Egyptian Journal of Soil Science

Soil Carbon and Nitrogen Stocks and Fractions for Improving Soil Quality and Mitigating Climate Change: Review

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GLOBALLY, there is an increased global awareness of some environmental issues such as climate change. In this regard, new accessible and reliable data, locally and globally, regarding soil carbon (C) and nitrogen (N) stocks and their physical and chemical fractions, are needed. These data assist in making suitable decisions towards the mitigation of climate change impacts. Soil acts an important role in the global cycles (i.e. carbon (C) and nitrogen (N)) and both are linked and related not only to climate change mitigation but also sustaining agricultural productivity and improving soil quality. Soil C and N sequestration. Moreover, using good and novel long-term management practices are the most important methods for increasing their stocks and mitigating greenhouse gases (GHGs) emission, from soil to the atmosphere as well for improving soil quality and increase economic crop production. Therefore, the aim of this review is to summarize some basic information about soil C and N stocks and their fractions, especially they are related to climate change mitigation and soil quality.

Keywords: Soil carbon stock, Soil nitrogen stock, Soil carbon fractionation, Climate change mitigation, Soil quality.

Introduction

A globally rising trend of changes in the atmospheric temperature and weather conditions is indicated as climate change, considered as a major environmental and socio-economical problem., In the lack of possible mitigation and adaptation processes, climate change can affect negatively the environment, water resources, and ecosystem services worldwide. As well, climate changes have a considerable effect on soil carbon (C), because of the changes in the patterns of temperature and rainfall, as well, atmospheric carbon dioxide (CO_2) concentrations affect soil C inputs and decomposition. It is widely known that the climate change affects global soil organic carbon (SOC) stocks (Soleimani et al., 2017). As well, it is reported that a slight change in soil C stocks will significantly impact the atmospheric CO_2 concentration and thus, globally, affect climate change. The SOC stocks and distributions

(*i.e.* horizontal and vertical) play a considerable part in C-based on GHGs abundance (Li et al., 2019). The cycling of carbon and nitrogen (N) is closely-linked and both cannot be efficiently studied separately. This requires better understanding of the correlated and dynamic stocks as well their processes in the terrestrial ecosystems (Nieder and Benbi, 2008). Agricultural production contributes globally to about 10-14% of total GHG emissions through the management of soils and livestock. Enhanced agricultural soil management practices can greatly reduce such emissions of atmospheric CO_2 sequestration and accumulation of roots and plant residues in the soil as soil organic matter (SOM) (Lozano-García et al., 2017). In addition to its important roles to mitigate climate change, soil C has a critical role to maintain soil health and soil productivity in agro-ecosystems. Thus, an accurate assessment of soil C stocks and distributions is essential in mitigating C emissions and enhancing soil health

(Li et al., 2019). As well, evaluating the relative proportions of the different soil C stocks holds great promise in improving our understanding of soil response to changing in management or climate. In this context, labile fractions of SOM including particulate organic matter (POM) and microbial biomass C (MBC), represent the active fractions of SOC that serve as primary indicators of SOC changes (Li et al., 2017) and evaluating soil quality (Yang et al., 2012).

According to Ravindranath and Ostwald (2008) there are two anthropogenic activities that contribute GHGs to atmosphere; fossil fuels burning and land use changes. As suggested, this will lead to global warming that possibly lead to some negative impacts which may be irreversible on the ecosystems such as loss of wetlands and biodiversity (Ravindranath and Ostwald; 2008, Soleimani et al., 2017). Therefore, reducing atmospheric of CO_2 levels became very important target of international negotiations (Eve et al., 2002).

The objectives of this review are to: 1) summarize some of the basic knowledge about soil C and N stocks to provide an insight about baseline inventory information especially with increasing awareness of climate change and its mitigation, 2) highlight some of the basic information about soil C and N fractions for better understanding of soil C and N management to improve soil quality and reduce atmospheric GHGs.

Soil carbon and nitrogen stocks

As the climate changes, new accessible and reliable information (about land and water resources) will be needed to assist mangers of these resources in decision making (Waltman, et al., 2010). From the viewpoint of C and N budgeting, soil represents a significant stock of C and N (Jian—Fenx et al., 2006). It worthy noticing that the importance of exchanging C and N between soil and atmosphere represented not only in global warming, but also on soil quality and its potential to perform ecosystem functions (Nieder and Benbi, 2008). Therefore; better agricultural practices can reduce net GHGs emission depending on some factors such as soil types, climatic factors and farming systems. Approximately, 90% of the total mitigations rates arise from enhancement sink (*i.e.* soil C sequestration) and around 10% from emissions reduction (IPCC, 2007).

Thus, the term "carbon (or nitrogen) inventory" has spread via the United Nations Framework Convention on Climate Change (UNFCCC), where C stock changes and emissions or removals of CO_2 are estimated and monitored in the different sectors of land use as part of the national GHGs emission inventory processes. As well, this inventory is required to estimate carbon mitigation potential of land use sectors nationally and globally (Ravindranath and Ostwald; 2008). The detailed SOC dynamics in several regions rely on agricultural management practices, and differ with soil and climate conditions. Practices of conservation agriculture such as no-tillage, stubble retention, organic amendments, avoiding of long fallow periods, and increased complexity of crop rotation (such as planting of cover crops and legumes) have been recommended for reducing SOC declines or enhancing carbon sequestration (Luo et al., 2010 and West & Post, 2002). More recently however, the international initiative "4 per 1000" points a yearly 4‰ enhancing of SOC in global agricultural soils for ensuring food security and mitigating climate change (Minasny et al., 2017). Nevertheless, the challenge has been faced this ambitious target by the soil C research community due to uncertainties surrounding C predictions through spatiotemporal scales and resources requirement like financial provision for farmers for change their agricultural practices to sequester C (Luo et al., 2019).

The soils worldwide act a crucial role in global C and N cycles (Qiu et al., 2010). This role is given, not only because of the soil C reservoir size (1576 peta gram) ($Pg = 10^{15}$), but also because of the dynamic nature of some SOC fractions (Jacinthe et al., 2001). Additionally, for example, optimizing the inputs of N fertilizer, may increase SOC concentration via increasing crop yields and hence returning the amount of residues to soils. Excessive N fertilizer may block the sequestration of SOC through suppression of the microbial populations or stimulation of mineralization of old native organic C (Qiu al., 2010). Levi (2007) mentioned that C and N are essential elements for soil formation and development. In particular, the biological soil forming factor is heavily dependent on C and N cycling and availability.

The available data signify that, managed soils have historically been a net source of atmospheric CO_2 contributing to more than 20% of the annual increase of CO_2; 3.2 pg C in the atmosphere, however soils can act a net sink of C through enhancing the long-term C storage (sequestration) in the soils and thus reduction

in CO_2 accumulation rate in the atmosphere (Jacinthe et al., 2001). Therefore; estimating sources and sinks of GHG emissions is required from individual countries to reduce emissions. The accurate inventory, the better understand of the importance of diverse sinks and sources and their spatial variability (Lokupitiya & Paustian, 2006 and Batlle-Bayer et al., 2010).

Estimating of global carbon and nitrogen stocks has been concerned by many scientists. The historical background showing that, as it was attracted by Jean-Baptiste Van Helmont as early as 1652. Since this time, many researchers had concerned to understand the physical and chemical laws that regulate those cycles on the earth. The impact of anthropogenic activates, has renewed the interest of C and N inventory in the last few decades (Corti et al., 2002). Consequently, soil carbon stock (SCS); hence soil nitrogen stock (SNS) means that a soil acts as a reservoir of C or N; or the capacity of soil to accumulate or release carbon. The stock unit is mass (*e.g.* tC) (*i.e.* ton carbon) (IPCC, 2000). In other meaning this term; SCP or SNP; refers to the total amount of C or N captured by a standard layer of soil having a certain area (Stolbovol, 2002).

Soil C stock
Soil is one of the largest C stocks in the global C cycle. It is the third largest active C pool (1550 Pg of organic C (OC) and 750 Pg inorganic C (IC) to a 1-m depth) next to the hydrosphere and the lithosphere (38 000 Pg and 5000 Pg respectively), and is strongly affected by agricultural management strategies. Soil stores organic carbon more than vegetation and atmosphere together (i.e. soil stores 1500 - 1600 Pg C approximately to depth 1 m, vegetation stores 650 Pg C and atmosphere stores 750 Pg C) (Bernoux, et al., 1998, Entry et al., 2002, Lal, 2003, Eshel et al., 2007, Mondini and Sequi, 2008, Lorenz, et al., 2011, Hou et al., 2012, Steenwerth et al., 2010, Elbasiouny et al., 2014, Li et al., 2019, Wang et al., 2019,Yoshida, et al., 2019). Lal (2004) mentioned that the global SCS of 2500 Gt consists of approximately 1550 Gt of soil organic carbon (SOC) and 950 Gt of soil inorganic carbon (SIC). Agricultural soil contains approximately 170 Pg of C in the upper 1 m. Agricultural soils can also contribute as a sink or source of C. No-till, organic amendments and other management practices; such as, conservation reserves, improved crop rotation and fertilization practices; can improve C sequestration in agricultural soils. Thus; globally

potential C sequestration in agricultural soils through these practices has been approximated by 600 to 900 Tg yr^{-1} (Lokupitiya and Paustian; 2006). Rolando et al. (2017) reported that SOC stock estimate of 2344 Gt C, stored in the top 3-m soil depth. Thus, sequestration of SOC is a key strategy for climate change mitigation, and it is favored in natural ecosystems with high plant primary productivity (NPP) and low SOC decomposition.

The SCS includes soil organic carbon stock (SOCS) and soil inorganic carbon pool (SICP) as follows:

Soil organic carbon stock (SOCS)
The SOC originates from living organisms inside and above the soil that convert atmospheric CO_2 into a broad variety of organic compounds. It assists in regulating soil physio-chemical properties, enhancing its structure, and improving its stability (Puget et al., 2005 and Wang et al., 2019). Thus, the knowledge about the dynamic of SOC dynamics in agricultural systems is very important (Duval et al., 2018). Moreover, maintenance of SOC is important not only for sustainable soil resources use, but also for interesting of promoting its sequestration in soils for mitigating the impacts of global climate change due to increasing atmospheric CO_2 levels (Su et al., 2009).

The term soil organic carbon stock (SOCS) describes the multiple components of SOC. The meaning of this term can vary from a researcher to other. For some researchers it means physical fraction of SOM in plant residues at various stages of decomposition, or particulate organic matter. For the others, it means chemical fraction which includes chemical structures or functional groups of SOC. The SOCS essentially depends on the balance between SOC inputs (such as plant residues) and outputs (such as decomposition and losses resulting from leaching and erosion). The SOCS varies with land use systems. The highest SOC concentration occurs in topsoil. Disturbance of topsoil leads to loss of SOC by oxidation (Jobbagy and Jackson, 2000; Wong et al., 2006; Ravindranath and Ostwald, 2008; and Wani et al., 2010).

Soil inorganic carbon stock (SICS)
Inorganic SC occurs essentially as carbonate minerals, such as calcium carbonate ($CaCO_3$) and dolomite ($MgCO_3$). It comprises of two components; lithogenic and pedogenic inorganic carbon. The first is originated from parent material,

while the latter comes from the precipitation of CO_3 ions resultant from root and microbial respiration as well calcium and magnesium ions produced by weathering reactions (Mi et al., 2008). This stock is also large; however, the national or global findings on SIC storage have been more tentative and have only focused on local or regional assessments of SOCS (Guo et al., 2006a). The SICS consists of elemental C and carbonate minerals (either primary carbonate which formed as a result of weathering; or secondary carbonate which formed as a result of CO_2 dissolution in soil water). Most of the SIC exists as carbonates and is believed to appear in arid and semiarid region (Guo, et al., 2006b). Although the role of SIC in the C sequestration process is less important than SOC, its estimation is very important for determining the role of soil as a sink of CO_2 (Diaz-Hernandez, 2010). However; both soil C stocks, is not only important to soil productivity and soil functions, but also to C sequestration and global C cycle (Qadir et al., 2006).

Soil nitrogen Stock (SNS)

The dynamics of C and N are largely linked via the chemical composition and stoichiometry of biomolecules (Gillis and Price, 2016). The unique relationship between the total N and the total OC implies that both reveal similar general trends of accumulation, degradation and subsurface transport, and hence, always follows similar patterns (Wong et al., 2008 and Sharma et al., 2017). N is often the most limiting factor for plant growth and carbon sequestration. Increased N inputs through deposition can effect on ecosystems in several ways: 1) deposition on N can increase photosynthetic efficiency, foliar biomass, and thus the ecosystem biomass, and 2) deposition of N can decrease the distribution of fine roots, decline respiration rates, speed up saturation of N in soil places of high N, and this causes N and other nutrients leaching loss to aquatic systems. The net primary production (NPP) was suggested to increase firstly with increasing N deposition, however it declines with N saturation. The NPP does not account for respiration and OM decomposition, however, it is considered the main process to absorb atmospheric C and thus increase C sequestration with increasing NPP due to enhancing N deposition rates that could be expected (Wei et al., 2012).

In addition, better understanding of soil N cycle is necessity for managing N availability to crops. Management practices lead to slow changes in soil total N because of N stock size and inherent variability. Thus, soil total N is not a mirror for the changes in nutrient status and soil productivity. Therefore, other parameters such as particulate organic N (PON) is required for this purpose (Sainju et al., 2012). As N is frequently a limiting factor for growth of vegetation in soils, and it is essential for increasing SOC concentrations, inputs of N should be considered in any future restoration efforts (Jelinski and Kucharik, 2009). Additionally, Qiu al. (2010) stated that optimizing the inputs of N fertilizer, for instance, may increase the content of SOC by enhancing crop yields and then the residue amount returned to soils. Levi (2007) mentioned that C and N are important elements for soil formation and development. In particular, the biological soil forming factor is heavily dependent on C and N cycling and availability.

The global nitrogen stock in SOM is estimated by 1.33×10^5 Tg N = compared to its corresponding in the atmosphere and terrestrial biomass of 3.9×10^{12} Tg N and 3.5×10^3 Tg N respectively. About 90% of soil N stock is principally stored in organic N forms and 10 % is stored as inorganic N (NH^+_4 and NO^{-3}) (Johnson & Uriu, 1989 , Nieder & Benbi, 2008 and Elbasiouny et al., 2014).

Soil C fractions

Soil organic matter consists of several fractions with varying from contrasting resistance to decomposition that are differently affected by revegetation processes and land abandonment. Soil aggregations provide physical protection of SOC versus rapid decomposition, and aggregates formation and stability is very closely related to SOC storage (Nadal-Romero et al., 2016). Thus, SOM consists of spectrum materials which range in mean residence time (from less than a few weeks for labile stocks (plant residues and root exudates)), to greater than several thousand years for recalcitrant stocks (the resistant humic substances) (Cheng et al., 2007). Thus, there are at least three distinct stocks of SOM depending on their turning over on different time scales; (1) an active (labile stock):one to five years, (2) a slow or intermediate stock: decades, and (3) a passive stock: centuries to millennia (Marín-Spiotta et al., 2008). Each stock plays a different role in the dynamics of SOC and the sequestration of SC. If a plant–soil system boosts SOM to translocating into labile stocks under elevated CO_2, this will quickly promote microbial decomposition and consequently decrease SC storage. On the contrary, if elevated CO_2 encourage more SOM to

entering in recalcitrant stocks, this will increase SOC stability and storage, and impacts greatly on C sequestration. Thus, information of SOC distribution and fractionation is essential for better understanding the SOC dynamics under specific environmental conditions like elevated CO_2 (Cheng et al., 2007). So; the main objective of SOC analysis into different sizes is to identify labile fractions that respond more readily to land use changes, provide indication of different levels of SOC protection and serve as better indicators than SOC as a whole (Oca, 2009).

The SOM has been described as the highest complex component of soils because it is a heterogeneous mixture of organic material with various chemical composition with different turnover rates. Therefore, total SOC is not always the best indicator of soil management changes, particularly in semiarid regions because high temperature and low precipitation are limiting factors for SOC storage. To elucidate the complex composition of SOM and understand its dynamics and stabilization mechanisms, the researchers have made great efforts for developing methods to separate SOM into fractions with different composition and stability. This allows distinguish labile and recalcitrant SOC stocks and determine those that can serve as initial indicators soil quality changes. This is applied on the particulate organic matter (POM) as it has been stated to be a sensitive labile fraction to soil management changes (Blanco-Moure et al., 2016). Therefore, traditional measurements of SOC as total OC using dry combustion or chemical oxidation is insufficient to describe SOC changes with regarding of soil physical, chemical and biological activities (Madhavan et al., 2017).

It is reported that different labile SOM fractions, such as hot-water extractable carbon (HWC), particulate organic carbon (POC), permanganate oxidizable carbon (POX-C) and hydrolyzable carbon with acid extractions (HAC) are used as early indicators of changes in soil quality as a result of management practices. These fractions are distinguished by presence the organic material in transitional case between fresh plant residues and stabilized OM in, different turnover time of<10 years (Duval et al., 2018). Thus, total organic C partitioning into fractions that are linked to active, intermediate or slow and passive or inert conceptual stocks used to explain their role in soil processes (Madhavan et al., 2017).

Changes in POM stocks are usually linked to land use types, agricultural and management practices; all affect the balance between OM inputs (from above and blow-ground plant biomass) and losses through microbial activity and decomposition (Salek-Gilani et al., 2013).

The POM is described as "fine root fragments and sand-sized organic debris" (Xiao et al., 2017), which is commonly high in plant-derived lignins, waxes, and fungal amino compounds. It is a rapid changing stock of SOM because its easy decomposition by soil microorganisms and accordingly responds rapidly to changes in the environment such as changes in land use and climate. The chemistry of POM may affect microbial community structure since microorganisms desire some substrates than others. For instance, POM with a higher lignin content and a higher C:N ratio tends to support considerable numbers of microorganisms in nutrient-poor environments such as fungi and actinobacteria. On the other hand, higher quality fresh organic C tends to support large numbers of gram-negative bacteria (Xiao et al., 2017). In the other meaning, POM can be defined as a labile intermediate part in the SOM continuum from fresh organic materials to humified soil organic carbon (SOC), composed primarily of partially decomposed plant material, root fragments, fungal hyphae, spores, and pollen grains, with a particle size ranging between 50 and 2000 μm and is more sensitive to changes in management practices, including fertilization, rotation and tillage management than total SOC (Cambardella and Elliott, 1993, Bouajila and Gallali, 2010; Mandiola, et al., 2011, Xie et al., 2014).

Madhavan et al. (2017) and Duval et al. (2018) stated also that SOC fractions may be a labile, humified and inert C in different turnover times (i.e. annual (<3 year), decadal (20-50 year) or millennial (>1000 year). Different functional fractions are known and accessible by several fractionation techniques. For example, physical fractions are particle sizes, aggregates, or density fractions, while chemical fractions are extractants dissolved organic matter, soil microbial biomass, soluble organic matter in alkali and acid, as well, mixture of fractionation methods are set up. Chemical fractionation of SOC relies mainly on the solubility of OC in oxidizer, acid or base, producing soluble OC. Thus, soil C fractionation allows improved understanding of main processes, such as nutrient cycling and availability, soil aggregation and C sequestration (Zou et al., 2005, Madhavan et al., 2017, Duval et al., 2018). Stockmann et al. (2013) cited from Von Lützow et al. (2007) summarized chemical and physical fraction methods of soil C in Table 1.

TABLE 1. Physical and chemical methods of soil C fractionation

Physical fractionation				
Aggregate size fractionation	Particle size fractionation	Density fractionation		
Macroaggregates (>250 µm) wet sieving / slaking/ dispersion (ultrasonic)	Clay-sized, silt sized and sand sized particles	Heavy fraction	Light fraction	POM (particulate organic matter)
DOC (dissolved organic matter)/less than 0.45 µm in solution	Separated using liquids with certain density (between 1.6 and 2.0 g cm^{-1})			
Chemical fractionation				
Chemical extractions	**Hydrolysis**	**Oxidation**		
Used to separate "humic substances" into humic acids, fulvic acids and humin / based on solubility in alkali and acid solutions. The most common are NaOH and $Na_4P_2O_7$. Microbial biomass C/ i.e. chloroform used as fumigant	Used to separate hydrolytic bonding of carbohydrates/ protein molecules, etc./ for instance HF to separate mineral- OM associations/ or HCl to quantify proportion of SOC association with proteins, amino acids, amino sugars	Used to remove labile/active fraction of SOM (i.e. plant residues) (most common agents are H_2O_2, NaOCl and $KMnO_4$		

Source: Stockmann et al. (2013) cited from Von Lützow et al. (2007).

Some factors should be considered when choosing a measurement method such as laboratory equipment, easiness of use, cost, analytical accuracy, environmental and safety concerns, in addition to, to its comparability to standard reference methods. For example, separating and quantifying POC is expensive because of the required labor and the need to combustion analyzer for quantifying the total C in the extracted fraction (Duval et al., 2018).

From the prospective of crop production, the labile stock is important for fueling the soil food web and influencing nutrient cycling for maintaining soil quality and productivity (Prasad et al., 2016). C and N in labile organic matter fractions are readily metabolized by soil microorganisms (Thomas et al., 2016), release nutrients for plant uptake, and are sensitive to management (Puget, et al., 2005).

The POM is mainly used as an indicator of the effect of anthropogenic practices on SOM dynamics (Oca, 2009; Qiu et al., 2010). Coarse fractions of SOM such as particulate organic matter have a faster turnover time than SOM which is associated with either silt or clay and encapsulated within microaggregates (Puget, et al., 2005). Therefore, realizing the distribution and fractionation of SOC and soil organic nitrogen (SON) is necessary for understanding the SOC dynamics and soil C sequestration for mitigating climate change; in addition to understanding soil nitrogen supply and dynamic because of bounding of SOC and SON (Puget, et al., 2005, Cheng et al., 2007 and Thomas et al., 2016).

Many physical, chemical and biological approaches have been used for separating and characterizing soil carbon stocks, such as particle size and density fractionation, humic fractionation, molecular fractionation, and conceptual fractionation with models (Cheng et al., 2007). Olk and Gregorich (2006) motioned that physical fractionation methods separate soil constituents based on size and/or density. Marín-Spiotta et al. (2008) reported that physical fractionation separates SOM without chemical modification by particle-size, aggregate-size, or density. Lorenz et al, (2011) reported that the physical soil fractionation, by separation into clay, silt and sand-sized separates, is a useful approach to study SOC turnover. The physical fractionation separate SOM into: 1) primary particles and, 2) secondary particles or organo-mineral complexes (*e.g.,* soil primary particles and soil aggregates). This fractionation is required to understand the dynamic and functional attributes of SOM. Coarse fractions such as particulate organic matter (POM) and SOM associated with macro-aggregates have a faster turnover time than SOM which is associated with either silt or clay which is encapsulated within microaggregates. The former fractions are labile, release nutrients for plant uptake, and are sensitive to management (Puget, et al., 2005). Hence; particulate organic matter can be defined as: The fraction of SOC that greatly and sensitively affected by land use change and management practices, (Oca, 2009 and Qiu et al., 2010). The POM fraction is composed mainly of incompletely decomposed root fragments (Cambardella and Elliott, 1993).

Thus; POM is a labile SOC and consists basically of visible materials plant-like structure and is not associated with mineral components of a soil; thus it is represent an intermediate part in the SOM continuum from fresh organic materials to humified SOC, and is more sensitive to management practices changes than total SOC (Chung et al., 2008 and Bouajila & Gallali, 2010).

The POM plays a major role in formation and stabilization of aggregates (Puget et al., 2005). Qiu et al. (2010) reported that POM is considered as a nucleus for aggregate formation. It is a big fraction of the fresh plant residues or those at different decomposition stages. Consequently; POM can strength soil aggregation through different binding agents such as fine roots, bacterial cells, fungal hyphae, , and polysaccharides. Untimely, as Sainju (2006) mentioned that particulate organic C and N (POC and PON) are intermediate stocks for changes of soil C and N with time that offer substrates for microbes and influence aggregation.

Soil C, N and soil quality

Soil quality is always defined in terms of growth of plants or biomass production, this is only one of many important soil functions (i.e. regulating water quantity and quality, C sequestration, remediation of human and animal wastes, regulating energy flow…) among other factors. Although, researchers have focused on evolving techniques to evaluate soil quality, there is no consensus regarding the exact characteristics of the highest quality soils (Lozano-García et al., 2016 and Elbasiouny et al., 2017b).

Total soil organic C is an essential indicator for soil quality assessment. This is because high level of total organic C is related to improving soil physical properties (such as soil structure), biological properties (especially microbial activity) and improving of nutrient supply to crops. As well, it raises the soil's buffering capacity and thus reduces pollution risks. Thus, increasing total soil C has the potential to greatly increase crop production and decrease its variability (Yang et al., 2012, Peng et al., 2014, Srinivasarao et al., 2014 and Huang et al., 2016). Liu et al. (2017) reported that since SOC is critical for food security because it offers substrate and energy, , it also protects the biodiversity that assist in preserving soil quality and the ecosystem functions. Therefore, the maintenance and sequestration of SOC turns out to be great challenges to humanity to highlight the crisis of food insecurity and global change. As well, Geraei et al. (2016) stated that the SOC is essential to improve soil quality, sustain

and enhance food production, and maintain clean water. Changes in total SOM content due to the changes in soil management practices, are difficult to notice as a result of high background levels and natural variability of soil. Furthermore, SOM is a heterogeneous mixture of materials that range from active or labile fractions, such as microbial biomass (MB), POM, and soluble organic matter (SOM) decompose in a about months and non-labile fractions (the more resistant) remain in the soil with millennia turnover rates.. Furthermore, Sainju et al. (2008) stated also that it is required to find novel management practices of soil and crop to sequester C not only to enhance soil C storage for C trading and mitigating GHGs emission, such as CO_2, from the soil profile, but also for improving soil quality and increasing economic crop production. Similarly, N sequestration is needed to reduce the rate and cost of N fertilization, N leaching, and N_2O emission, another destructive GH gases causing global warming.

Furthermore, as the SOC is a key indicator of both of soil quality and productivity, restoring the quality of degraded soils requires increasing the sequestration of soil C through increasing SOC density, improving depth distribution of SOC as well stabilization and protecting SOC in stable micro-aggregates. Thus, adopting recommended management practices in agro-ecosystems, in addition to such practices that can create a positive soil C budget which is a crucial strategy for SOC sequestration in the terrestrial ecosystems (Srinivasarao et al. 2014). As reported by Puget et al. (2005), understanding the effects of agricultural management practices on SC stocks and dynamics under particular soil-climatic conditions is guaranteed by the necessity of atmospheric C sequestration in agricultural soils for mitigating the impacts of climate change. Adoption of sustainable agricultural practices, such as conservation tillage, residue retention, and using animal or green manure, can increase SOC concentration and thus enhance soil quality. In addition, reduced tillage practices such as no-till and chisel till may increase the concentration and the amount of SOC in topsoil. However, this may not occur in fine-textured soils, under cold and poorly drained conditions, or where the antecedent SOC concentration is high (Puget et al. 2005).

Soil C sequestration and mitigating climate change

Carbon and nitrogen losses are increased as a result of decreased plant inputs and increased decomposition and erosion associated with

agriculture (Knops and Tilman, 2000). The most important factor that determines SOC level is the dynamic balance between C inputs; through photosynthesis and deposition, and C losses; through respiration, erosion and leaching (Jacinthe et al., 2001 and Su et al., 2009). Net carbon emissions indicate loss of CO_2 from soil and biomass to the atmosphere via decomposition or combustion. While, the net C removals or sequestration indicate the net CO_2 uptake and storage in soil and biomass (Ravindranath and Ostwald, 2008). Available data indicate that, managed soils have historically been a net source of atmospheric CO_2 contributing to more than 20% of the annual increase of CO_2; 3.2 Pg C in the atmosphere, however soils can be a net sink for C through enhancement of long-term C storage or sequestration in the soils and thus reduction in CO_2 accumulation rate in the atmosphere (Jacinthe et al., 2001). Hou et al. (2012) motioned that cropland soil has a huge potential as a C sink (0.4 – 0.8 Pg yr^{-1}), which could decrease CO_2 concentrations in the air and mitigate global emissions. As SOC is crucial to soil physical, chemical, and biological properties, more SOC sequestration in soil could help in sustaining soil fertility and agronomic productivity. The CO_2 in agriculture is released through (1) crop residues and SOC decomposition, which is increased by intensive tillage practices, (2) production and application of crop inputs, (3) direct using of fossil fuels in farm machinery, and (4) burning or other oxidation of biomass. The photosynthesis is only process of CO_2 uptake and the only stock that can sequester C is the soil (West and Marland, 2002). Sainju et al. (2008) explained that the relationship between C and N sequestration by that SOM, as indicated by soil C and N levels, can significantly impact crop production. The increase in crop production with increased SOM storage is a result of enhancing soil structure and improving soil water–nutrient–crop productivity interactions. Sequestration of C in the soil can also conserve N, since SOC and total N (TN) levels are highly correlated.

Therefore; estimating sources and sinks of GHGs emissions is required from individual countries to reduce emissions. The accurate inventory, the better understand of the importance of several sinks and sources and their spatial distribution (Lokupitiya and Paustian, 2006).

There are two potential ways to balance global C cycle: 1) cutting the emission rate of

CO_2 and/or 2) developing natural C sink (such as increasing forest areas) that can to absorb the increasing CO_2 concentrations (Ahirwal et al., 2017). SOC sequestration, as a key strategy for mitigating climate change, is ideal in natural ecosystems with high plant primary productivity and low decomposition of SOC (Rolando et al. 2017). Soil C sequestration represents about 90% of total mitigation practices. The most prominent mitigation options in agriculture are improved cropland management, restoring of degraded land, restoring of cultivated organic soils, and improved grazing land management. Although rice and livestock managements are less important, it is still substantial mitigation potential (IPCC, 2007). Therefore; an inventory of C pool is necessary for C mitigation projects such as afforestation, reforestation, agroforestry and land reclamation projects (Ravindranath and Ostwald, 2008).

Carbon sequestration is defined as the storage of carbon in long-term terrestrial or aquatic C stocks, resulting in reducing the atmospheric CO2 concentration (West and Marland, 2002). The term; soil C sequestration implies "removal of atmospheric CO_2 by plants through photosynthesis and transfer of the biomass C into soil as humus" (Srinivasarao et al., 2014).

In this prospective, adopting what called "recommended management practices (RMPs)" in carefully managed croplands, and any strategy that create a positive soil C budget, is an important for sequestering SOC. Thus, in this regard, land use change can be an important tool (Wu et al., 2008 and Srinivasarao et al., 2014). The SOC sink capacity for adsorbing atmospheric CO_2 can be significantly enhanced if degraded soils and ecosystems are restored (Srinivasarao et al., 2014 and Elbasiouny et al., 2017b). Furthermore, the soil potential to sequester C depends regional variation because of climate, plant species composition, inherent of soil properties, and age of ecosystem (Li et al., 2017).

Fan et al. (2014) emphasized on the great concern of the dynamics of SOC stocks as well the long-term role that the soil may act to accumulate and sequester atmospheric CO_2 due to their impacts on mitigating of the climate change, sustaining crop productivity, and enhancing soil fertility. They also reported that a high level of SOC in cropland can be achieved by appropriate crop rotations, proper application rates of organic manures in addition to inorganic fertilizers, conservation tillage, and integrated soil fertility

management. This will lead to preserving good soil health not only for sustainable crop production, but also managing global climate change (Lal, 2004, Sainju et al., 2008, Yang et al., 2012, Fan et al., 2014 and Elbasiouny et al., 2017b). Thus, mitigation of atmospheric CO_2 by increased soil C sequestration, mostly makes sense in the scope of other global challenges such as combating land degradation, improving soil quality and productivity, and preserving biodiversity (Batjes and Dijkshoorn, 1999). Similarly, soil N sequestration is vital to minimize the rate and cost of N fertilization, N leaching, as well, N_2O emission as a another destructive GHG causing global warming (West and Marland, 2002).

Conclusion

Soil acts an important role in both global C and N cycle. Soil store C more than vegetation and atmosphere. Soil C stock is comprised from two major parts that have very important role in the global C cycle; organic and inorganic. Both soil C and N are linked and related to soil organic matter which imply similar trends for their behavior in the soil. Inventory of soil C and N helps in better understanding of their managing especially in regards of climate change and soil quality. As well soil labile fractions play an important role soil C and N dynamics and sequestration. Adopting good management practices implies not only absorbing atmospheric CO_2 by soil plants and mitigating climate change, but also sustaining agroecosystem productivity and improving soil quality.

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مخزون ومفصولات كربون ونيتروجين التربة لتحسين جودة التربة والتخفيف من التغيرات المناخية

هبه البسيونى و فتحى البحيرى
قسم العلوم البيئية و البيولوجية ـ كلية الاقتصاد المنزلى ـ جامعة الازهر ـ القاهرة ـ مصر
المعمل المركزى للدراسات البيئية ـ جامعة كفرالشيخ ـ كفرالشيخ ـ مصر

هناك وعي عالم متزايد تجاه بعض القضايا البيئية الهامة، مثل التغيرات المناخية. وفي هذا الصدد، يأتي الدور الهام للمعلومات الجديدة والموثوقة، سواء محليا أو عالميا، فيما يتعلق بمخزون الكربون والنيتروجين في التربة وكذلك مفصولاتهم المختلفة فيزيائيا أو كيميائيا. وتساعد هذه المعلومات في اتخاذ القرارات المناسبة تجاه التخفيف من آثار التغيرات المناخية، حيث تلعب التربة دورا هاما في دورة الكربون والنيتروجين العالمية نظرا للارتباط الوثيق بينهما واتصالهما ليس فقط بالتغيرات المناخية العالمية ولكن أيضا باستدامة الإنتاجية الزراعية وتحسين جودة التربة. ويعتبر حجز الكربون والنيتروجين في التربة باستخدام الممارسات الزراعية الجيدة والحديثة واحدا من أهم طرق خفض انبعاثات غازات الصوبة في الغلاف الجوي وبالتالي التخفيف من تلك التغيرات وتعزيز جودة التربة والإنتاجية كذلك. ولذلك كان الهدف من هذا البحث المرجعي هو تلخيص بعض المعلومات الهامة فيما يتعلق بكربون ونيتروجين التربة نظرا لأهمية ذلك في هذه القضية الراهنة.