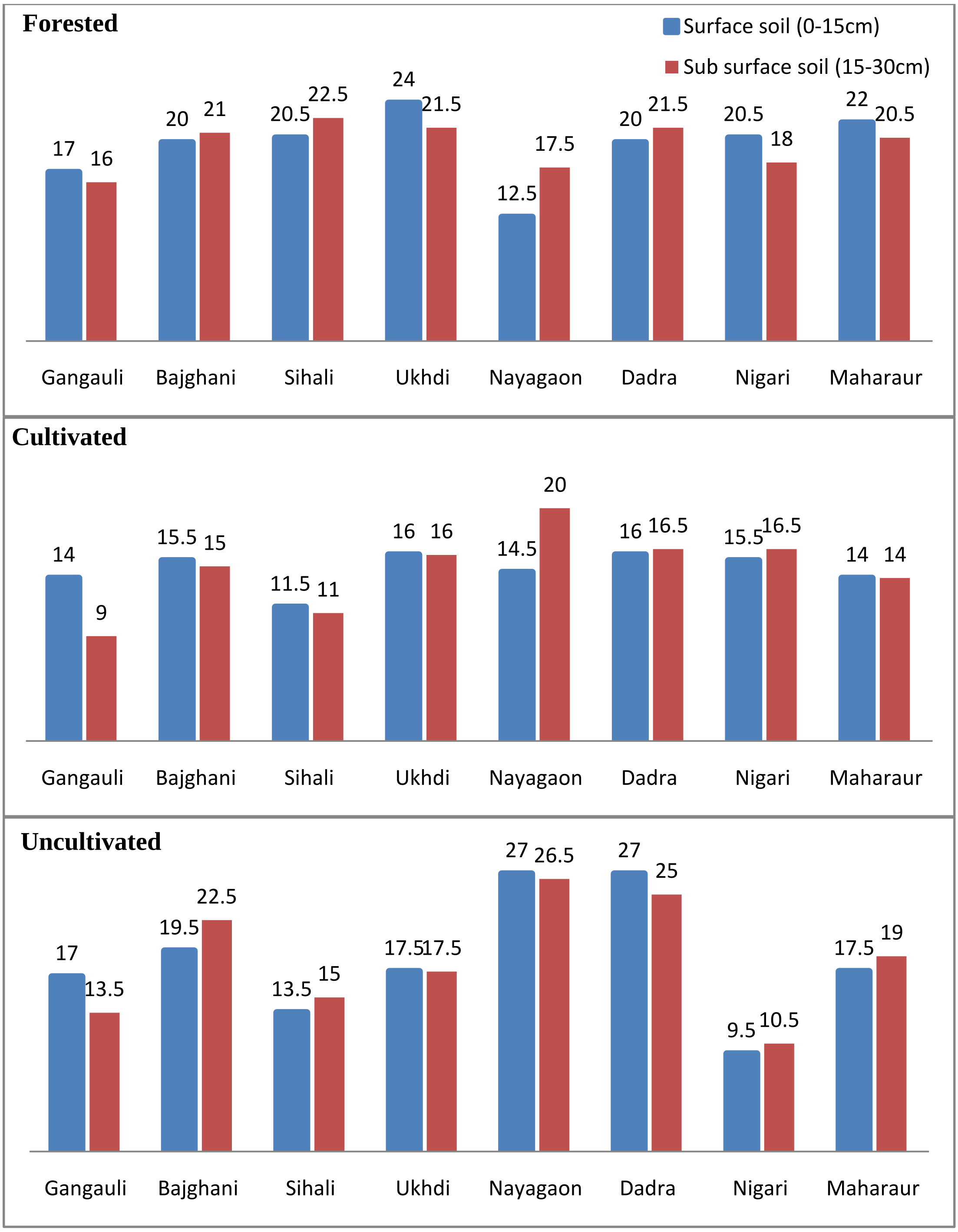


**Fig. 4.09. Comparative studies of soil organic carbon stock in different landuse i.e., forested, cultivated and uncultivated land of different soil series of Dewa block, Barabanki.**

### 4.3.5 Carbon Sequestration Potential in different soil series

The comparative studies of different soil series showed that Carbon Sequestration Potential of soil in surface soil were ranged from 48.5 – 89.5 $CO_2$ Mt Equivalent $ha^{-1}$ in forested land while in subsurface soil ranged from 58.5 – 83 $CO_2$ Mt Equivalent $ha^{-1}$ that was slightly lower than surface soil. Maximum soil Carbon Sequestration Potential in surface soil was observed in Ukhdi Soil Series (89.5 $CO_2$ Mt Equivalent $ha^{-1}$) while minimum in Nayagaon soil series (48.5 $CO_2$ Mt Equivalent $ha^{-1}$) (Fig. 4.10).

The soil Carbon Sequestration Potential of cultivated soil were ranged from 43.5 – 61.5 $CO_2$ Mt Equivalent $ha^{-1}$ in surface soil while in subsurface soil were ranged 35.5 – 73.5 $CO_2$ Mt Equivalent $ha^{-1}$. The maximum Carbon Sequestration Potential was observed in surface soil of Ukhdi Soil Series (61.5 $CO_2$ Mt Equivalent $ha^{-1}$) while minimum in Sihali soil series (43.5 $CO_2$ Mt Equivalent $ha^{-1}$) but in subsurface soil maximum Carbon Sequestration Potential was observed in Nayagaon soil series (73.5 $CO_2$ Mt Equivalent $ha^{-1}$) that was slightly more than surface soil in cultivated land which may be due to agricultural practice adopted by farmers (Fig. 4.10).

The soil Carbon Sequestration Potential of uncultivated soil were ranged from 35 – 102 $CO_2$ Mt Equivalent $ha^{-1}$ in surface soil while in subsurface soil these were ranged from 37.5 – 97.5 $CO_2$ Mt Equivalent $ha^{-1}$. Thus maximum soil Carbon Sequestration Potential was observed in surface soil of Dadra Soil Series (102 $CO_2$ Mt Equivalent $ha^{-1}$) while minimum Carbon Sequestration Potential in uncultivated soil was seen in surface soil of Nigari soil series (35 $CO_2$ Mt Equivalent $ha^{-1}$) (Fig. 4.10).

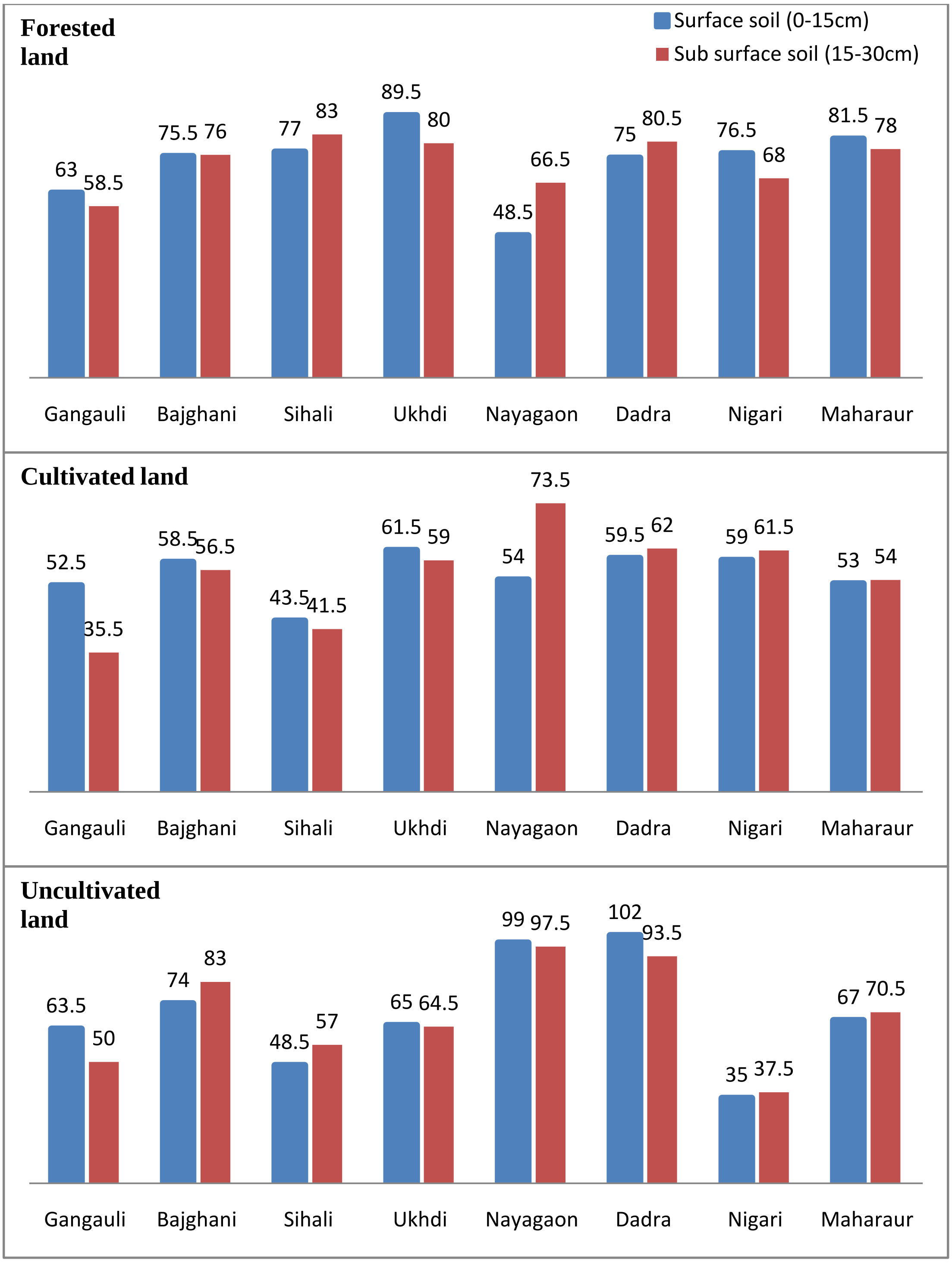


**Fig. 4.10. Comparative studies of carbon sequestration potential in different landuse i.e., forested, cultivated and uncultivated land of different soil series of Dewa block, Barabanki.**

### 4.4 Comparative study of change in Soil Properties within three decades in different soil series

#### 4.4.1 Comparative study of change in Soil pH within three decades in different soil series

The comparative study of soil properties were calculated on the basis of average mean of all types of landuse i.e., cultivated, uncultivated and forested soil. Result showed that the soil surface (0-15 cm depth) pH was significantly decreased in soil series of Bajghani, Ukhdi, Nigari and Mahraur of Dewa Block that was 31.3%, 28%, 23.2% and 31.51% respectively than the soil pH before three decades (1978-85) while in Gangauli and Sihali soil series insignificant increase were observed. But in Nayagaon soil series no change in soil pH in surface soil (Fig. 4.11).The subsurface soil (15-30cm depth) pH also showed somewhat similar trend as observed in surface soil i.e., Bajghani, Ukhdi, Nigari, Mahraur soil series showed decreased soil pH which was 30.3%, 34.9%, 24.4% and 34.54% respectively whereas unlike surface soil, subsurface soil of Nayagaon soil series showed a little increased in soil pH % (2.56%).

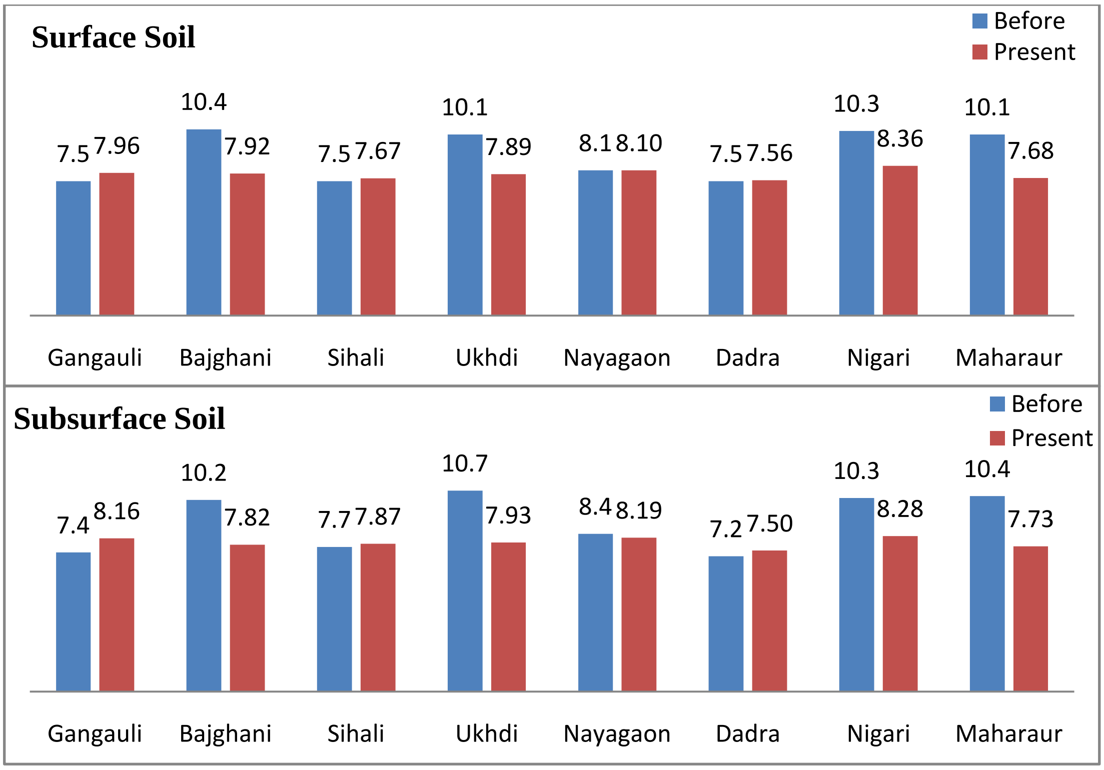


**Fig. 4.11. Comparative study of change in soil pH(1 : 2.5 soil water) in between present soil (2015-16) with three decades before (1985-86) in surface (0-15 cm depth) and subsurface soil (15-30 cm depth) of different soil series of Dewa Block, Barabanki**

Gangauli and Sihali soil series were categorized in Udic Ustochrepts while Bajgahani, Nayagaon and Maharaur were Aeric Halaquept. Ukhdi and Nigari were Natric Ustochrepts but Dadra soil series was Typic Ustochrepts.

Before three decades, the soil pH in Udic Ustochrepts was 7.5 in surface (0-15 cm depth) and 7.4-7.7 in subsurface which was slightly increases in surface soil 7.67-7.96 and 7.93- 8.16. in subsurface soil. In Aeric Halaquept soil pH was ranged from 8.1-10.2 in surface soil while 8.4 – 10.4 in subsurface soil. But after three decade, it was ranged 7.63-8.1 in surface soil and 7.73 – 8.19 in subsurface soil that was significantly decreases after three decades. In Natric Ustochrept soil pH was ranged from 10.1 – 10.3 in surface soil while in subsurface it was 10.3 – 10.7 but after three decades soil pH was significantly decreased 7.63-7.89 in surface soil and

7.73-7.93 in subsurface soil. While Typic Ustochrepts showed normal pH range both in surface and subsurface soil and there was non-significant change in pH after three decades.

**Table No.4.16** : soil type wise change in pH during last three decades.

| Soil Type and Series | Surface soil pH range | | SubSurface soil pH range | |
|---|---|---|---|---|
| | **Before** | **After** | **Before** | **After** |
| Udic Ustochrepts (Gangauli and Sihali) | 7.5 | 7.67 – 7.96 | 7.4 – 7.7 | 7.87– 8.16 |
| Aeric Halaquept (Bajgahani, Nayagaon, Maharaur) | 10.1 – 10.4 | 7.68 – 8.1 | 8.4 – 10.4 | 7.73– 8.19 |
| Nitric Ustochrept (Ukhdi and Nigari) | 10.1 – 10.3 | 7.89 – 8.36 | 10.3 – 10.7 | 7.93– 8.23 |
| Typic Ustochrepts (Dadra) | 7.5 | 7.56 | 7.2 | 7.50 |

### 4.4.2 Comparative study of change in Soil Bulk Density with three decades difference Bulk Density ($gcm^{-3}$):

Soil Bulk Density of surface soil (0-15cm) was appeared changed in comparison to present soil bulk density with three decades before soil bulk density in different soil series of Dewa Block. There were decreased in BD i.e., 1.94%, 6.57%, 3.24%, 5.9%, 3.94%, 4.66%, 5.99% and 7.23 % in Gangauli, Bajghani, Sihali, Ukhdi, Nayagaon, Dadra, Nigari and Mahraur respectively. Similar trend was also observed in subsurface soil (15-30cm) (Fig. 4.12) but there was more higher decreased were observed than the surface soil i.e., in Gangauli (3.2%), Bajghani (7.28%) , Sihali (5.22%), Ukhdi (6.57%), Nayagaon (7.33%), Dadra (7.33%), Nigari (5.19%) and Mahraur (7.23%) respectively.

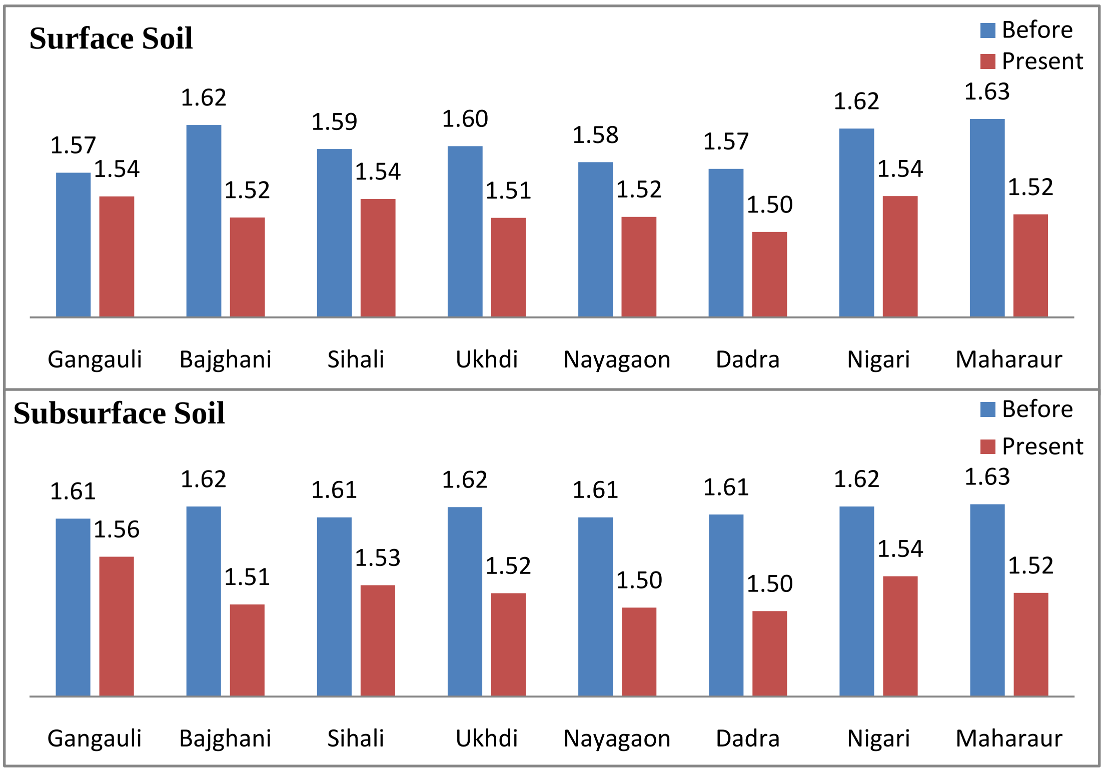


**Fig. 4.12. Comparative study of change in soil Bulk Density (g cm$^{-3}$) in between present soil decades before (1985-86) in surface (0-15 cm depth) and subsurface soil (15-30 cm depth) of different soil series of Dewa Block, Barabanki**

**Table No.4.17**. Soil type wise soil bulk density during three decades

| Soil Type and Series | Surface bulk density range (g cm$^{-3}$) | | SubSurface bulk density range (g cm$^{-3}$) | |
|---|---|---|---|---|
| | **Before** | **After** | **Before** | **After** |
| Udic Ustochrepts (Gangauli and Sihali) | 1.57 – 1.59 | 1.54 | 1.61 | 1.53 – 1.56 |
| Aeric Halaquept (Bajgahani, Nayagaon, Maharaur) | 1.58 – 1.63 | 1.52 | 1.61 – 1.63 | 1.50 – 1.52 |
| Nitric Ustochrept (Ukhdi and Nigari) | 1.60 – 1.62 | 1.51 – 1.54 | 1.62 | 1.52 – 1.54 |
| Typic Ustochrepts (Dadra) | 1.57 | 1.5 | 1.61 | 1.5 |

Before three decades, bulk density in Udic Ustochrepts was ranged 1.57-1.59 gcm$^{-3}$ in surface while in subsurface it was 1.61 gcm$^{-3}$. After three decades it was slightly decreases in surface as well as subsurface soil. Similar trends were observed in Aeric Halaquept, Natric Ustochrept and Typic Ustochrept.

### 4.4.3 Comparative study of change in Soil Organic Carbon with three decades difference Soil Organic Carbon (%)

Change in Soil Organic Carbon during last three decades showed that there were significant increased in organic carbon content maximum increased Organic Carbon in surface soil (0-15cm) were observed in Bajghani, Ukhdi, Nigari and Mahraur i.e., 87.2%, 67.8%, 78.7% and 91.35% respectively (Fig. 4.13). While in Gangauli (26.5%) and Sihali (58.5%), Nayagaon (53.01%) and Dadra (54.63%) Organic Carbon were increased. In subsurface soil, maximum increase was seen in Bajghani (87.64%), Sihali (73.23%), Ukhdi (86.25%), Nayagaon (79.34%), Dadra (82.1%), Nigari (83.33%) and Mahraur (88.88%) whereas only Gangauli Soil series showed 59.18% increase which was still higher than surface soil increased percentage value.

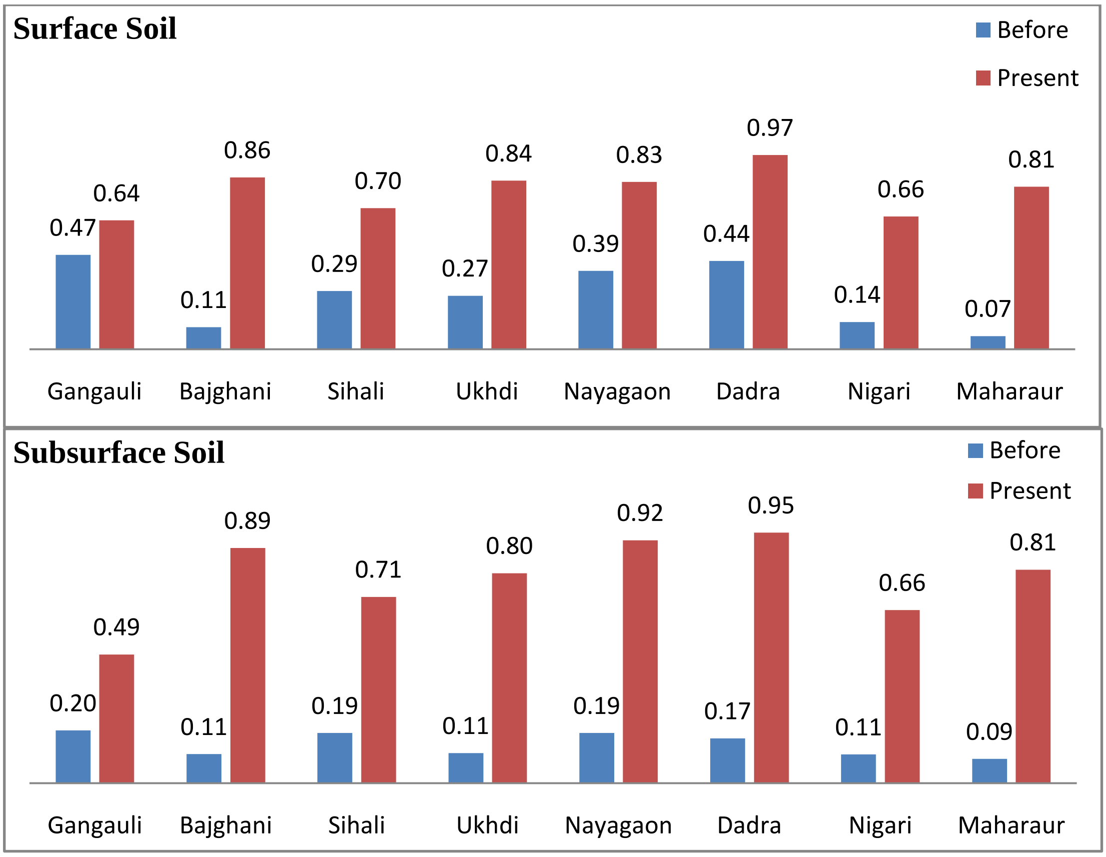


**Fig. 4.13. Comparative study of change in soil Organic Carbon (%) in between present soil (2015-16) with three decades before (1985-86) in surface (0-15 cm depth) and subsurface soil (15-30 cm depth) of different soil series of Dewa Block, Barabanki**

**Table No.4.18**. Soil type wise Organic carbon during three decades.

| Soil Type and Series | Surface Organic Carbon range (%) | | SubSurface Organic Carbon range (%) | |
|---|---|---|---|---|
| | **Before** | **After** | **Before** | **After** |
| Udic Ustochrepts (Gangauli and Sihali) | 0.29 – 0.47 | 0.64 – 0.7 | 0.19 – 0.20 | 0.49 – 0.71 |
| Aeric Halaquept (Bajgahani, Nayagaon, Maharaur) | 0.07 – 0.39 | 0.81 – 0.86 | 0.09 – 0.19 | 0.81 – 0.89 |
| Nitric Ustochrept (Ukhdi and Nigari) | 0.14 – 0.27 | 0.66 – 0.84 | 0.11 | 0.66 – 0.80 |
| Typic Ustochrepts (Dadra) | 0.44 | 0.97 | 0.17 | 0.95 |

Before three decades, SOC in Udic Ustochrepts (Gangauli and Sihali soil series) was ranged 0.29-0.47% in surface while in subsurface it was ranged 0.19-0.21% that was less than surface soil. After three decades it was significantly increased in surface (0.64-0.70%) as well as subsurface soil (0.49-0.71%). Similar trends were also observed in Aeric Halaquept (Bajgahani, Nayagaon and Maharaur soil series), Natric Ustochrept (Ukhdi and Nigari soil series) and Typic Ustochrept (Dadra soil series). Although, Aeric Halaquept had reported least organic carbon in surface soil (0.07-0.39%) and subsurface soil (0.09-0.19%) before three decades which was significantly increased after three decades in surface soil (0.81-0.86%) and subsurface soil (0.81-0.89%) and Natric Ustocrept had also low organic carbon content in surface(0.14-0.27%) as subsurface soil(0.11%) before three decades which was significantly increased after three decades in surface soil (0.66-0.84%) and subsurface soil (0.66-0.80%). Thus, soil organic carbon contents were maximum increases in Aeric Halaquept > Natric Ustocrept > Udic Ustocrept > Typic Ustocrept.

### 4.4.4 Comparative study of change in SOC Stock with three decades difference

**SOC Stock (M t ha$^{-1}$)**

Comparative study of change in Soil Organic Carbon Stock (Mtha$^{-1}$) during last three decades showed significant increase in surface soil s of various soil series i.e., Gangauli (39.9%), Bajghani (97.21%), Sihali (65.46%), Ukhdi (93.26%), Nayagaon (67.25%), Dadra (68.03%), Nigari (94.2%) and Mahraur (98.8%) (Fig. 4.14). The increase in present Soil Organic Carbon Stock of subsurface soil showed a little less increase when compared to surface soil i.e, in Gangauli (20.89%), Bajghani (80.45%), Sihali (49.59%), Ukhdi (74.48%), Nayagaon (65.98%), Dadra (78.13%), Nigari (81.23%), and Mahraur (91.08%).

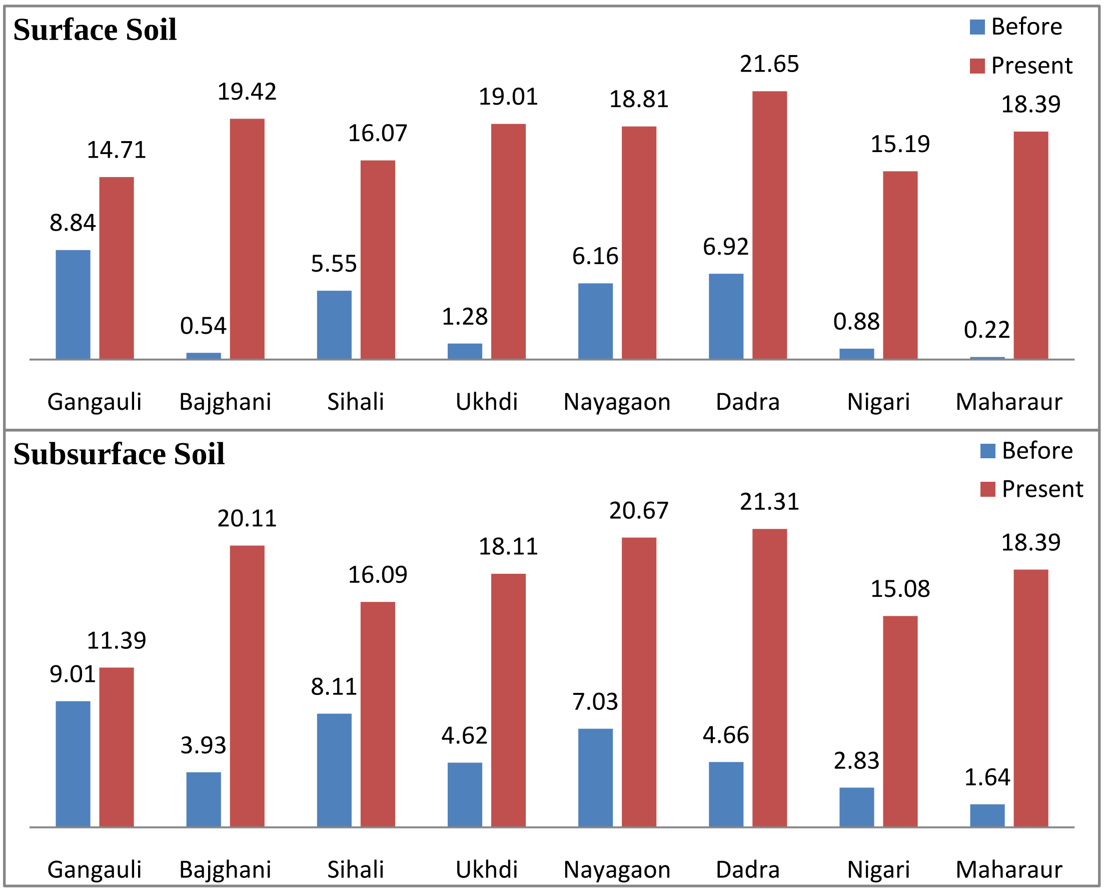


**Fig. 4.14. Comparative study of change in soil Soil Organic Carbon Stock (M t ha$^{-1}$) in between present soil (2015-16) with three decades before (1985-86) in surface (0-15 cm depth) and subsurface soil (15-30 cm depth) of different soil series of Dewa Block, Barabanki**

**Table No.4.19.** Soil type wise Soil Organic Carbon Stock during three decades.

| Soil Type and Series | Surface SOC Stock range (M t ha$^{-1}$) | | Sub Surface SOC Stock range (M t ha$^{-1}$) | |
|---|---|---|---|---|
| | Before | After | Before | After |
| Udic Ustochrepts (Gangauli and Sihali) | 5.55 – 8.84 | 14.71–16.07 | 9.01 – 8.11 | 11.39– 16.09 |
| Aeric Halaquept (Bajgahani, Nayagaon, Maharaur) | 0.22 – 6.92 | 1.64 – 7.03 | 19.39– 19.42 | 18.39– 20.67 |
| Nitric Ustochrept (Ukhdi and Nigari) | 0.88 – 1.28 | 15.19–19.01 | 2.83 – 4.62 | 15.08– 18.11 |
| Typic Ustochrepts (Dadra) | 6.02 | 21.65 | 4.66 | 21.31 |

Before three decades, SOC stock in Udic Ustochrepts (Gangauli and Sihali soil series) was ranged 5.55-8.84 M t ha$^{-1}$ in surface while in subsurface it was ranged 8.11 - 9.01M t ha$^{-1}$ that was less than surface soil. After three decades it was significantly increased in surface ( 14.71-16.07 M t ha$^{-1}$) as well as subsurface soil (11.39 – 16.09 M t ha$^{-1}$). Similar trends were also observed in Aeric Halaquept (Bajgahani, Nayagaon and Maharaur soil series), Natric Ustochrept (Ukhdi and Nigari soil series) and Typic Ustochrept (Dadra soil series). Although, Aeric Halaquept had reported least SOC stock in surface soil ( 0.22-6.92 M t ha$^{-1}$) and subsurface soil (1.64- 7.03 M t ha$^{-1}$) before three decades which was significantly increased after three decades in surface soil ( 19.39-19.42 M t ha$^{-1}$) and subsurface soil ( 18.39-20.67 M t ha$^{-1}$) and Natric Ustocrept had also low SOC stock in surface( 0.88-1.28 M t ha$^{-1}$) and in subsurface soil ( 2.83-4.62 M t ha$^{-1}$) before three decades which was significantly increased after three decades in surface soil (15.19-19.01 M t ha$^{-1}$) and subsurface soil ( 15.08-18.11M t ha$^{-1}$).

### 4.4.5 Comparative study of change in soil Carbon Sequestration Potential with three decades difference Carbon Sequestration Potential ($CO_2$ Mt Equivalent ha$^{-1}$)

Change in Carbon Sequestration Potential during last three decades showed that there were significant increased. Maximum increased Carbon Sequestration

Potential in surface soil (0-15cm) was observed in Bajghani ( 97.24%) , Sihali (65.47%), Ukhdi ( 93.27%, ), Nayagaon (67.26%), Dadra (68.26%), Nigari ((4.19%) and Maharaur (98.82%). While in Gangauli soil series, it increased by 39.92% (Fig. 4.15).In subsurface soil, maximum increase was seen in Bajghani (80.46%), Ukhdi (74.47%), Nayagaon (65.97%), Dadra (78.12%), Nigari (81.23%) and Maharaur (91.05%) while Gangauli showed 20.94% increase and Sihali showed increase by 49.63%. Increase of Carbon Sequestration Potential in subsurface soil was comparatively lower than surface soil comparatively.

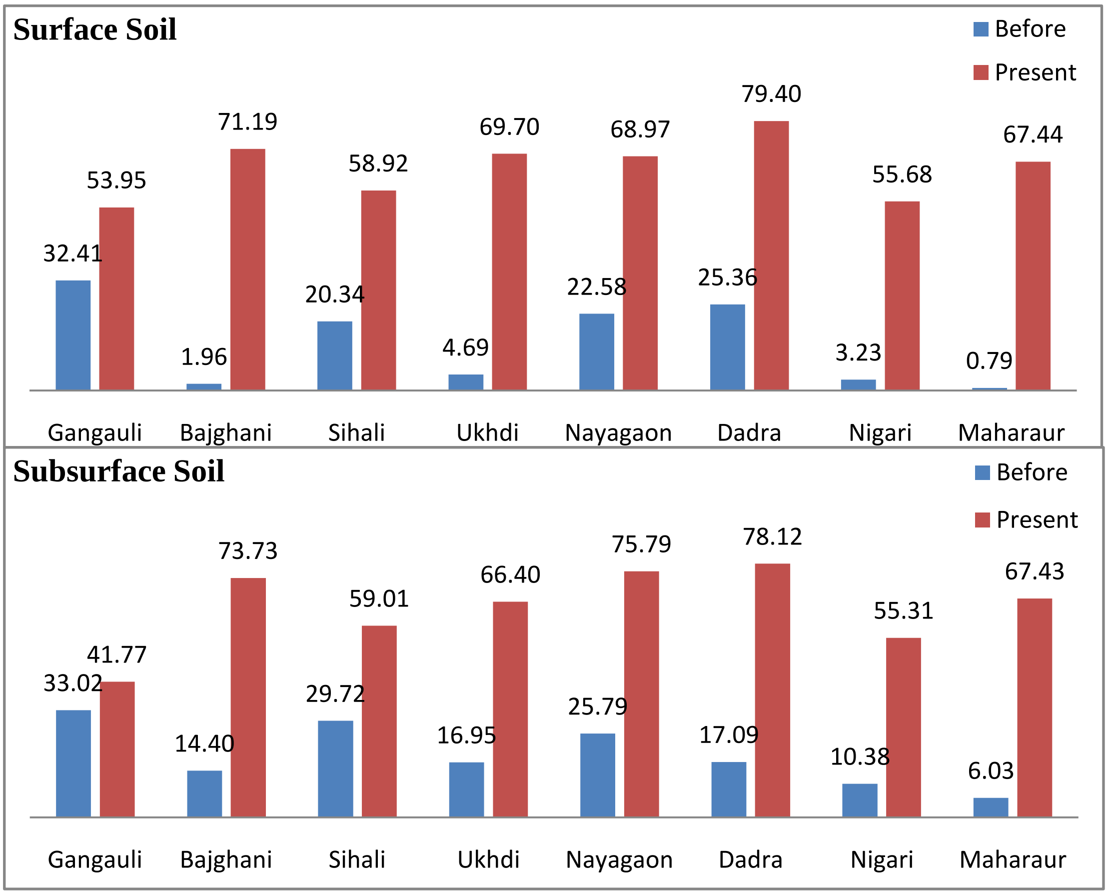


**Fig. 4.15. Comparative study of change in soil Carbon Sequestration Potential ($CO_2$ Mt Equivalent $ha^{-1}$) in between present soil (2015-16) with three decades before (1985-86) in surface (0-15 cm depth) and subsurface soil (15-30 cm depth) of different soil series of Dewa Block, Barabanki**

**Table No.4.20.** Soil type wise Carbon Sequestration Potential during three decades.

| Soil Type and Series | Surface Carbon Sequestration Potential ($CO_2$ Mt Equivalent $ha^{-1}$) | | Sub Surface Carbon Sequestration Potential ($CO_2$ Mt Equivalent $ha^{-1}$) | |
|---|---|---|---|---|
| | **Before** | **After** | **Before** | **After** |
| Udic Ustochrepts (Gangauli and Sihali) | 20.34 -32.41 | 53.95–58.92 | 29.72–33.02 | 41.77-59.01 |
| Aeric Halaquept (Bajgahani, Nayagaon, Maharaur) | 0.79 – 22.58 | 67.44–71.19 | 6.03 – 25.79 | 67.43– 73.73 |
| Nitric Ustochrept (Ukhdi and Nigari) | 3.23 – 4.69 | 55.68–58.92 | 10.38–16.95 | 55.31– 66.40 |
| Typic Ustochrepts (Dadra) | 25.36 | 79.68 | 17.09 | 78.12 |

Before three decades, soil carbon sequestration in Udic Ustochrepts (Gangauli and Sihali soil series) was ranged 20.34-32.41 Mt $CO_2$ equivalent $ha^{-1}$ in surface while in subsurface it was ranged 29.72-33.02 Mt $CO_2$ equivalent $ha^{-1}$ that was slightly higher than surface soil. Present time it was significantly increased after three decades in surface (53.95 – 58.92 Mt $CO_2$ equivalent $ha^{-1}$) as well as in subsurface soil (41.77 – 59.01 Mt $CO_2$ equivalent $ha^{-1}$) which was less than surface soil. Similar trends were also observed in Aeric Halaquept (Bajgahani, Nayagaon and Maharaur soil series), Natric Ustochrept (Ukhdi and Nigari soil series) and Typic Ustochrept (Dadra soil series). Although, Aeric Halaquept had reported least carbon sequestration in surface soil (0.79-22.58 Mt $CO_2$ equivalent $ha^{-1}$) and subsurface soil (6.03-25.79 Mt $CO_2$ equivalent $ha^{-1}$) before three decades which was significantly increased after three decades in surface soil (67.41-71.19 Mt $CO_2$ equivalent $ha^{-1}$) and subsurface soil (67.43-73.73 Mt $CO_2$ equivalent $ha^{-1}$) and Natric Ustocrept had also low carbon sequestration in surface(3.23-4.69 Mt $CO_2$ equivalent $ha^{-1}$) and in subsurface soil ( 10.38-16.95 Mt $CO_2$ equivalent $ha^{-1}$) before three decades which was significantly increased in present both in surface soil (55.68-58.92 Mt $CO_2$ equivalent $ha^{-1}$) and subsurface soil (55.31-66.40 Mt $CO_2$ equivalent $ha^{-1}$).

**4.5 Comparative study of Climatic change during last three decades**

Climatological data was compiled on an average of ten years data during 1976-1986 and 2006-2016. Observation showed that in May, June and July average temperature were ranged 29.8°C to 31.4°C during 1976-1986 after three decades in 2006-2016 average temperature ranged 29°C-35°C. Hottest month was observed in May. Thus, it indicated that nearly 4°C temperature increases within three decades in May. Coolest month was observed average temperature in month of December i.e. 6.8°C during 1976-1986 while average coolest month during 2006-2016 was 21°C in month of January. Before three decades the average annual temperature of Barabanki was 21.9 °C which has increased up to annual average temperature of 27.5 $^0$C. Thus there was average annual temperature increased about 6.4°C within three decades (Table No. 4.21).

Average annual rainfall during 1976-1986 was 98.8 mm which has increased to average annual rainfall of 103 mm during 2006-2016. Highest rainfall was absorbed in month of July i.e., 325.99 mm during 1976-1986 and 394.7 mm during 2006-2016.

Average annual humidity during 1976-1986 was 63.0 % which has decreased to average annual 58.8 % during 2006-2016. Highest was absorbed in month of August i.e., 75.7% during 1976-1986 and 83% during 2006-2016.

**Table No. 4.21. Comparison between average mean of Climatological Parameter of present (2006 - 2016) with three decades before (1976-1986).**

| month | Temperature $^0$C | | Temperature difference ( $T_2$-$T_1$) | Rainfall in mm (1976-1986) | Rainfall in mm (2006-2016) | Relative Humidity (Average)% (1976-1986) $H_1$ | Relative Humidity (Average)% (2016) $H_2$ | Humidity difference ($H_1$ – $H_2$) | Wind velocity km/hour (1976-1986) $W_1$ | Wind velocity km/hour (2006-2016) $W_2$ | Wind velocity difference ($W_1$-$W_2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Avg (1976-1986) $T_1$ | Avg (2006-2016) $T_2$ | | | | | | | | | |
| January | 14.3 | 21 | 6.7 | 20.08 | 9 | 64.1 | 54 | 10.1 | 3.89 | 2 | 1.89 |
| February | 15.8 | 24 | 8.2 | 19.18 | 15.9 | 62.5 | 48 | 14.5 | 5.19 | 3 | 2.19 |
| March | 22.1 | 29 | 6.9 | 9.36 | 7.6 | 58.1 | 40 | 18.1 | 5.62 | 3 | 2.62 |
| April | 27.4 | 32 | 4.6 | 0.06 | 29.3 | 54.6 | 37 | 17.6 | 5.73 | 5 | 0.73 |
| May | 31.4 | 35 | 3.6 | 20.37 | 15 | 50.3 | 35 | 15.3 | 6.26 | 6 | 0.26 |
| June | 30.8 | 32 | 1.2 | 119.8 | 203.2 | 62.6 | 61 | 1.6 | 5.12 | 8 | -2.88 |
| July | 29.8 | 28 | -1.8 | 325.99 | 394.7 | 74.8 | 82 | -7.2 | 5.24 | 8 | -2.76 |
| August | 28.8 | 28 | -0.8 | 243.0 | 297.5 | 75.7 | 83 | -7.3 | 4.5 | 6 | -1.5 |
| September | 27.8 | 28 | 0.2 | 345.5 | 210 | 73.9 | 79 | -5.1 | 4.36 | 4 | 0.36 |
| October | 17.5 | 27 | 9.5 | 53.45 | 40.7 | 62.7 | 68 | -5.3 | 2.81 | 2 | 0.81 |
| November | 11.3 | 24 | 12.7 | 4.28 | 13.2 | 62.5 | 62 | 0.5 | 2.47 | 2 | 0.47 |
| December | 6.8 | 22 | 15.2 | 20.34 | 10.7 | 63.6 | 57 | 6.6 | 2.93 | 1 | 1.93 |
| average | 21.9 | 27.5 | 5.6 | 98.8 | 103.9 | 63.0 | 58.8 | 4.2 | 4.51 | 4.1 | 0.41 |

# Chapter 5
# Discussion

# DISCUSSION

In present study soil carbon sequestration potential in different land use (i.e., forested, cultivated and uncultivated land) were studied in different soil series of Dewa block, District Barabanki, U.P. The main purpose of this study was characterized, classified and to estimate carbon sequestration potential in different soil series. Dewa block were categorized in eight soil series i.e., Gangauli, Bajgahani, Sihali, Ukhadi, Nayagaon, Dadra, Nigari and Maharaur soil series on the basis of his characteristic feature. Characterization of different soil series were as follows:

(i) Gangauli series was a member of coarse loamy, mixed, hyperthermic family of Udic Ustochrepts. These soils were very deep and well drained. The slope varies from 0-15%. The surface texture was sandy loam to loam under lain with loam to sandy loam sub soils.

(ii) Bajgahani Series was the member of fine silty calcarious mixed, hyperthermic family of Aeric Halaquepts. These soils were very deep, poorly drained occurring on low land. The slope varies from 0-3%. The surface texture was silty loam, which merges into silty clay loam to clay loam sub soils.

(iii) Sihali Series was a member of fine loamy, mixed hyperthermic family of Udic Ustochrepts. The soil was very deep, moderately well drained; the slope varies from 0-5%. The surface texture was loam to silty loam and underlain with Sicl to silt sub soils.

(iv) Ukhdi series was a member of fine silty, mixed hyperthermic family of Natric Ustochrepts. These soils were very deep, moderately well drained occurring on mid land. The slope varies from 0-3%. The surface texture was silty loam which merges into clay loam to silty clay loam subsoil.

(v) Nayagaon series was a member of fine clayey, mixed hyperthermic family of Aeric Haplaquepts. These soils were very deep, poorly drained, occurring on low land depressions. The slope varies from 0-3%. The surface texture was silty clay loam which merges into silty clay. The subsoil was silty clay loam to silty clay.

(vi) Dadra series was member of fine silty, mixed hyperthermic family of Typic Ustochrepts. These soils were very deep, moderately well drained occur in on midland. The slope varies from 0-5%. The surface texture was loam to silty loam and under lain with silty loam to gravely silty clay loam.

(vii) Nigari series was a member of fine silty, mixed, hyperthermic family of Natric Ustochrepts. These soils were very deep, moderately well drained occurring on mid land. The slope varies from 0-1%. The texture was silty loam which merges into clay loam to silty clay loam subsoil.

(viii) Mahraur series was a member of fine clayey, mixed hyperthermic family of Aeric Halaquepts. These soils were very deep, imperfectly drained occurring on low land with 0-1% slope. The surface texture was silty loam to silty clay loam sub soils.

Gangauli and Sihali soil series were Udic Ustochrepts while Bajgahani, Nayagaon and Maharaur were Aeric Halaquept. Ukhdi and Nigari were Natric Ustochrepts but Dadra soil series was Typic Ustochrepts.

Before three decades, the soil pH in Udic Ustochrepts was 7.5 in surface (0-15 cm depth) and 7.4-7.7 in subsurface which was slightly increases in surface soil 7.67-7.96 and 7.93- 8.16. in subsurface soil. In Aeric Halaquept soil pH was ranged from 8.1-10.2 in surface soil while 8.4 – 10.4 in subsurface soil. But after three decade, it was ranged 7.63-8.1 in surface soil and 7.73 – 8.19 in subsurface soil that was significantly decreases after three decades. In Natric Ustochrept soil pH was ranged from 10.1 – 10.3 in surface soil while in subsurface it was 10.3 – 10.7 but after three decades soil pH was significantly decreased 7.63-7.89 in surface soil and 7.73-7.93 in subsurface soil. Soil pH values at different depths of soils under three types of land cover are comparable with earlier studies in tropical forests (Johnson and Wedin, 1997; Paudel and Sah, 2003).

Soil pH of surface soil (0-15cm) was significantly increases in uncultivated land than forested and cultivated land. The pH was 8.77 in uncultivated soil which showed alkali in nature while in forested (pH 7.37) and cultivated (pH 7.73) it was normal. While in subsurface soil (15-30cm depth) soil pH was non-significantly higher in comparison to surface soil. An earlier study (Laik et al., 2009) also did not find any significant change in pH values at two different depths of different plantations supporting observation of this study. Soil pH values observed under three types of land cover at different depths are more or less similar to earlier studies (Shukla, 2009; Keel, 1975). Soil pH may also have an indirect effect on the C- to- N ratio of soil organic matter via changes in litter quality (Kemmitt et al., 2006). Also Kemmitt et al. (2006) hypothesized that increased soil acidity would lead to a greater accumulation of soil organic matter due to a reduced rate of microbial mineralization. However, soil pH values at different depths and SOC content under three types land cover are not supporting the above hypothesis.

Soil bulk density is an important indicator of soil compaction and the ability to function for structural support, water, solute movement and soil aeration (Martinez et al.1999). Bulk density in surface soil was significantly higher in cultivated and uncultivated land than the forested land while in subsurface soil it was significantly vary in uncultivated and cultivated soil than the forested soil. Before three decades, bulk density in Udic Ustochrepts was ranged 1.57-1.59 $gcm^{-3}$ in surface while in subsurface it was 1.61 $gcm^{-3}$. After three decades it was slightly decreases in surface as well as subsurface soil. Similar trends were observed in Aeric Halaquept, Natric Ustochrept and Typic Ustochrept. Bulk density (BD) values for different mineral soils may have, at least, a two-fold range, it is important that BD values are used in conjunction with concentrations of soil nutrients in ecological studies (Parfitt et al., 2010). In assessing stocks of carbon in soils, BD is also required for quantifying carbon on an area basis (Schlesinger, 1990; Morisada et al., 2004; Ramachandran et al., 2007; Arai and Tokuchi, 2010).

Soil organic carbon content in surface soil was ranged from 0.4 % to 0.88% while in subsurface soil 0.29% to 0.70%. Organic Carbon in surface soil was significantly decreased in uncultivated soil than forested and cultivated soil. Similar trend was also observed in subsurface soil i.e., forested soil was high Organic Carbon level (0.7%) and cultivated soil was medium organic carbon (0.48%) and in uncultivated it was very low (0.29%). In subsurface soil organic carbon significantly decreased in uncultivated and cultivated soil than the forested soil. SOC content in three types of land use are in accordance with the earlier reports (Wang et al., 2004; Shrestha et al., 2004; Chen et al., 2005; Rossi et al., 2009; Usuga et al., 2010) mentioning that soils under natural vegetation had a high SOC content compared to other land use systems. Soil carbon pool plays a crucial role in the soil quality, availability of plant nutrients, environmental functions and global carbon cycle (Srinivasarao et al., 2009b,).

Before three decades, SOC in Udic Ustochrepts (Gangauli and Sihali soil series) was ranged 0.29-0.47% in surface while in subsurface it was ranged 0.19-0.21% that was less than surface soil. After three decades it was significantly increased in surface (0.64-0.70%) as well as subsurface soil (0.49-0.71%). Similar trends were also observed in Aeric Halaquept (Bajgahani, Nayagaon and Maharaur soil series), Natric Ustochrept (Ukhdi and Nigari soil series) and Typic Ustochrept (Dadra soil series). Although, Aeric Halaquept had reported least organic carbon in surface soil (0.07-0.39%) and subsurface soil (0.09-0.19%) before three decades which was significantly increased after three decades in surface soil (0.81-0.86%) and subsurface soil (0.81-0.89%) and Natric Ustocrept had also low organic carbon content in surface(0.14-0.27%) as subsurface soil(0.11%) before three decades which was significantly increased after three decades in surface soil (0.66-0.84%) and subsurface soil (0.66-0.80%). Thus, soil organic carbon contents were maximum increases in Aeric Halaquept > Natric Ustocrept > Udic Ustocrept > Typic Ustocrept. Similar finding was also reported by Srinivasa rao et al., (2009b) and observed that organic carbon stocks in the soil profiles across the country showed wide variations and followed the order Vertisols>Inceptisols>Alfisols>Aridisols. There are three forms of carbon present on earth viz., 1) elemental 2) inorganic and 3) organic (Schumacher, 2002). The primary sources for elemental carbon in soils and sediments are as incomplete combustion products of organic matter from geologic sources (i.e., graphite and coal), or dispersion of these carbon forms during mining, processing, or combustion of these materials (Schumacher, 2002). Inorganic carbon in the soil occurs largely in carbonate minerals, such as calcium carbonate ($CaCO_3$)

and dolomite (CaMg $(CO_3)_2$) (Nieder and Benbi, 2008). The naturally occurring organic carbon (OC) forms are mainly derived from the decomposition of plants and animals. In soils a wide variety of OC forms are present, ranging from freshly deposited litter such as leaves, twigs, and branches to highly decomposed forms such as humus (Buringh, 1984). Plant litter and microbial biomass are the major parent materials for soil organic matter (SOM) formation (Knabner, 2002; Kramer and Gleixner, 2006). The three forms of carbon (elemental, organic and inorganic) are recycling between the reservoirs such as ocean, biosphere, atmosphere and living things by photosynthesis, respiration, burning, burial of organic matter, decomposition, and weathering processes (West, 2008).

Soil organic matter (SOM) is an important source of nutrients for plant growth in meaningless, and is itself influenced by land use, soil type, parent material, time, climate and vegetation. It is also one of the important factors affecting soil quality, sustainability of agriculture, soil aggregate permanence and crop yield (Karchegani,2012). The soil texture was loam in the upper soil layers but changed to silt loam as the depth increased. Bulk density increased with soil depth, and had a negative relationship with soil organic C. A significant positive correlation between SOC and clay content was observed. About 69 % of soil carbon in the profile was confined to the upper 40 cm soil layer where C stock ranged from 8.5 to 15.2 t C $ha^{-1}$ (Singh, 2011). Conservation of biodiversity and mitigation of the fallout of climate change are two major environmental challenges today. The relationship between plant biodiversity and soil organic carbon (SOC) sequestration has become a subject of considerable scientific interest. The Earth's terrestrial vegetation plays a pivotal role in the global carbon cycle. Not only are tremendous amounts of carbon stored in the terrestrial vegetation, but large amounts are also actively exchanged between vegetation and the atmosphere. In agroforestry systems C sequestration is a dynamic process and can be divided into phases. At establishment, many systems are likely to be sources of green house gases (loss of C and N from vegetation and soil). Then follows a quick accumulation phase and at maturation period, wherein tons of C are stored in the boles, stems, roots of trees and in the soil. At the end of the rotation period, when the trees are harvested and the land returned to cropping (sequential systems), part of the C is released back to the atmosphere. (Saha et.al., 2012).

Land use can be an important factor mitigating climate change, as it may have an impact on soil organic matter (SOM) storage (Schils *et al*., 2008). From the global evidence it can be seen that the effects of land use change on soil carbon stocks are of concern in the context of international policy agendas on the mitigation of global greenhouse gas emissions (GHGs) (UNFCCC). Other studies (Batjes, 1996; Lal *et al*., 1997; Post *et al*., 1999) also showed that land use change has a global concern due to its adverse effect on climate through emission of GHGs. Land use change is rapid in the developing countries and the problem has been increasing due to population growth and increasing land scarcity (Lal, 2000; Upadhyay,et.al., 2006) which leads to encroachment into forests and/or crop intensification. If a land management or land use change is reversed, the C accumulated will be lost, usually more rapidly than it was accumulated (Smith *et al*., 1996).

In present study, SOC stock in surface soil was ranged from 9.69 to 20.2 M t $ha^{-1}$ while in subsurface soil 10.03 to 19.28 M t $ha^{-1}$. SOC stock in surface soil was significantly increased in forested soil than cultivated and uncultivated soil. Maximum SOC stock was observed in forested soil (20.2 M t $ha^{-1}$) while in cultivated it was 15.67 M t $ha^{-1}$ and in uncultivated it was low level (9.69M t $ha^{-1}$) in surface soil. Similar trend was observed in subsurface soil i.e., forested soil was high SOC stock (19.28 M t $ha^{-1}$) and cultivated soil was medium organic carbon (15.94 M t $ha^{-1}$) and in uncultivated it was very low (10.03M t $ha^{-1}$). In subsurface soil SOC stock significantly increased than the surface soil in cultivated and uncultivated while decreased in forested soil. The soils contain high organic matter content associated with large carbon stocks in the soil profile, which is where the highest carbon volume is accumulated in the system (Usuga et al., 2010). SOC in the top layer (0-2 cm) differed corresponding to the type of vegetal cover. An earlier study (Kirby and Potvin, 2007) also observed the variations in carbon storage among different tree species. Results of this study are in confirmity.

Singh et.al (2011) estimated the distribution of carbon in soil profile in agroecosystems of Indo- Gangetic Plains and explored the factors which are responsible for distribution. A significant positive correlation between SOC and clay content was observed. About 69 % of soil carbon in the profile was confined to the upper 40 cm soil layer where C stock ranged from 8.5 to 15.2 t C $ha^{-1}$. We estimate the agricultural soils of Indo-Gangetic Plains may contain 12.4 to 22.6 t $ha^{-1}$ of organic C in the top 1 m soil depth. Since agricultural soils contain significantly lower C content than the soils of natural forest ecosystem in the same climate zone, management practices such as residue placement and reduced or no tillage are required to enhance C sequestration.

Before three decades, SOC stock in Udic Ustochrepts (Gangauli and Sihali soil series) was ranged 5.55-8.84 M t $ha^{-1}$ in surface while in subsurface it was ranged 8.11 - 9.01M t $ha^{-1}$ that was less than surface soil. After three decades it was significantly increased in surface ( 14.71-16.07 M t $ha^{-1}$) as well as subsurface soil

(11.39 – 16.09 M t $ha^{-1}$). Similar trends were also observed in Aeric Halaquept (Bajgahani, Nayagaon and Maharaur soil series), Natric Ustochrept (Ukhdi and Nigari soil series) and Typic Ustochrept (Dadra soil series). Although, Aeric Halaquept had reported least SOC stock in surface soil ( 0.22-6.92 M t $ha^{-1}$) and subsurface soil (1.64- 7.03 M t $ha^{-1}$) before three decades which was significantly increased after three decades in surface soil ( 19.39-19.42 M t $ha^{-1}$) and subsurface soil ( 18.39-20.67 M t $ha^{-1}$) and Natric Ustocrept had also low SOC stock in surface( 0.88-1.28 M t $ha^{-1}$) and in subsurface soil ( 2.83-4.62 M t $ha^{-1}$) before three decades which was significantly increased after three decades in surface soil (15.19-19.01 M t $ha^{-1}$) and subsurface soil ( 15.08-18.11M t $ha^{-1}$). The carbon stocks in different types of forests ecosystems have been estimated on the basis of forest inventories and using appropriate conversion factor to both biomass and carbon (Chhabra et al., 2002; Dadhwal et al., 2009; Kumar et al., 2011; Lal and Singh, 2000; Patil et al., 2010; Ravindranath et al., 1997; Sahu et al., 2015). Litter fall constitutes an important component of organic matter dynamics in a forest and its input depends upon vegetation composition, age of trees, canopy cover, weather conditions and biotic factors (Bargali, 1995; Lodhiyal and Lodhiyal, 1997; Rawat and Singh, 1988). Soils capture and store both organic and inorganic forms of carbon and thus act both as source and sink for atmospheric $CO_2$ (Bhattacharyya et.al 2008). Soil organic carbon is controlled by the balance of carbon inputs from plant production and outputs through decomposition (Schlesinger, 1977) and its storage is the most accepted method for long term carbon sequestration in terrestrial ecosystems.

Soil carbon sequestration is also important in maintaining a balance in greenhouse gas emissions and is strongly related to site conditions, i.e., soil texture, soil structure, initial soil carbon content, climate (Montagnini and Nair, 2004; Nair et al., 2009). Soil carbon in its various pools within the soil, provides structure and stability to soil also (Palm et al., 2007). Although $CO_2$ is cycled through four main global carbon stocks: the atmosphere, the oceans, fossil fuels, and terrestrial biomass and soils. Soil is big reservoir of atmospheric $CO_2$. Soil carbon has gained increased interest in the recent past owing to its importance in carbon sequestration studies and its potential impact on sustainable crop production. Carbon sequestration implies removing atmosphere carbon and storing it in natural reservoirs for extended periods (Lal, 2011).

Soil carbon sequestration is the process of transferring carbon dioxide from the atmosphere into the soil through crop residues and other organic solids, and in a form that is not immediately emitted. This transfer or sequestering of carbon helps to off-set emissions from fossil fuel combustion and other carbon-emitting activities while enhancing soil quality and long-term agronomic productivity. However, accuracy in estimating soil carbon sequestration to determine best management practices is hindered by inherent variability of soil properties (Srinivasarao et al., 2008, 2009b).

Carbon sequestration in soils is very important because aboveground litter production in forests is likely to increase as a consequence of elevated atmospheric $CO_2$ concentrations, rising temperatures, and shifting rainfall patterns. As litter fall represents a major flux of carbon from vegetation to soil, changes in litter inputs are likely to have wide-reaching consequences for soil carbon dynamics. Such disturbances to the carbon balance may be particularly important in the tropics because tropical forests store almost 30% of the global soil carbon, making them a critical component of the global carbon cycle (Sayer et al., 2007). Soil carbon quantities are a result of the balance between carbon input to the soil and the decomposition of organic carbon in the soil (Takahashi et al., 2007). Carbon input to the soil through litter fall (both above-ground and below-ground) could vary depending upon the types of vegetal cover and climatic factors. Several studies have estimated the contribution of afforestation to the global carbon cycle at both regional (Niu and Duiker, 2006; Potter et al., 2007; Kula, 2010) and global scales (Benitez et al., 2007).

Trees play an important role in soil C sequestration (Takimoto et al., 2009); with an increase in the number of trees till complete stocking (high tree density) in a system, the overall biomass production per unit area of land will be higher, which in turn may promote more C storage in soils. In fact, recent research has reported higher soil C stock (amount of carbon stored in soil) under deeper soil profiles in agroforestry systems compared to treeless agricultural or pasture systems under similar ecological settings (Nair et al., 2009). The rise in SOC is negligible in comparison with the quantities of litter added annually indicating that most of the litter that falls gets decomposed. This also shows that SOC present in the top layers of soil does not come from fresh litter alone. It is from the cumulative accumulation of undecomposed / partially decomposed leftovers of litter of previous years (up to decadal). The study revealed that SOC gets 'soaked' into lower layers. Addition coming from the decomposition of fresh litter (especially of leaves) is less. At all the experimental points leaf litter gets decomposed within a year while pieces of stem / branch remain for longer time. An earlier study (Brown and Lugo, 1982) reported that the turnover time of litter in tropical forests is less than one year. The results are in confirmity. There is a significant difference in the downward movement of SOC in the three types of vegetal cover. This confirms that SOC in tropical soils depends on the type of vegetal cover. SOC value itself is seen to be much higher than the values mentioned in some earlier reports (Richter et al., 1999; Zhou et al., 2006; Schwendenmann et. al., 2007).

The comparative studies of different soil series showed that carbon sequestration potential of soil in surface soil were ranged from 48.5 – 89.5 ($CO_2$ Mt equivalent $ha^{-1}$) in forested land while in subsurface soil ranged from 58.5 – 83 ($CO_2$ Mt Equivalent $ha^{-1}$) that was slightly lower than surface soil. Maximum soil Carbon Sequestration Potential in surface soil was observed in Ukhdi Soil Series (89.5 $CO_2$ Mt Equivalent $ha^{-1}$) while minimum in Nayagaon soil series (48.5 $CO_2$ Mt Equivalent $ha^{-1}$) while in cultivated soil it was ranged from 43.5 – 61.5 ($CO_2$ Mt equivalent $ha^{-1}$ ) in surface soil while in subsurface soil were ranged 35.5 – 73.5 ($CO_2$ Mt Equivalent $ha^{-1}$). The maximum Carbon Sequestration Potential was observed in surface soil of Ukhdi Soil Series (61.5 $CO_2$ Mt Equivalent $ha^{-1}$) while minimum in Sihali soil series (43.5 $CO_2$ Mt Equivalent $ha^{-1}$) but in subsurface soil maximum Carbon Sequestration Potential was observed in Nayagaon soil series (73.5 $CO_2$ Mt Equivalent $ha^{-1}$) that was slightly more than surface soil in cultivated land which may be due to agricultural practice adopted by farmers. The soil Carbon Sequestration Potential of uncultivated soil were ranged from 35 – 102 ($CO_2$ Mt Equivalent $ha^{-1}$ ) in surface soil while in subsurface soil these were ranged from 37.5 – 97.5 ($CO_2$ Mt Equivalent $ha^{-1}$). Thus maximum soil Carbon Sequestration Potential was observed in surface soil of Dadra Soil Series (102 $CO_2$ Mt Equivalent $ha^{-1}$) while minimum Carbon Sequestration Potential in uncultivated soil was seen in surface soil of Nigari soil series (35 $CO_2$ Mt Equivalent $ha^{-1}$).

Before three decades, soil carbon sequestration in Udic Ustochrepts (Gangauli and Sihali soil series) was ranged 20.34-32.41 Mt $CO_2$ equivalent $ha^{-1}$ in surface while in subsurface it was ranged 29.72-33.02 Mt $CO_2$ equivalent $ha^{-1}$ that was slightly higher than surface soil. Present time it was significantly increased after three decades in surface (53.95 – 58.92 Mt $CO_2$ equivalent $ha^{-1}$) as well as in subsurface soil (41.77 – 59.01 Mt $CO_2$ equivalent $ha^{-1}$) which was less than surface soil. Similar trends were also observed in Aeric Halaquept (Bajgahani, Nayagaon and Maharaur soil series), Natric Ustochrept (Ukhdi and Nigari soil series) and Typic Ustochrept (Dadra soil series). Although, Aeric Halaquept had reported least carbon sequestration in surface soil (0.79-22.58 Mt $CO_2$ equivalent $ha^{-1}$) and subsurface soil (6.03-25.79 Mt $CO_2$ equivalent $ha^{-1}$) before three decades which was significantly increased after three decades in surface soil (67.41-71.19 Mt $CO_2$ equivalent $ha^{-1}$) and subsurface soil (67.43-73.73 Mt $CO_2$ equivalent $ha^{-1}$) and Natric Ustocrept had also low carbon sequestration in surface(3.23-4.69 Mt $CO_2$ equivalent $ha^{-1}$) and in subsurface soil ( 10.38-16.95 Mt $CO_2$ equivalent $ha^{-1}$) before three decades which was significantly increased in present both in surface soil (55.68-58.92 Mt $CO_2$ equivalent $ha^{-1}$) and subsurface soil (55.31-66.40 Mt $CO_2$ equivalent $ha^{-1}$).

Global circulation models estimate the magnitude and time-scale of these changes and their effects on drought, floods, industry, agriculture etc. (Peiris et al., 1996). The rate of soil organic carbon sequestration with adoption of recommended technologies depends on soil texture and structure, rainfall, temperature, farming system, and soil management. Strategies to increase the soil carbon pool include soil restoration and woodland regeneration, no-till farming, cover crops, nutrient management, manuring and sludge application, improved grazing, water conservation and harvesting, efficient irrigation, agroforestry practices, efficient use of pesticides, irrigation, and farm machinery and growing energy crops on spare lands. ( West and Marland, 2002; Baker et.al, 2007 and Lal, 2008). Similar finding was observed by Grace et.al 2012 and said that C sequestration in wheat-based production systems on the Indo-Gangetic Plain (IGP) on conversion to no-tillage is estimated to be 44.1 Mt C over 20 years. Implementing no-tillage practices in maize–wheat and cotton–wheat production systems would yield an additional 6.6 Mt C. According to Yan et.al(2007) arable land soils generally have lower organic carbon (C) levels than soils under native vegetation; increasing the C stocks through improved management which suggested as an effective means to sequester $CO_2$ from the atmosphere. The C sequestration by agricultural soils is affected by many environmental factors (such as climate and soil conditions), biological processes (crop C fixation, decomposition and transformation), and crop and soil management (e.g. tillage and manure application). They found that practicing no-tillage on 50% of the arable lands and returning 50% of the crop residue to soils would lead to an annual soil C sequestration of 32.5 Tg , which accounts for about 4% of China’s current annual C emission. Agroforestry provides a unique opportunity to combine the twin objectives of climate change adaptation and mitigation. It has the ability to enhance the resilience of the system for coping with the adverse impacts of climate change (Pandey, 2002, Schoeneberger, 2009; Fanish and Priya, 2013; Murthy et.al.,2013; Lorenz and Lal 2014). Singh et.al (2011) estimated the distribution of carbon in soil profile in agroecosystems of Indo- Gangetic Plains and explored the factors which are responsible for distribution. They observed that soil texture was loam in the upper soil layers but changed to silt loam as the depth increased. Bulk density increased with soil depth, and had a negative relationship with soil organic C. A significant positive correlation between SOC and clay content was observed. About 69 % of soil carbon in the profile was confined to the upper 40 cm soil layer where

C stock ranged from 8.5 to 15.2 t C $ha^{-1}$. They estimated the agricultural soils of Indo-Gangetic Plains may contain 12.4 to 22.6 t $ha^{-1}$ of organic C in the top 1 m soil depth. Since agricultural soils contain significantly lower C content than the soils of natural forest ecosystem in the same climate zone, management practices such as residue placement and reduced or no tillage are required to enhance C sequestration. So, a mix of agroforestry with crop fields may be an option to enhance C sequestration in soils.

Before three decades the average annual temperature of Barabanki was 21.9 °C which has increased up to annual average temperature of 27.5 $^{0}$C. Thus there was average annual temperature increased about 6.4°C within three decades. According to the Inter-governmental Panel on Climate Change (IPCC, 2007) a temperature increase between 1.1 and 6.4°C by the end of the 21st Century due to GHGs has been reported which is similar to present finding. Temperature affects almost all aspects of terrestrial carbon processes, increasing earth's surface temperature likely enhances ecosystem carbon fluxes, potentially feeding back to a buildup of atmospheric $CO_2$ concentration and climate dynamics (Luo et. al.,2007). Average annual rainfall during 1976-1986 was 98.8 mm which has increased to average annual rainfall of 103 mm during 2006-2016. Highest rainfall was absorbed in month of July i.e., 325.99 mm during 1976-1986 and 394.7 mm during 2006-2016.Average annual humidity during 1976-1986 was 63.0 % which has decreased to average annual 58.8 % during 2006-2016. Highest was absorbed in month of August i.e., 75.7% during 1976-1986 and 83% during 2006-2016.

# Chapter 6
# Summary and Conclusion

# SUMMARY AND CONCLUSION

Present work entitled **"Evaluations of Soil Carbon Sequestration Potential in different landuse systems of Dewa Block, Barabanki, U.P."** carried out to assess the carbon sequestration potential in different land use in different soil series of Dewa Block, Barabanki. Change in climate, soil properties, soil carbon stock and soil carbon sequestration potential were studied in last three decades (i.e.1976 to 2016).

The main purpose of this study was to characterized, classified and to estimate carbon sequestration potential in different soil series. Dewa block which was categorized in eight soil series i.e., Gangauli, Bajgahani, Sihali, Ukhadi, Nayagaon, Dadra, Nigari and Maharaur soil series on the basis of his characteristic feature. Characterization of different soil series were as follows:

(i) Gangauli series was a member of coarse loamy, mixed, hyperthermic family of Udic Ustochrepts. These soils were very deep and well drained. The slope varies from 0-15%. The surface texture was sandy loam to loam under lain with loam to sandy loam sub soils.

(ii) Bajgahani Series was the member of fine silty calcarious mixed, hyperthermic family of Aeric Halaquepts. These soils were very deep, poorly drained occurring on low land. The slope varies from 0-3%. The surface texture was silty loam, which merges into silty clay loam to clay loam sub soils.

(iii) Sihali Series was a member of fine loamy, mixed hyperthermic family of Udic Ustochrepts. The soil was very deep, moderately well drained; the slope varies from 0-5%. The surface texture was loam to silty loam and underlain with Sicl to silt sub soils.

(iv) Ukhdi series was a member of fine silty, mixed hyperthermic family of Natric Ustochrepts. These soils were very deep, moderately well drained occurring on mid land. The slope varies from 0-3%. The surface texture was silty loam which merges into clay loam to silty clay loam subsoil.

(v) Nayagaon series was a member of fine clayey, mixed hyperthermic family of Aeric Haplaquepts. These soils were very deep, poorly drained, occurring on low land depressions. The slope varies from 0-3%. The surface texture was silty clay loam which merges into silty clay. The subsoil was silty clay loam to silty clay.

(vi) Dadra series was member of fine silty, mixed hyperthermic family of Typic Ustochrepts. These soils were very deep, moderately well drained occur in on midland. The slope varies from 0-5%. The surface texture was loam to silty loam and under lain with silty loam to gravely silty clay loam.

(vii) Nigari series was a member of fine silty, mixed, hyperthermic family of Natric Ustochrepts. These soils were very deep, moderately well drained occurring on mid land. The slope varies from 0-1%. The texture was silty loam which merges into clay loam to silty clay loam subsoil.

(viii) Mahraur series was a member of fine clayey, mixed hyperthermic family of Aeric Halaquepts. These soils were very deep, imperfectly drained occurring on low land with 0-1% slope. The surface texture was silty loam to silty clay loam sub soils.

Gangauli and Sihali soil series were Udic Ustochrepts while Bajgahani, Nayagaon and Maharaur were Aeric Halaquept. Ukhdi and Nigari were Natric Ustochrepts but Dadra soil series was Typic Ustochrepts.

- The comparative studies of different soil series showed that pH of in surface soil were ranged from 6.85 – 8.05 in forested land while in subsurface soil ranged from 7.3 – 8.15 that was slightly higher than surface soil. Maximum soil pH in surface soil was observed in Nayaaon Soil Series (8.05) while minimum in Sihali soil series (6.85) which was slightly acidic in nature which may be due to high humus content.
- The soil pH of cultivated soil were ranged from 7.40 – 8.5 in surface soil while in subsurface soil were ranged 7.45 – 8.25. The maximum pH was observed in surface soil of Bajghani Soil Series (8.5) while minimum in Dadra soil series (7.40) but in subsurface soil maximum pH was observed in Nigari soil series(8.25) that was slightly less than surface soil in cultivated land which may be due to agricultural practice adopted by farmers.
- The soil pH of uncultivated soil were ranged from 7.35 – 8.95 in surface soil while in subsurface soil these were ranged from 7.25 – 8.85. Thus maximum soil pH was observed both in surface and subsurface soil of Nigari Soil Series that was sodic in nature. Although Gangauli and Ukhdi Soil Series were also showed alkaline (sodic) in nature.
- The comparative study of present data with three decades before data showed that the soil pH in Udic Ustochrepts was slightly increased in surface and subsurface soil. In Aeric Halaquept and Natric Ustochrept soil pH after three decade significantly decreased.

- Bulk density in surface soil was significantly higher in cultivated and uncultivated land than the forested land while in subsurface soil it was significantly vary in uncultivated and cultivated soil than the forested soil.
- Before three decades, bulk density in Udic Ustochrepts was ranged 1.57-1.59 $gcm^{-3}$ in surface while in subsurface it was 1.61 $gcm^{-3}$. After three decades it was slightly decreases in surface as well as subsurface soil. Similar trends were observed in Aeric Halaquept, Natric Ustochrept and Typic Ustochrept.
- Organic Carbon in surface soil was significantly decreased in uncultivated soil than forested and cultivated soil. Similar trend was also observed in subsurface soil i.e., forested soil was high Organic Carbon level (0.7%) and cultivated soil was medium organic carbon (0.48%) and in uncultivated it was very low (0.29%). In subsurface soil organic carbon significantly decreased in uncultivated and cultivated soil than the forested soil.
- Before three decades, SOC in Udic Ustochrepts (Gangauli and Sihali soil series) was ranged 0.29-0.47% in surface while in subsurface it was ranged 0.19-0.21% that was less than surface soil. After three decades it was significantly increased in surface (0.64-0.70%) as well as subsurface soil (0.49-0.71%). Similar trends were also observed in Aeric Halaquept (Bajgahani, Nayagaon and Maharaur soil series), Natric Ustochrept (Ukhdi and Nigari soil series) and Typic Ustochrept (Dadra soil series). Although, Aeric Halaquept had reported least organic carbon in surface soil (0.07-0.39%) and subsurface soil (0.09-0.19%) before three decades which was significantly increased after three decades in surface soil (0.81-0.86%) and subsurface soil (0.81-0.89%) and Natric Ustocrept had also low organic

carbon content in surface(0.14-0.27%) as subsurface soil(0.11%) before three decades which was significantly increased after three decades in surface soil (0.66-0.84%) and subsurface soil (0.66-0.80%). Thus, soil organic carbon contents were maximum increases in Aeric Halaquept > Natric Ustocrept > Udic Ustocrept > Typic Ustocrept.

- SOC stock in surface soil was ranged from 9.69 to 20.2 M t $ha^{-1}$ while in subsurface soil 10.03 to 19.28 M t $ha^{-1}$. SOC stock in surface soil was significantly increased in forested soil than cultivated and uncultivated soil. Maximum SOC stock was observed in forested soil (20.2 M t $ha^{-1}$) while in cultivated it was 15.67 M t $ha^{-1}$ and in uncultivated it was low level (9.69M t $ha^{-1}$) in surface soil. Similar trend was observed in subsurface soil i.e., forested soil was high SOC stock (19.28 M t $ha^{-1}$) and cultivated soil was medium organic carbon (15.94 M t $ha^{-1}$) and in uncultivated it was very low (10.03M t $ha^{-1}$). In subsurface soil SOC stock significantly increased than the surface soil in cultivated and uncultivated while decreased in forested soil.
- Before three decades, SOC stock in Udic Ustochrepts (Gangauli and Sihali soil series) was ranged 5.55-8.84 M t $ha^{-1}$ in surface while in subsurface it was ranged 8.11 - 9.01M t $ha^{-1}$ that was less than surface soil. After three decades it was significantly increased in surface ( 14.71-16.07 M t $ha^{-1}$) as well as subsurface soil (11.39 – 16.09 M t $ha^{-1}$). Similar trends were also observed in Aeric Halaquept (Bajgahani, Nayagaon and Maharaur soil series), Natric Ustochrept (Ukhdi and Nigari soil series) and Typic Ustochrept (Dadra soil series). Although, Aeric Halaquept had reported least SOC stock in surface soil ( 0.22-6.92 M t $ha^{-1}$) and subsurface soil (1.64- 7.03

M t ha$^{-1}$) before three decades which was significantly increased after three decades in surface soil ( 19.39-19.42 M t ha$^{-1}$) and subsurface soil ( 18.39-20.67 M t ha$^{-1}$) and Natric Ustocrept had also low SOC stock in surface( 0.88-1.28 M t ha$^{-1}$) and in subsurface soil ( 2.83-4.62 M t ha$^{-1}$) before three decades which was significantly increased after three decades in surface soil (15.19-19.01 M t ha$^{-1}$) and subsurface soil ( 15.08-18.11M t ha$^{-1}$).

- The comparative studies of different soil series showed that carbon sequestration potential of soil in surface soil were ranged from 48.5 – 89.5 ($CO_2$ Mt equivalent ha$^{-1}$) in forested land while in subsurface soil ranged from 58.5 – 83 ($CO_2$ Mt Equivalent ha$^{-1}$) that was slightly lower than surface soil.
- Maximum soil Carbon Sequestration Potential in surface soil was observed in Ukhdi Soil Series (89.5 $CO_2$ Mt Equivalent ha$^{-1}$) while minimum in Nayagaon soil series (48.5 $CO_2$ Mt Equivalent ha$^{-1}$) while in cultivated soil it was ranged from 43.5 – 61.5 ($CO_2$ Mt equivalent ha$^{-1}$ ) in surface soil while in subsurface soil were ranged 35.5 – 73.5 ($CO_2$ Mt Equivalent ha$^{-1}$). The maximum Carbon Sequestration Potential was observed in surface soil of Ukhdi Soil Series (61.5 $CO_2$ Mt Equivalent ha$^{-1}$) while minimum in Sihali soil series (43.5 $CO_2$ Mt Equivalent ha$^{-1}$) but in subsurface soil maximum Carbon Sequestration Potential was observed in Nayagaon soil series (73.5 $CO_2$ Mt Equivalent ha$^{-1}$) that was slightly more than surface soil in cultivated land which may be due to agricultural practice adopted by farmers.
- The soil Carbon Sequestration Potential of uncultivated soil were ranged from 35 – 102 ($CO_2$ Mt Equivalent ha$^{-1}$ ) in surface soil while in subsurface soil these were ranged from 37.5 – 97.5 ($CO_2$ Mt Equivalent ha$^{-1}$). Thus

maximum soil Carbon Sequestration Potential was observed in surface soil of Dadra Soil Series (102 $CO_2$ Mt Equivalent $ha^{-1}$) while minimum Carbon Sequestration Potential in uncultivated soil was seen in surface soil of Nigari soil series (35 $CO_2$ Mt Equivalent $ha^{-1}$).

- Before three decades, soil carbon sequestration in Udic Ustochrepts (Gangauli and Sihali soil series) was ranged 20.34-32.41 Mt $CO_2$ equivalent $ha^{-1}$ in surface while in subsurface it was ranged 29.72-33.02 Mt $CO_2$ equivalent $ha^{-1}$ that was slightly higher than surface soil. Present time it was significantly increased after three decades in surface (53.95 – 58.92 Mt $CO_2$ equivalent $ha^{-1}$) as well as in subsurface soil (41.77 – 59.01 Mt $CO_2$ equivalent $ha^{-1}$) which was less than surface soil.

- Similar trends were also observed in Aeric Halaquept (Bajgahani, Nayagaon and Maharaur soil series), Natric Ustochrept (Ukhdi and Nigari soil series) and Typic Ustochrept (Dadra soil series). Although, Aeric Halaquept had reported least carbon sequestration in surface soil (0.79-22.58 Mt $CO_2$ equivalent $ha^{-1}$) and subsurface soil (6.03-25.79 Mt $CO_2$ equivalent $ha^{-1}$) before three decades which was significantly increased after three decades in surface soil (67.41-71.19 Mt $CO_2$ equivalent $ha^{-1}$) and subsurface soil (67.43-73.73 Mt $CO_2$ equivalent $ha^{-1}$) and Natric Ustocrept had also low carbon sequestration in surface(3.23-4.69 Mt $CO_2$ equivalent $ha^{-1}$) and in subsurface soil ( 10.38-16.95 Mt $CO_2$ equivalent $ha^{-1}$) before three decades which was significantly increased in present both in surface soil (55.68-58.92 Mt $CO_2$ equivalent $ha^{-1}$) and subsurface soil (55.31-66.40 Mt $CO_2$ equivalent $ha^{-1}$).

Thus present work concluded that soil carbon sequestration potential depend on climatic condition, litter fall, biomass, rate of decomposition, time, soil texture and organic matter. Carbon dioxide can be reduced through absorption by soil which also depends on different human activities i.e., agricultural practices, plantation and cropping pattern.

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# LIST OF PUBLICATIONS

- Pramod Kumar Singh, NeelamVerma, **Neetu Pandey**, Prashant Singh (2015): Soil Sodicity induced changes in aromatic plants: Effects on growth, water relation, anti-oxidative enzymes, cations uptake and quality of *Ocimum sanctum*. *Research Journal of Medicinal Plant* 9 (8): 375-394, 2015 ISSN 1819-3455 / DOI: 10.3923/rjmp.2015.375.394

- Pramod Kumar Singh, **Neetu Pandey**, Monika Gupta and Alok Kumar ( 2015): Sustainable Municipal Solid Waste Management through Vermitechnology: Impact of Vermicompost on Sweet flag (*Acorus calamus*) plants and Sodic Degraded Land. *International Advanced Research Journal in Science, Engineering and Technology (IARJSET) v*ol. 2, Special Issue 1, 139-46.

**Seminars and Conferences attended**

- Paper presented on the topic **"Effects of land use system on soil carbon stocks and soil carbon sequestration potential in Dewa Block, Barabanki"** in **International Seminar** on Sources of Planet Energy, Environmental and Disaster Science: Challenge and Strategies (SPEEDS-2016) organized by SMS Lucknow, in association with The Institution of Engineers, AKTU Lucknow and Council of Science & Technology, Uttar Pradesh on 19 & 20 Nov, 2016. (**Oral**).

- Paper presented on the topic of **"Soil Carbon Sequestration Potential in Silvipasture land situated in different Agro-climatic Zones of Utter Pradesh"** in **International Seminar** on Sources of Planet Energy, Environmental and Disaster Science: Challenge and Strategies (SPEEDS-2015) organized by SMS Lucknow, in association with The Institution of Engineers, AKTU Lucknow and Council of Science & Technology, Uttar Pradesh on Nov 21-22, 2015. (**Oral**).

- Paper presented on the topic **"Terrestrial carbon sequestration in Silvipasture: An approach to develop silvipasture for environment conservation and socio-economic development."** in **International Seminar** on Sources of Planet Energy, Environmental and Disaster Science: Challenge and Strategies (SPEEDS-2014) organized by SMS Lucknow, in association with The Institution of Engineers, U.P. State Centre, Lucknow, UPTU Lucknow and Council of Science & Technology, Uttar Pradesh on 1st & 2nd Nov, 2014. (**Oral**)

- Paper presented on the topic "**Sustainable Municipal Solid Waste Management through Vermitechnology: Impact of Vermicompost on Sweet flag (*Acorus calamus*) plants and Sodic Degraded Land"** in **National Conference** on Renewable Energy and Environment (NCREE-2015) IMS Engineering College, Ghaziabad (**Oral**)

- Paper presented on the topic **"Exchangeable Sodium Induced Changes on growth, photosynthetic pigments, antioxidative enzymes and quality of *Acorus calamus* "** in **National Seminar** "Plant Biotechnology for Better Future" Sponsored by UGC and Organized by Department of Botany, Govt. College, Anantpur, Andhra Pradesh, 27$^{th}$ and 28$^{th}$ June 2014, (**Oral**).