6. Soil as A Net Carbon Sink

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Abstract:

Carbon (C) is a vital element and found in all life forms, and is regulated by the exchange between oceanic, geologic, pedologic, biotic and atmospheric pools largely in the form of CO2. Among this, the C stored in the upper part of the terrestrial are susceptible to anthropogenic activities and can act as a source as well as sink of C. As a C sink, soils have the potential to sequester 0.45 to 0.90 Pg C per year. This storage may be through soil inorganic carbon (SIC) and soil organic carbon (SOC), although the mechanism and extend of sequestration though SIC is largely unknown. Both the SIC and SOC storage can be affected by a wide number of factors, including climate, soil characteristics, and other management factors. Soil C stabilization is necessary for soils to act as a C sink, and occurs mainly through three mechanisms of soil C stabilization: physical, chemical, and biological. Theoretically, there exists a soil C saturation level, beyond which additional C input will only accumulate in labile soil C pools that have a relatively faster turnover. Saturation deficit is the difference between a soil's theoretical saturation level and the current C content. The proportion of C stabilized would be greater in soils with larger C saturation deficits, and the relative stabilization efficiency would decrease as C input level increased.

Keywords:

Carbon stock, storage, organic carbon, inorganic carbon, sequestration, saturation

6.1 Introduction:

Long-term changes in global weather patterns and temperatures caused by human activities, Carbon (C) is a vital element present in all living cells and is the major building block for life on Earth. It also occurs in numerous minerals found in soils and geological strata, rocks, ocean, fossil fuels, sedimentary deposits, terrestrial biosphere, and atmosphere [1]. The global C cycle is regulated by five main reservoirs, and there is an exchange of C mainly in the form of CO_2 from one reservoir to another: oceanic (~39000 Pg of C, 1 Pg = 10^{15} g), geologic (~5000 Pg C), pedologic (soil) (~2500 Pg C), biotic (~560 Pg C) and the atmospheric reservoir (~750 Pg C) [2]. The stored C in terrestrial biosphere (soil, vegetation), atmosphere, and upper layers of ocean are active in nature and are susceptible to anthropogenic activities whereas those in the sedimentary rocks are relatively inert, and change over a scale of millions of years [1].

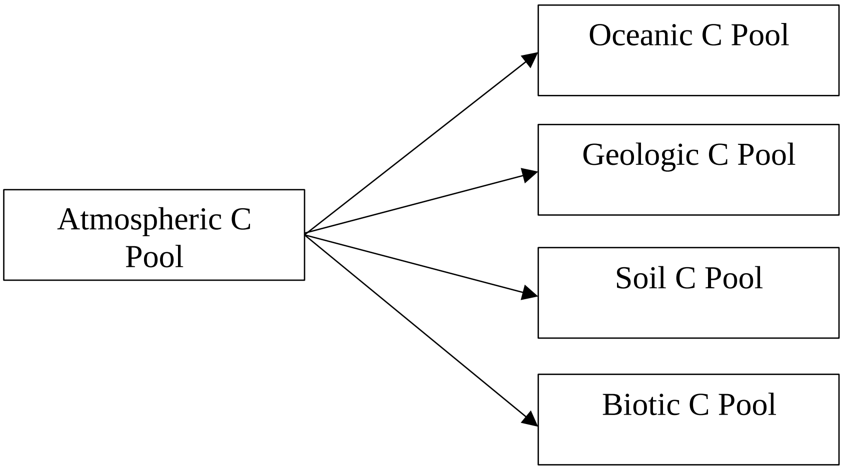

Figure 6.1: Principal carbon reservoirs on the earth [1].

6.2 Soil Carbon Pools:

Soil C pools can be broadly divided into soil inorganic carbon (SIC) and soil organic carbon (SOC). Upto 100 cm soil depth, the SOC is predicted to be 1200-1600 Pg, whereas SIC is estimated to be about 695-940 Pg [3]. In most regions, SOC is the major contributor to total soil C except in dryer regions such as arid, semiarid and/or semi-humid areas where SIC, mainly in the form of Ca and Mg carbonates forms the dominant pool [4]. In arid and semiarid areas, the SIC might be 2 to 10 times higher than that of SOC [5].

The SIC is further divided into primary carbonate, also known as lithogenic inorganic carbon (LIC), and secondary deposited carbonate known as pedogenic inorganic carbon (PIC). The LIC are inherited from parent materials whereas PIC is formed through dissolution and precipitation of carbonates in parent materials and derived from the weathering of $CaSiO_3$ [6].

Compared to SIC, the SOC gained more attention because the SOC pool is more reactive, highly dynamic, played vital role in soil quality, fertility, productivity, climate change mitigation, and reflect the soil and ecosystem processes [1]. The SOC is divided into different pools depending on their mean residence time (MRT) in the soil. The labile C have the quickest turnover among the different SOC pools and its MRT ranged a few days only. It may consist of simple sugars, simple organic acids and microbial metabolites that can be easily mineralized. The slow or intermediate consists of structural plant residues and physically stabilized C that turnovers in decades whereas the resistant fraction are the inert fraction largely resistant to decomposition by soil microbes with MRT of thousand years [7]. The labile SOC is subjected to rapid mineralization by soil microbes while the stable and recalcitrant remains chemically inert and microbial transformation [8].

6.3 SIC As A Net C Sink:

Soil serve as an important C sink with the ability to sequester 0.45 to 0.90 Pg C per year [2]. Soil can sequester C either by direct or indirect sequestration. Direct soil C sequestration occurs by inorganic chemical reactions that convert CO_2 into SIC compounds such as Ca and Mg carbonates, while indirect C sequestration takes place when CO_2 in the atmosphere is removed through photosynthesis and stored in the soil after decomposition. During the formation of LIC and PIC, one mole of carbonate requires two moles of carbonic acid and liberate one mole of CO_2 to the atmosphere (Eq (1)) [9]:

$$Ca^{2+} + 2HCO_3^- \leftrightarrow CaCO_3 + H_2O + CO_2\uparrow \quad (1)$$

This reaction will act as a net C sink if the source of CO_2 in the HCO_3^- is respiration of soil microbes or decomposition of organic matters in soil. However, this reaction will become a source of atmospheric CO_2 if the HCO_3^- is from irrigation water [10]. During the formation of secondary carbonate from $CaSiO_3$ weathering, two moles of atmospheric CO_2 are converted to bicarbonate (HCO_3^-) (Eq (2)). This can lead to the sequestration of atmospheric CO_2 in soils [11].

$$CaSiO_3 + 2CO_2\downarrow + 3H_2O \rightarrow HCO_3^- + Ca^{2+} + H_4SiO_4 \quad (2)$$

However, the rate of this reaction in soil is extremely slow and are typically on the order of 50–500 mol Ca^{2+} ha^{-1} yr^{-1} [12]. Even if soil management practices could hasten the speed of the reaction to twice or thrice, only 0.001–0.01 t C-CO_2 ha^{-1} yr^{-1} will be consumed which suggest that this reaction is of minor importance as the global C sink [9]. As a result, many studies do not consider SIC as a C sink, probably due to the longer time needed for changes in carbonates compared to SOC. However, recent studies have demonstrated soil organisms to be an important component in the formation of secondary carbonate and may quicken the turnover of the SIC too [13].

6.3.1 Factors Affecting SIC As a Net C Sink:

The ability of the soil to store C as carbonates depends on factors such as climate, soil characteristics and other management factors.

A. ***Climatic Factors:*** Climatic factors such as precipitation and temperature significantly affect the processes of evaporation and leaching, which in turn influence the dissolution and re-precipitation of carbonates [14]. At high temperature and low precipitation, such as arid and semi-arid areas, there is accumulation of PIC due to slow carbonate dissolution and leaching [10]. Increasing aridity also encourages formation of petrocalcic and calcic strata as there is little water to leached down the accumulated carbonates [15]. The quantity and depth of carbonate accumulation is also affected by the amount and frequency of precipitation received in the region. Thus, the time taken to store the same quantity of SIC will be longer in arid areas and shorter in humid area [16].

B. ***Topography and Landscape:*** The topography and position of the soil affects the amount, rate and depth of carbonate accumulation in soil. In general, carbonates may or may not be present in the upper parts of a hillslope, while thick calcretes may be formed at toeslope [17]. Stability of a landscape also influences the amount and depth of carbonate accumulation in the profile. Unstable soil surfaces prone to erosion and water movement leads to less carbonate accumulation and their deeper localization [10].

C. ***Vegetation and Soil Organisms:*** The presence of roots and microbes in soil modulates the concentration of CO_2 and pH in soil. At the vicinity of the roots, the CO_2 increases a hundred-fold accompanied by lower pH [18]. This increase protons and carboxyl groups released by the roots carbonate dissolution five to ten-fold [10]. Carbonate solubility increases near the roots because the CO_2 concentration is almost 100 times higher in the rhizosphere. Soil microorganisms can also produce a visible accumulation of carbonates within a few days if Ca^{2+} ions are available in solution, bacteria. Extracellular polymers such as polysaccharides and amino acids may also control the formation and morphology of $CaCO_3$ [20].

D. ***Land Cover and Land Use Change:*** The characteristics of vegetation and changes in land use also affects the SIC deposition in soil. Among the different natural vegetation, desert has the highest SIC, followed by grassland, farmland, marsh, shrubland, meadow, and forest [21]. Conversion of natural vegetation to agricultural use was found to increase not only the loss of even the most recalcitrant SIC, but also redistributes it in the profile [22]. In China, losses of SIC from 51% of total cultivated soil was estimated at about 0.5–4.0 kg C m^{-2} [11].

E. ***Soil acidification through fertilizers:*** Acidification of soil due to long-term application of acidic fertilizers or other soil acidifying agents also could affect the SIC sequestration in soil. The decrease in soil pH aid the dissolution in the carbonates thereby resulting in lower SIC accumulation in the surface soil [23].

F. ***Soil Characteristics:*** Soil physicochemical properties such as by soil texture, structure, pH, ion strength and soluble Ca^{2+} and Mg^{2+} affects the accumulation of carbonates. The texture and structure of a particular soil affects the infiltration, percolation, translocation and the quantity of water it can absorbed which thereby influenced the amount and depth of carbonate accumulation in soil [24]. The soil pH influences the size of the carbonate crystal, morphology and bicarbonate/carbonate ratio in soil [25]. As the soil pH increases above 7, there is lower bicarbonate/carbonate which favours carbonate crystal formation and precipitation of smaller crystals into bigger ones [25]. The ionic strength of different salts also affect the rate of carbonate dissolution and precipitation, and as a result, carbonate dissolution in saline soils takes longer and occurs earlier compared to salt-free soils. The pattern of carbonate distribution in soil is similar to the pattern of the Ca^{2+} and Mg^{2+} present in soil, but the relation is stronger with soluble Ca^{2+} Also, higher concentration of soluble Ca^{2+} and Mg^{2+} in soil favours carbonate precipitation [26].

6.4 SOC As a Net C Sink:

For the SOC to act as a net C sink, atmospheric CO_2 must be transferred into plant biomass and its conversion into long-lived stable and recalcitrant SOC through humification that is resistant to changes [27]. This process primarily relies on removal of atmospheric CO_2 and storage in the plant biomass through photosynthesis, decomposition of the pant biomass in the soil and storage as stable and protected fraction SOM [28].

Thus, SOC sequestration could be achieved by increasing above and below-ground vegetation in a unit land area, retaining the biomass to be converted into SOC, protection and stabilization of the SOC against decomposition and erosion [27].

6.4.1 Factors Affecting SOC Sequestration:

SOC sequestration depends on many factors including climate, soil depth, soil texture and mineral present, nutrient content, topography and aspects, and the initial content of SOC [27].

A. ***Climate:*** Climatic factors such as temperature and precipitation enormously affect soil C sink capacity through its effects on C inputs through biomass production and C losses through decomposition. Temperature directly affects SOC sequestration by increasing the rate of organic matter decomposition whereas presence of moisture slows down the decomposition thereby facilitating in the accumulation and stabilization of SOC [29]. As a result, decomposition of SOC is more rapid in tropical regions than in temperature regions. Also, soils of humid regions generally have higher SOC content that those from dry regions which could be attributed to higher biomass production in humid regions [27]. It is estimated that the decrease in SOC with per degree increase in mean annual temperature is 1896 kg ha^{-1} [30]. Soils of humid regions are often richer in SOC than soils of dry regions and this can be due to a greater production of biomass and lesser decomposition in humid regions [31].
B. ***Soil Properties:*** Soil texture, mineralogical compositions, depth and types, pH, bulk density and porosity determine the amount of C sequestered. Soil texture (amount and type) is key soil property that govern the potential of the soil to sequester SOC in soils. Soils with more clays could sequester more C, and among the different types of clay; smectitic clays are more potent in C accumulation and sequestration [32]. Irrespective of soil types, higher SOC are found at the surface soil and decreases with increasing depth of profile except in some vertisols due to natural mixing of soil [33]. Among the different soil orders, soils with low organic matter content such as aridisols have lowest SOC whereas highest SOC is found in histosols [34]. Soil mineral composition determine the quantity of SOC stored in soil, its turnover time, and atmosphere-ecosystem C fluxes. The presence of multivalent cations such as Ca^{2+}, Al^{3+} or Fe^{3+} leads to accumulations of SOC in comparison to other cation types [35]. Soil pH affects microbial enzymatic efficiency, and mineralization of SOM is most rapid at neutral pH, suggesting that both extremely alkaline and acidic condition are detrimental for the growth of microbes in soil [36]. Soil porosity affects the movement and availability of water and air in soil thereby affecting the decomposition and accumulation of SOC [37].
C. ***Management Factors:*** The change of forestland to cultivated land destroys the soil aggregate structure, which enhances SOM mineralization and CO_2 emissions that subsequently reduce the soil C sink capacity. It has been estimated that 303 t C ha^{-1} is retained in tropical forests [38], 66 t C ha^{-1} and 44 t C ha^{-1} in temperate and boreal forests, respectively [39]. Clearance of forests for cultivation or other uses as result of urbanization in the past one and half century was estimated to result in losses of about 136 (±55) Gt C in to the atmosphere [40]. Cropping and their management practices that increase C input and reduce the release of CO_2 to the atmosphere will aid in building up the SOC content of soils. Thus, suitable management practices under different land-use and agro-climatic conditions is important to sequester C in the soil [41].

6.5 Crop Management Practices for Improving Soil C Sink Capacity:

Adoption of improved practices can increase the C sequestration in soil. Some of these practices discussed in brief.

A. ***Adoption of Conservation Agriculture CA):*** According to the FAO, conservation agriculture (CA) system combines minimum soil disturbance, maintaining a permanent soil cover with crop residues and/or cover crops, and diversification of plant species through varied crop sequences and associations involving at least one legume crop. Excessive tillage is responsible for disrupting soil aggregate, and exposes particulate organic matters (POM) protected within soil macroaggregates to microbial decay [42]. When the number of tillage is reduced through the adoption of reduced tillage or no-till, SOC exposure to decomposition by microbes is reduced thereby reducing the loss of SOC from the soil [43].

   Adoption of reduce tillage or no-till have been considered an important C sequestration tool. In the US, SOC sequestration under no-till widely varies from 0.45 Mg C ha^{-1} y^{-1} [44] to 0.27 Mg C ha^{-1} y^{-1} in the South-East, from 0.27 to 0.40 Mg C $ha^{-1}y^{-1}$in the North West and between 0.30 and −0.07 Mg C $ha^{-1}year^{-1}$ in the North [45]. The worldwide C sequestration potential under no-till system is projected to be around 0.57 Mg C $ha^{-1}y^{-1}$ [46]. Data from 69 paired conventional tillage and no-till showed that adoption of no-till increased soil C by 3.15 (± 2.42) t ha^{-1} in the surface soil, but declined by 3.30 (± 1.61) t ha^{-1} in the 20–40 cm soil layer [47].

   Overall, adopting NT did not enhance soil total C stock down to 40 cm. in vertisol of Central India, no-till (4.22 ± 0.133 Mg C ha^{-1}) resulted in significant increase of SOC content in soil as compared to reduced tillage (3.84 ± 0.123 Mg C ha^{-1}) and conventional tillage (3.65 ± 0.04 Mg C ha^{-1}) in the surface 5 cm layer [48]. It is estimated that, CA could increase SOC stock by 1.8 t C ha^{-1} yr^{-1} in the first 10-years of adoption [31]. Returning crop residue back to the soil is done either through incorporation or retention which provide large inputs of C to soils and enhance SOC. Maintaining a permanent soil cover through addition of crop residue accompanied by no-tillage improve the soil physical, chemical and biological properties with reduced greenhouse gas emission especially CO_2 [25]. Meta-analysis results indicated that residue return in China increased SOC storage by 11.3% compared to residue removal [49]. It can sequester about 14 to 30 t CO_2e ha^{-1} in European Union [50]. One of the main disadvantages of improving C sequestration through crop residue return is the potential of elevated N_2O emission that offset the benefits from C sequestration [51]. In soils with very low fertility, the soil may not be able to produce sufficient crop biomass to significantly increase the C sequestration in the soil [52].

   Transitioning from conventional agriculture to no-till or minimum tillage could also possibly result in yield penalty thereby affecting the quantity of crop residue available for retention or incorporation with very less or no C sequestration [53]. Diversifying the cropping system with legumes is important to improve SOC content in soil. Inclusion of suitable crop species such as legumes which have more root systems in the rotation rather than a monoculture system can add more biomass into the system and is often accompanied by enhancing the soil C sequestration [54, 55]. Biomass addition into the soil through roots of a cover crop in no-till system was found to have a close relationship with the increase in SOC stocks over the years [55]. Meta analyses of 139 plots at 37 different sites showed higher SOC sequestration under cover crop than in the reference croplands [56].

B. ***Organic Manures:*** Composts and farmyard manures are a good source of organic matter and their application to soil could be an effective way of enhancing the SOC contents of soil, both by virtue of the added C in the amendment itself and through improvement of soil properties such as nutrient transformation and supply, soil–water balance control or buffering of pollutants. Both single addition of large dose and multiple addition of smaller dose of stable compost showed similar rates in SOC sequestration but the response was highest in the first thirty years in case of single addition but build up continued for over a century in the stable and recalcitrant pools [57]. Meta analyses of 101 research findings encompassing over 592 treatments disclosed that application of organic manures could improve the SOC stock by 10.7 Mg C ha^{-1}, which is 35.4% from the control [58].

C. ***Mulching:*** Mulching is one of the most sustainable approaches in sequestering C. Not only this, organic mulching using crop residues also keep the soil thermal regime at moderate level, reduce evaporation and erosion, improve soil health and nutrient availability. Saroa and Lal [59] reported that the rate of mulch application had a significant positive effect on the SOC concentration in 0–5 cm depth and was highest when soil received 16 Mg C ha^{-1}.

D. ***Organic Agriculture:*** Farming practices affect both input and turnover rates of SOM. Organic farming systems is a farming system devoid of the use of any chemical inputs such as chemical fertilizers and pesticides to improve ecosystem functions, animal and human health. It relies on the use of organic products instead of harmful chemical to protect crops and increase productivity. Many studies have reported the positive effects of organic agriculture [60], while inconsistent or unreliable conclusions have also been reported [61]. Analysis of 68 datasets revealed that after conversion of conventional system to organic system, the mean increase in SOC content was 2.2% per year [62]. Another analysis of datasets from 74 studies found that SOC stocks were 3.50±1.08 Mg C ha^{-1} higher in organically managed soils than in inorganically managed soils [63].

E. ***Agroforestry:*** Association of trees with crops on the same land-unit could improve soil C sequestration compared with pastures or field crops and is affected by the number of site-specific biological, climatic, soil, and other management factors. Many authors believed that agroforestry systems have a higher potential to sequester C in soil. This inference can be drawn from the huge amount of atmospheric CO$_2$ captured by trees during photosynthesis and storage of C in their biomass and acts a potent C sequestration tool. It is estimated that the C sequestration potential in agroforestry system can range from 1.25 to as high as 173 Mg C ha^{-1} y^{-1} [64].

F. ***Integrated Nutrient Management (INM):*** Integrated nutrient management (INM) is the judicious use of both organic and chemical inputs to enhance farm productivity and production. These chemical and biological inputs acts in synergy to improve crop protection, nutrient availability, soil properties and health, and thus the crop productivity. INM has been established as an efficient management practice that can enhance SOC [65]. In an inceptisol, long term application of recommended dose of primary nutrients with farm yard manure for over four decades resulted in maximum increase SOC and organic matter compared with the unfertilized one [66]. An increase of 17% SOC in the top 15 cm layer was observed when 20 t ha^{-1} of farm yard manure was along with mineral fertilizers after 32 years in the upper Indo-Gangetic Plains [67].

Compared with the use of chemical fertilizers alone, INM was found to improves the soil C sequestration by 2.3 Mg C ha^{-1} [68].

G. ***Restoration Of Degraded Lands:*** Restoring degraded and abandoned lands could be an important tool for sequestering C in soil through ecological succession [2]. Restoration of degraded land can promote soil and vegetation health thereby increasing C stocks both in soil and in biomass. Lal and Bruce [69] estimated that 100 M ha of degraded land worldwide are unfit for cultivation. If the C sequestration rate of these land to be around 0.25 t C ha^{-1}, it may be estimated that this degraded land can be used to sequester about 0.025 Gt C $year^{-1}$. In India, it has been projected that restoration of degraded soils could effectively sequester 9.8–13.9 Tg C ha^{-1} [52]. Meena et al. [70] reported that creation of agricultural ecosystem models on degraded land increase the C sequestration potential; and highest CO_2 sequestration (Mg C ha^{-1}) was found in the forest land system (115.1) followed by karonda (*Carissa carandas*) cultivation land (41.1), guava + green gram cultivation land (38.9), mono-cropping wheat cultivated land (22.0), mono-cropping rice cultivation land (17.6), pasture land (9.40) and lowest in seasonal pond area (0.87).

H. ***Biochar Application:*** Biochar is a stable C compound produced as a byproduct of pyrolysis of biowaste. Due to its inertness, biochar application is another way of increasing soil refractory organic C pool. Meta analysis showed that biochar derived from crop residue increased SOC stock and contributes largely to the stable pool [71]. Result from 64 studies with 736 individual treatments showed a mean increase in SOC stocks by 13.0 Mg C ha^{-1} [72]. However, there are also some reports that biochar application may accelerate degradation of both native SOC and biochar C, and may not an effective tool for C sequestration. The effect of biochar in increasing the SOC contents of soils were higher in soils with higher clay contents than those with lower clay contents [72]. Recently, the potential of biochar in the restoration of degraded lands (e.g., saline soils and mine tailings) has been confirmed [73].

6.6 Assessment of Soil C Sequestration:

Assessment on soil C stock requires data on soil bulk density (Mg m^{-3}), concentration of soil SIC or SOC expressed as % (w/w) basis and soil depth (in m). The C sequestration is usually calculated in terms of increase in C stock in soil.

$$\text{SOC (Mg ha}^{-1}) = \text{SOC (\%)} \times \text{Bulk density (Mg m}^{-3}) \times \text{Depth (cm)} \tag{3}$$

Total soil C is determined by high temperature combustion in CN analyser [74] while SOC is determined by [75], and SIC is the difference between total and organic C.

6.7 Soil C Stabilization:

For soils to sequester and act as a C sink, soil C needs to be stored in stable C pools. Soil C stabilization is critical for the determination of the soil C sink capacity under different climatic and management regimes. Soil C stabilization that retards the decomposition of SOM by reducing the C mineralization rate through three main mechanisms: (a) physical, (b) chemical, and (c) biological (biochemical) [76].

~~*A.*~~ ***Physical Protection:*** In physical stabilization, stabilization of soil C is due to physical protection of the soil C within the macro (>250 µm) and micro-aggregates (<250 µm) through their intimate association with clay and amorphous minerals in soil. This type of protection limits the accessibility of soil microbes and their enzyme from mineralizing it. It also obstructs movement of oxygen, water and other substrates necessary for microbes.

B. ***Chemical Stabilization:*** Chemical stabilization refers to C associated with the formation of primary organomineral complexes that are chemically inert from mineralization or inherently recalcitrant such as that of lignin. This is the dominant mechanism controlling the soil C stabilization and is central to soil C sequestration [77]. Chemical stabilization in soil is greatly influenced by amorphous and poorly crystalline Fe/Al mineral components in soil, and is the main mechanism leading to soil aggregate formation [78].

C. ***Biological Stabilization:*** Biological stabilization of SOC refers to the complex inherence chemical structure of the biomolecule, which is a function of intra- and inter-structural bond strength, their degree of regularity in occurrence and aromaticity [42].

6.8 Soil C Saturation:

Soil C Saturation is a concept that suggests that soils C capacity is not unlimited and this is determined by the reactive mineral surface area available for retaining SOC. Beyond the maximum limit, the soil will not further sequester any C [79]. Many SOC models assume that their soil C sequestration increase linearly with increase in C added to the soil irrespective the antecedent SOC content [42]. Practically, this was observed to be true in many cultivated soils that have low and moderate SOC status. In contrast, soil inherently high in SOC status did not show any rise in the SOC content following continued exogenous C input that suggest that the SOC have eventually reach equilibrium known as soil C saturation level. This phenomenon is also visible from some long-term studies that shows signs of C saturation as evident from the non-responsive nature of SOC status to continuous input of C sources. This suggests that with increasing C supply, the SOC stock will reach the upper limit beyond which the SOC accumulation rate will start decreasing. Beyond this level, additional C input will only accumulate in labile soil C pools that have a relatively faster turnover and will not add to the stable C pools in soil. The difference in SOC levels between the SOC saturation level and present SOC level is known as SOC saturation deficit [79]. The larger the deficit, the higher will be the proportion of SOC stabilized in soil.

6.9 Conclusion:

Soil plays a crucial role as a net C sink, actively sequestering and storing C from the atmosphere after its stabilization into inert and recalcitrant forms. Through the accumulation of SOC and SIC, soils have the potential to mitigate climate change by reducing atmospheric CO_2 levels. The quantity of C sequestered in soil is affected by climate, soil site characteristics and management factors. Among the various agricultural practices, practices that improve soil C sink capacity includes conservation agriculture, retention of crop residues, organic farming, crop rotation, mulching, restoration of degraded land, agroforestry, etc. The ability of the soil to sequester C is not unlimited. It is mainly affected by initial soil C status and proportion of C stabilized will be greater when the deficit is higher.