International Journal of Plant & Soil Science

32(6): 31-48, 2020; Article no.IJPSS.56919
ISSN: 2320-7035

Agricultural Land Use and Management Practice Influence on Efflux and Influx of Carbon between Soil and the Atmosphere: A Review

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/IJPSS/2020/v32i630290
Editor(s):
(1) Dr. Francisco Cruz-Sosa, Metropolitan Autonomous University, México.
Reviewers:
(1) Deepa Dhital, Nepal Academy of Science and Technology, Nepal.
(2) Norhayati Hashim, Universiti Pendidikan Sultan Idris, Malaysia.
Complete Peer review History: http://www.sdiarticle4.com/review-history/56919

Review Article

Received 24 March 2020
Accepted 30 May 2020
Published 10 June 2020

ABSTRACT

The objective of this paper is to formulate suitable policies and management practices that can firmly reduce CO_2–C (carbon dioxide –carbon) emissions and sequester it in a sustainable way. Land use and management practices can influence both efflux and influx of carbon between soil and the atmosphere. Organic matter dynamics and nutrient cycling in the soil are closely related to nutrient immobilization and mineralization. Unplanned conversion of lands to agricultural production causes a sharp decrease in carbon stored in soil. In the atmosphere, 4.0 Gt C yr^{-1} is enriched by different sources. Increasing soil organic carbon (SOC) improves soil health and mitigate climate change. Histosol, clayey and fine particle size have good capacity to sequestrate C in soil. Land use pattern controls organic matter status in soil. Crop/grass, forestry/agroforestry, reduced tillage, quality of organic matter, soil biotic - abiotic are the major factors to sequestrate significant C in soil. The application of fertilizers especially nitrogen usually results in an increase in crop growth as well as a corresponding increase in root development takes place for building up active organicmatter in soil. Biochar amendments can impact soil C storage and net CO_2 removals from the atmosphere in three different ways such as longer residence time due to resistant to microbial decay, plant productivity and reduce N_2O emission. Wetland soil, effective management practices and control

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deforestation sequestrate 0.2, 2.0 and 1.6 Gt C yr^{-1}, respectively. Based on these information, it is possible to increase 4‰ carbon a year the quantity of carbon contained in soils at 0-40 cm soil depth to halt carbon dioxide enrichment (4.0 Gt C yr^{-1}) in the atmosphere.

Keywords: Carbon sequestration; climate change mitigation; management practices; land use; fossil fuel burning; atmospheric carbon.

1. INTRODUCTION

Organic matter dynamics and nutrient cycling in the soil are closely related to nutrient immobilization and mineralization. Increasing soil organic carbon (SOC) can improve soil health and mitigate climate change. The conversion of forest to pasture or to cropland or the conversion of pasture to cropland decreases SOC stocks [1, 2]. Most agricultural soils have lost 30% to 70% of their antecedent SOC pool [3]. The overall effect of this green house gas is calculated to increase the earth's surface temperature between 1.5 and 4.5 by the year 2100 [4]. As a result, soil physical, chemical and biological properties are hampered. Ultimately crop production will be hampered after a certain periods. Estimates of annual fluxes of carbon among various sources are shown in Table 1 indicate a net imbalance of about 4.0 gigaton C yr^{-1} [5].

Land use and management practices can influence both efflux and influx of carbon between soil and the atmosphere [1]. Table 1 indicates that the highest amount of CO_2 efflux from residue decay. If we can develop an effective method to reduce or retard CO_2 evolution from residue decay that will be helpful to reduce environmental pollution as well as increase soil fertility level. Soil CO_2 emission depends on agricultural practices such as tillage and residue management as well as different climatic conditions [6]. Worldwide restoration of soil carbon levels is important for reducing atmospheric CO_2 concentrations [7]. People from developing, under developing and least developing countries do not sustain C stocks in soil due to food supply for over increasing population. Carbon quantity and rate of accumulation in soils depend on numerous factors such as the nature and amount of organic materials returned, soil moisture, soil temperature, the degree of soil aeration, topography. Integration among different approaches is required for different soil and climate conditions [8]. However, the activities require based on the same principle: increasing biomass production in order to build active organic matter in the soil. Because active organic matter provides habitat and food for beneficial soil organisms that can help build soil structure and porosity, provide nutrients to plants, and improve the water holding capacity of the soil [9]. Since the 1850s, some 60 to 150 Pg C held in soil organic matter have been lost due to land use-conversion, agriculture, and disturbance [10, 11]. Within the next two decades, the global demand for food is projected to increase by 50%, demand for water by 35% to 60%, and demand for energy by 45% [12]. This is putting increasing pressure on many agro-ecosystems with adverse environmental effects [13]. Among the green house gases, carbon dioxide is responsible for 50% global warming is expected to increase by 30% in the next 50 yrs. Growing public concern over environmental issues and increasing scientific proof of human interference with the earth's climate has influenced climate change into the political arena in the past 30 yr. If carbon sinks 0.4% per year from the quantity of carbon contained in soils can halt the annual increase in CO_2 in the atmosphere [14]. In this regard, published results are available about the trend of soil organic matter decomposition at different situations in agricultural land but these results are not in the organized form to integrate better agricultural management practices to enrich carbon stocks in the soils. Schrag [15] reported that there are three strategies of offsetting CO_2 emissions to mitigate climate change through reducing the global energy use, developing low or no-carbon fuel, and sequestering CO_2 from point sources or atmosphere through natural and engineering techniques. The objective of this paper is to discuss the process and technological options of carbon dioxide (CO_2 emission)- carbon sequestration in terrestrial ecosystem to halt the annual CO_2 increase in the atmosphere. A detailed literature search was carried out as starting point for this review. The selection of papers was made through specific searches for peer-reviewed articles on agricultural land use and management practices on carbon dynamics between terrestrial ecosystems and atmosphere. The review was completely systematic, as using a keywords-based approach resultedin a large for this review as they explain in this issue.

Table 1. Carbon exchange among various reservoirs (adapted from 5, 14)

Flux	Reservoir		Rate (gigaton C yr^{-1})
Efflux to the atmosphere	(i)	Fossil fuel burning	9
	(iii)	Plant respiration	60
	(iv)	Residue decay	60
		Sub-total	129
Influx from the air	(i)	Photosynthesis	123
	(ii)	Ocean uptake	2
		Sub-total	125
Imbalance (efflux - influx)			4
Increase by 0.4% a year the quantity of carbon contained in soils			4
Balance (influx-efflux)			0

A database was created using MS-Excel 2010 in order to store the information for getting outcomes from the selected articles.

2. RESULTS AND DISCUSSION

2.1 Factors Affecting Carbon Stocks in Soil

2.1.1 Soil and their topography

Soil is the unique ability to sequester and store large amounts of carbon. It is the largest reservoir of organic carbon in terrestrial ecosystems, containing three times more C than the atmospheric carbon pool and doubles that in the biota [16]. As such, they represent a potential sink for the anthropogenic emissions of carbon dioxide (CO_2) that will help the stability of the Earth's climate. Histosols contain the highest organic carbon (390 Pg C) whereas vertisols contain the lowest organic carbon content (38 Pg C) according to area basis (Fig. 1). Highest values of SOC storage and area-density found in Histosol and intermediate in Mollisols weathered soils [17].

Organic matter content of the above mentioned soil orders depends on mainly its parent material, texture, moisture, weather condition and land

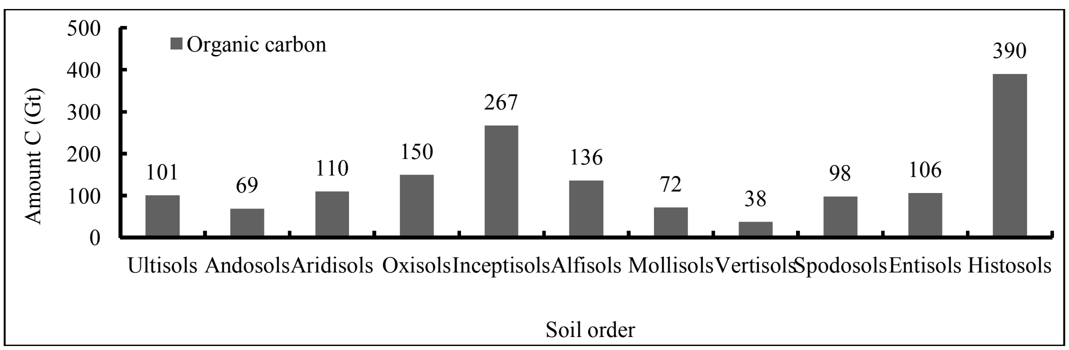

Fig. 1. Organic carbon in different soil orders of the world in 0 to 100 cm depth

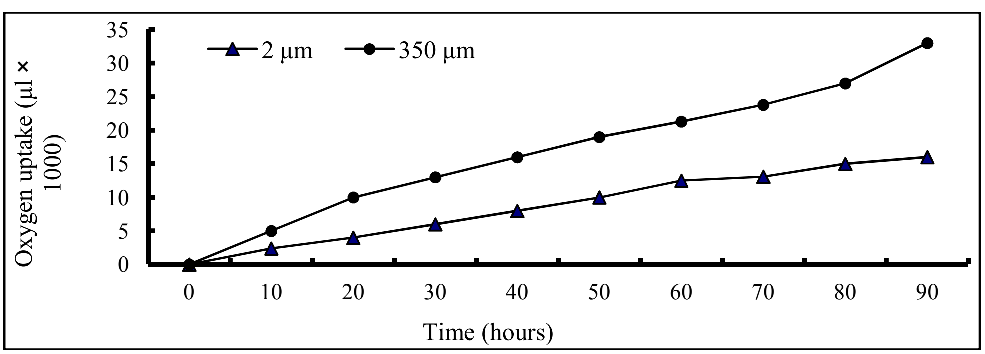

Fig. 2. Effect of particle size on decay rate of organic materials

utilization. Mineralization results of organic matter by soil particle size are presented (Fig. 2). Particle size (350 µm) evolved higher carbon dioxide than small particle size (2 µm). Similar findings were discussed by Ding et al. [18].

Pools of potentially mineralizable carbon (C_0) and associated rate constant (k) are calculated for sand and clay sized separates by $C_t = C_0 (1-e^{-kt})$, Ct being carbon mineralization in time t. From this investigation, decomposition rate is found 2.4 times higher for clay than for sand. The clay soil efficiency is higher to degrade organic matter. Results also report that higher CO_2 evolution from sand is ascribed to a larger pool of potentially mineralizable carbon in this size separate, the C_0 being 8 times higher for sand than for clay. Soil organic matter increases with the increase of clay particles. This increase depends on two mechanisms. First, bonds between the surface of clay particles and organic matter retard the decomposition process. Secondly, soils with higher clay content increase the potential for aggregate formation. Some researchers were conducted organic matter decomposition behavior study under greenhouse conditions in different soil textures such as clay, silt clay and silt [19]. The clay soil efficiency was higher to degrade organic matter. Physical, chemical, and biological properties of soil greatly influence the C protection capacity. They also discussed that both physical and chemical properties of soils are directly or indirectly governed by clay minerals, which are the most reactive soil particles. Clay minerals provide both permanent and variable surface charges as well as different specific surface areas that are crucial to determine the C protection capacity of soils. They form organo–mineral complexes, promote aggregate establishment and protect soil organic matter against microbial decomposition. Carbon mineralization from the clay fractions was rapid initially but then decreased to a rate similar to that of the silt fractions, indicating that a small amount of readily decomposable SOM was present initially in the clay, possibly as an artifact that was sorbed during dispersion of the whole soil samples. Similar findings were discussed the effect of soil particles on carbon stabilization in soil by Sarkeret. al. and Parfitt& Salt [20,21]. Soil organic carbon stocks in the mineral soil are smaller in the forest soil than in the agricultural soil. Land type use and soil cultivation are important factors for controlling organic carbon storage in soils as well as they may also change the relative importance of different mechanisms of soil organic matter stabilization [22]. The effect of differences in pore size distribution in different clay tactoids, and by implication aggregates formed from them is that the smaller the pore size of clay tactoids the greater is the protection of aggregate stabilizing SOM against microbial and enzymatic decomposition. Ca-montmorillonite protects the associated SOM most effectively whereas kaolinite is likely to be the least effective [23]. This behaviour is most readily observed in vertisols where the smectitic clays and oxisols with a clay fraction high in hydroxides of iron and aluminum. The SOM exists in pore sizes < 10 ηm is usually protected against the microbial and enzymatic decomposition until the soil aggregates are broken down and that SOM fraction is exposed to microorganisms, for example by cultivation. Soil organic matter accumulation is significantly affected by the textural class of soil (Fig. 3) [24].

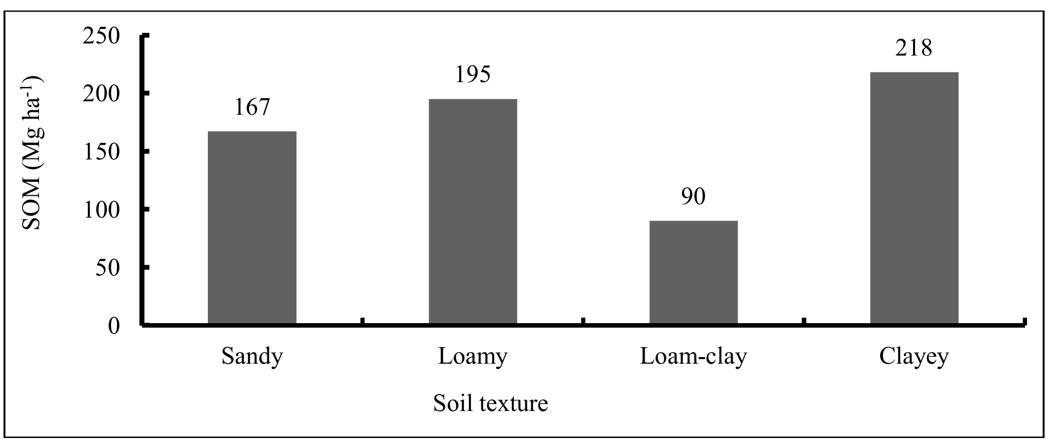

Fig. 3. Soil organic matter accumulation by soil texture

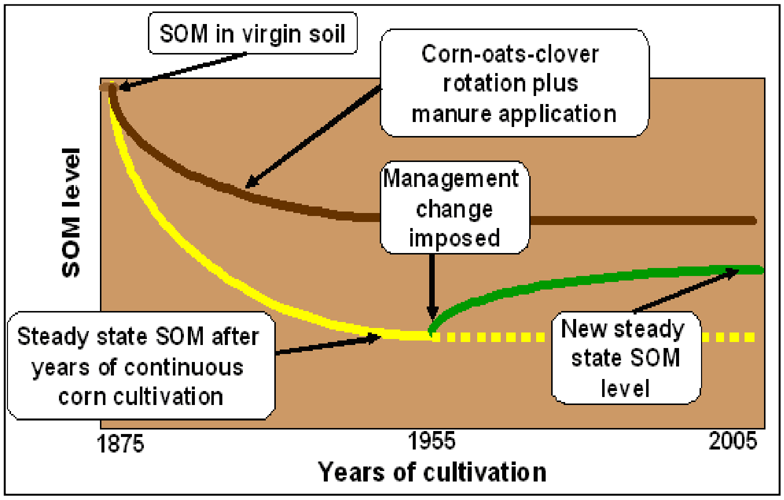

Fig. 4. Soil organic matter status by management practices

Clayey textural soil contained maximum soil organic matter on the other hand, the minimum soil organic matter accumulation was observed in loam-clay textural soil [24]. Amount of carbon stocks in soil is in the order clay > sand.

2.1.2 Land use

Land use pattern controls organic matter status in soil. Conversion of lands to agricultural production causes a sharp decrease in carbon stored in soil [25]. Several cases have demonstrated that it is possible to restore organic matter levels in the soil by effective land management [8]. Although there is a depletion of soil organic matter immediately following the bringing into cultivation of virgin lands, there is some consolation in the first fact that this high rate will not continue indefinitely. SOM decreased by about 65% from 1875 to 1955 with the greatest loss occurring in the first 20 years when continuous corn productions without fertilizer use (Fig. 4). During the first 15 – 20 years of cultivation and then the rate of loss slows and reaches a steady state level much lower than in the original soil. From 1955 to 2005, SOM levels have remained nearly constant due to continuous corn production.

Cover crops, refraining from burning crop residues and reduced or zero tillage imposed, SOM quantity changes to a different level with a new steady state condition is reached [26,27]. Plots that were in corn-oats-clover rotations with manure added lost only about 40% of SOM. The resulting increase in corn production also increased SOM by about 50%. While cultivation and management may have decreased the passive pool a little bit and by far most of the changes have occurred in the active pool and somewhat less in the slow pool. Soil organic matter status is in the following order virgin land>cropped land. Management practices increase of 0.5 t C ha^{-1} yr^{-1} where water is not limiting [28]. Land use selection depends on time paths of CO_2 emission and sequestration and examines the sensitivity of carbon sequestration costs to key underlying factors. Some researchers focus on the empirically relevant land-use options of forest and farm. Landowners are assumed to observe current and past values of economic, hydrologic, and climatic factors relevant to decisions regarding the use of their lands for forestry or agricultural production and on the basis of expectations of future values of respective variables [29]. Another important cause is that agricultural land is shrinking day by day due to rapid urbanization. Given this information, landowners plan to maximize the expected long-term economic return to the set of productive activities that can be carried out on their land. Relevant factors a landowner would be expected to consider include: typical agricultural and forestry revenues for the area; the quality of a specific land parcel for agricultural production; agricultural costs of production; and the cost of converting land from a forested state to use as cropland. The first necessary condition implies that a parcel of cropland should be converted to forest use if the present value of expected net forest revenue exceeds the present value of expected net agricultural revenue. On the other hand, a forested parcel should be converted to cropland if the present value of expected net agricultural revenue exceeds the present value of expected net forest revenue plus the cost of conversion. We faced some natural calamities, Eila, Nargis due to the imbalance of CO_2 content between atmosphere and soil. Forestation on uncovered hilly areas and control deforestation are good options for offsetting CO_2 in the atmosphere [30]. In desert area, we can improve the soil texture by introducing clay content soil as well as creating irrigation facility with effective mulch [31]. In this regard, government should implement an effective policy for the increasing of forest and crop areas for effective land use that will be helpful to increase C stocks in soil. New equilibrium of SOC level may be achieved over 25 to 50 years using recommended management practices with specific references to crop rotations and tillage practices, cover crops, ley farming and agroforestry, use of manure and bio-solids, N fertilization, and precision farming and irrigation [32].

2.1.3 Crops/grass

No single crop management strategy can be developed and implemented to change biotransformation processes and soil C storage. Crop management practice and the type of arable crop grown can also influence soil organic matter content. The small grain crops such as wheat do not deplete the soil organic matter. The inter-cultivated crops cotton, maize and jowar hasten organic decomposition but add very little fresh organic matter by crop residues. Soil organic matter declines under continuous root crops than under continuous cereals [33]. Some cover crops have high levels of lignin and phenolic acids. These give the residues a higher resistance to decomposition and thus result in soil protection for a longer period and increase soil organic matter [34]. Wheat and common vetch residues decompose 5 and 31% higher than oat, respectively. Low C:N and lignin containing organic residues can decompose easily [35]. Soil organic matter characteristically declines when grassland soils are converted to continuous arable cropping [36]. The cool and humid regions, type of vegetation has the main influence on carbon storage within the soil profile. Several studies conducted on podzolicsoils in eastern Canada have compared the mass of organic C and N on an equivalent soil mass basis. These illustrate that vegetation changes have the main influence on organic matter storage. Returning crop residues instead of removing them can double the amount of carbon returning to the soil in some production systems. SOC level under no tillage and stubble retention was 2.5 per cent and the same soil which had been under 3 pass tillage and stubble burning SOC level was 1.5 per cent after 19 years of cultivation [37]. Crop rotations, especially hay and forage crops, have been shown to increase soil organic matter. Results revealed that the highest C sequestration potential (64.54 Mg ha^{-1}) was in the above ground biomass of forest land and the lowest (33.50 Mg ha^{-1}) in cropland [38]. In France, SOC stocks increased in mineral soils (0-40 cm) were 0.035 kg C $m^{-2}y^{-1}$ during 1993-2012 [39]. These comparisons should also take into consideration the relatively large pool of C stored in the above ground biomass in forested areas. Therefore, while deciding on the cropping plan, an attempt should be made to include a legume or a grain crop in the rotation. It is important to start for the first year with cover crops those cover the surface with a large amount of residues that decompose slowly. In the following years, when soil health has begun to improve, legumes can be incorporated in the rotation. Legumes allow the sequestration of carbon (1.42 Mg C ha^{-1} yr^{-1}) in soils and induce the conservation of fossil energy inputs in the system [40]. Later, when the system is stabilized, it is possible to include cover crops with an economic function, e.g. livestock fodder. But in developing countries, cereal crop production areas increase day by day for the food supply of over increasing population. In this regard, developing countries have some limitations to allocate the lands for forage, legume or cover crops. Globally, the carbon dioxide removal potential through conversion to pasture is significant and has been estimated at 0.5 t C ha^{-1} yr^{-1} [41].

2.1.4 Forest/agroforestry

Forests cover 4×10^7 km^2 of the earth's surface, equivalent to 30% of the global land area [42]. Forest ecosystems play a central role in the global carbon (C) cycle with their high potential for atmospheric CO_2 sequestration (45 Tg C yr^{-1} by 2040) [43]. A key opportunity in tropical regions is the reduction of carbon emissions from deforestation and land degradation [44]. With political supports in tropical regions, forests can contribute to climate change protection through carbon sequestration help to offer economic, environmental and socio-cultural benefits. Results suggest that above-ground live forest carbon fell from 434 Tg (tera gram) before settlement to 120 Tg C at the peak of agricultural clearing in the 1930s and has since recovered to approximately 276 Tg [45]. IPCC estimates of the global mitigation potential from forests are substantial, up to 3.8 Pg C yr^{-1} by 2030 but dependent on financial incentives for forest establishment [37]. Forests and forest products currently offset 12–19% of fossil fuel emissions for the USA [46]. However, in the short term, a decrease in the rate of deforestation will contribute more to mitigating CO_2 emissions than forest establishment [47]. Globally, the rates of deforestation between 2000 and 2005 were 7.3 million ha yr^{-1}, amounting to a source of 1.4–2.0 Pg (peta gram) C yr^{-1} to the atmosphere [42,46, 48]. They report that the net carbon accumulation in tree ecosystem is 1.96 times more than that of in grassland [42,46,48]. The soil carbon in the initial 7 yr of planting decreases at the rate of 0.1871 kg C m^{-2} yr^{-1} and then it increases at the rate of 0.090 kg C m^{-2} yr^{-1}. The carbon accumulation in the studied plantation ecosystem is estimated to be 76–81% of that value in equilibrium state. The spatial distribution of above-ground live forest carbon has shifted significantly. Former savanna ecosystems in the south, now store more above-ground live forest carbon due to fire suppression and forest in growth, despite the fact that most of the region remains in agriculture, whereas northern forest still store much less carbon than before settlement.Restoring historical carbon stocks across the landscape are reassessed overall land use choices, but a range of options can be ranked and considered under changing needs for ecosystem services [48]. Broad-scale groupings by foliage life span are successful in isolating general patterns of SOM in soil (Fig. 5). Forests dominated by evergreen tree species had significantly lower SOM accumulations in soil than sites dominated by a mixture of deciduous and evergreen species [49]. So, the strategy should be needed to increase biodiversity by different species in marginal lands. About 50 – 60 gigaton C yr^{-1} is emitted from the residue decay that is needed to maintain in proper way (Fig. 5).

Fresh organic residues are processed for bio gas production. After collection of bio gas, slurry will be collected and processed for field application as an organic fertilizer (Fig. 6). This technology will help to reduce CH_4 based air pollution as well as we can use this bio gas as fuel purpose. USDA [50] reported that Eastern Region stored approximately 930 Tg of total forest ecosystem carbon in 1990 and reached approximately 1040 Tg in 2013. Globally, the carbon dioxide removal potential through afforestation and reforestation is significant and has been estimated at 0.6 t C ha^{-1} yr^{-1} [41]. Reforestationmeasures have similarly a great potential and could account for 1-2.7 Gt C yr^{-1} globally. Through the selection of perennial food producing shrubs and trees, global food production could be improved. Deforestation contributes 1.6 Gt C yr^{-1} in the world [51].

An increase in the soil organic carbon pool by 1 × 10^{-9} Pg C ha^{-1} can increase crop yield by 20 to 70 kg $ha^{-1}$for wheat (*Triticumaestivum*), 10 to 50 kg ha^{-1} for rice (*Oryza sativa*), 30 to 300 kg ha^{-1} for corn, and 10 to 20 kg ha^{-1} for beans (*Phaseolus vulgaris*) [52].

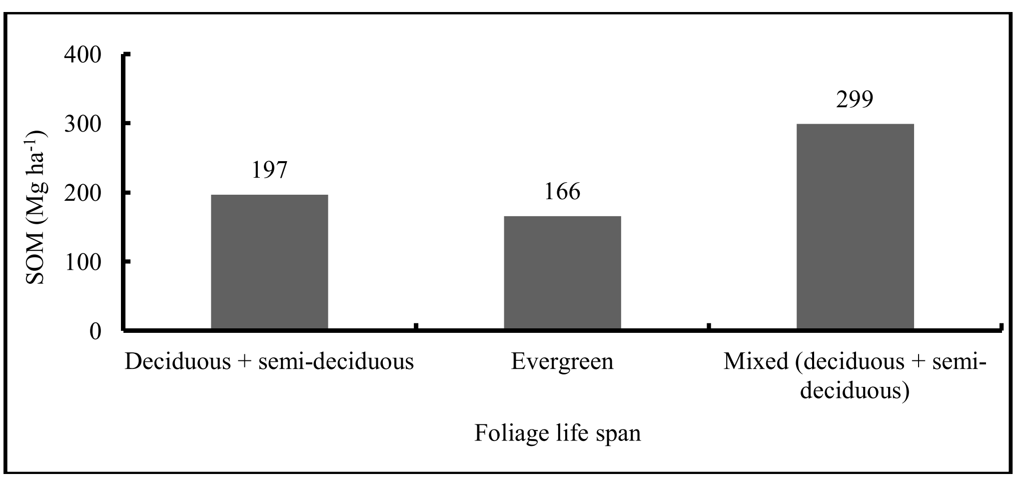

Fig. 5. Soil organic matter accumulation by forest life span

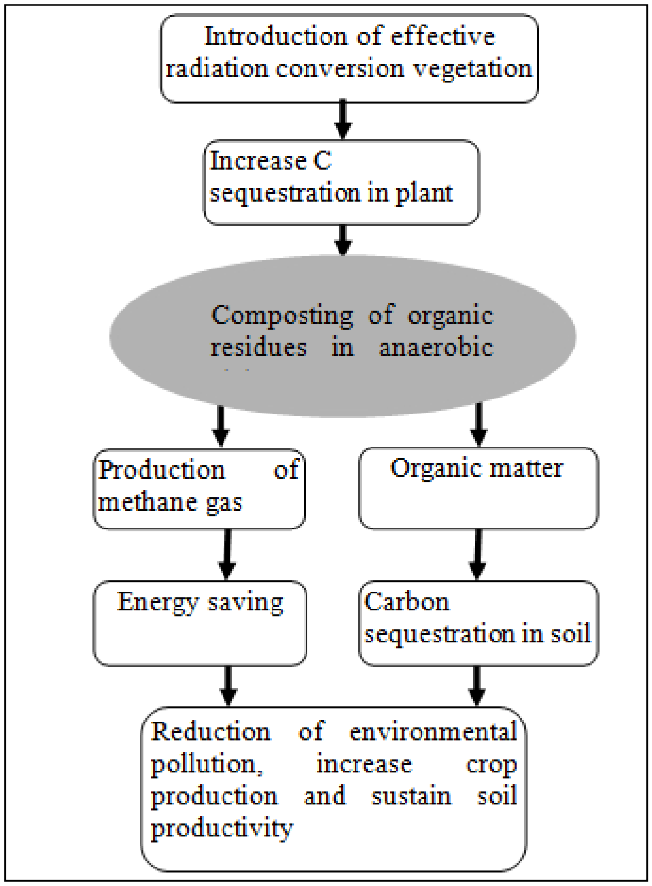

Fig. 6. Conceptual model for effective radiation conversion through photosynthesis to increase carbon stocks in soil

2.1.5 Tillage methods

Conventional or traditional tillage is more effective than no tillage due to enhance organic matter oxidation, erosion and nutrient mining by increased crop production [53]. Tillage method can influence both the pattern of organic matter accumulation in soil profile and the quantity of organic matter present. Carbon sequestration in the 30 cm layer can be improved if no tillage or minimum tillage is used in lieu of conventional practice [54]. Five year-old grass/clover pasture is converted to arable crops the annual rate of decline in organic C content over a nine year period is 1.8 t C ha^{-1} under zero tillage but 2.6 t C ha^{-1} under conventional tillage [55]. USA agriculture has seen a 17% increase in no-tillage practice and an 11% decrease in conventional tillage practice from 1990 to 2004 [56], there is still major potential for reducing CO_2 efflux through greater adoption of soil conservation tillage practices to sequester C. Plough decreases the organic matter concentration as well as its location is changed. After being mixed with topsoil, surface material loses its value in controlling runoff but it supplies the topsoil to plough depth with more plant nutrients, especially nitrogen. No tillage adoption may be increased soil organic carbon with land use change from native vegetation to cropland management in the Cerrado region of Brazil [57]. No tillage farming system offers innumerable benefits to soil - water conservation for potential sequester soil organic carbon and related soil properties varies widely [58]. The lowest organic matter decreased in direct seeding method side by side the highest organic matter loss was found in mouldboard plough + disc harrow treatment (Fig. 7).

In terms of short-term organic matter loss, the more a soil is tilled, the more the organic matter is broken down [59]. Conventional tillage soil has 26-55% lower SOC and 7-34% lower N compared to forest soil [60]. Optimum crop yield is not possible through minimum tillage due to the lack of sufficient vegetative growth of crops. Farmers of developing countries are not interested to introduce minimum tillage for crop production. In this regard, government should take an effective policy to subsidise for the farmers to show positive response for increasing of organic matter status in soils through effective techniques. Generally, unless conservation tillage increases crop C production and inputs to the soil, the major influence of conservation tillage is organic C placement and distribution within the soil profile [61]. Carbon stock in the soil is the following order no tillage>conventional tillage. Globally, the carbon dioxide removal potential through no or reduced till is significant and has been estimated at 0.3 t C ha^{-1} yr^{-1} [41].

2.1.6 Fertilization

The application of fertilizers especially nitrogen usually results in an increase in crop growth as well as a corresponding increase in root development takes place. This additional root substance together with the larger amount of growth may be used in manure production or returned to the soil directly can lead to some increase in soil humus. Farmyard manure (FYM) increases in clay and silt soil organic matter, probably because animal manure provides an additional input of biologically processed material. Balanced fertilization also increases biomass production in order to build active organic matter. Active organic matter provides habitat and food for beneficial soil organisms that help build soil structure and porosity, provide nutrients to plants, and improve the water holding capacity of the soil. Location specific and yield goal basis, fertilizer recommendation should be followed for crop based on soil test values. This approach will help to increase crop production as well as more organic materials can supply to soil for the C stocks in the soil. Balanced fertilizer dose is computed using the following equation [62].

$$F_{t=}\frac{Uf-Ci\times(St-Ls)}{Cs}$$

Where,

F_t= fertilizer nutrient required for given soil test value, U_t= upper limit of the recommended fertilizer nutrient for the respective soil test value index, C_i= units of class intervals used for fertilizer nutrient recommendation, C_s= units of class intervals used for soil test value index class, S_t= soil test values and L_s= lower limit of the soil test value within soil test value index class.

Generally, solid manures accumulate more organic carbon in soil than with liquid manures when applying similar amounts of nitrogen. Adding fertilizer nitrogen increased organic matter carbon levels in all cases. The determining role played by nitrogen in the production of humus from organic materials applied to the soil may be illustrated in Fig. 8. Carbon dioxide emission decreased with increased concentrations of N, which shows negative effect when the soil was fertilized with N [63]. We can fit an effective dose of nitrogenous fertilizer for producing highest humus in the soil as well as to minimize CO_2 and NO_3 emission

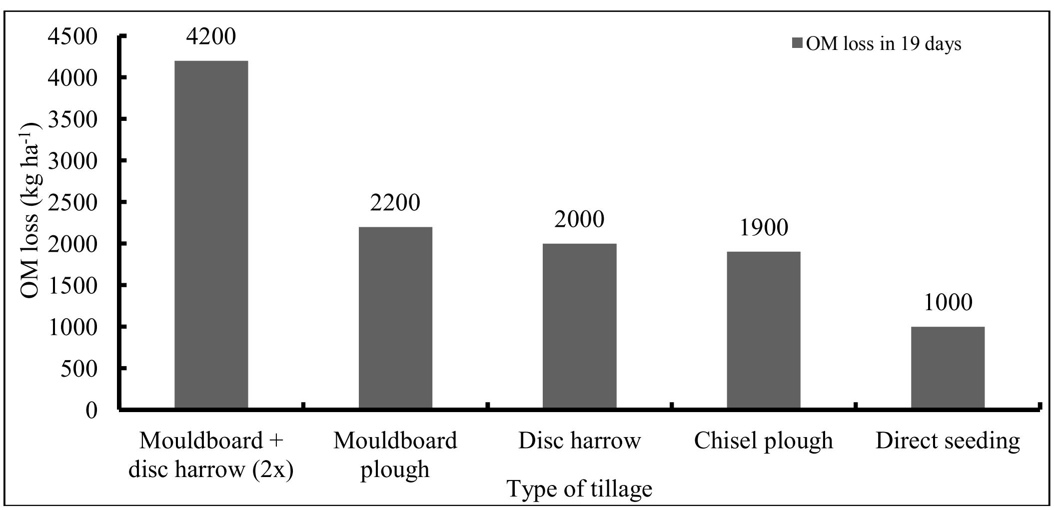

Fig. 7. Tillage induced flush of decomposition of organic matter in 19 days

from the organic residues by nitrogen analysis of plant and soil (Fig. 8). An additional consideration has been raised regarding constraints on aggressive targets for soil C sequestration is needed for additional inputs of nitrogen [64]. They also reported that in most mineral soils, soil organic matter has a relatively narrow C: N stoichiometry, typically ranging from 8 to 20, with a C:N of 10–12 as a general "rule-of-thumb" for agricultural soils. If soil organic matter stocks were to increase 1.1 Gt C yr^{-1}, then about 100 million tons per year of N would need to be incorporated into the added soil organic matter. On the other hand, imbalanced fertilization especially nitrogen resulting in more weed competition, higher pest incidence, loss of quality of the product on the ultimately the carbon sequestration in soil will be hampered. Therefore, fertilizers should be applied in sufficient quantities and in balanced proportions. Compost 0.1% did not able to accumulate organic matter in the soil.Overall, it is observed that the addition of 0.1% compost cannot accumulate organic matter in soil, whereas 0.25% compost insignificant effects for three weeks after that it's accumulation is significant. The addition of 0.5% compost helped to increase organic matter accumulation as compared to control [19, 65]. Continuous application of compost increases total SOC concentration in plough layers and improved soil physical properties. Manure treated soil increased 50% more organic matter than chemical fertilizer treated soil contained 1.99% organic matter during 50 years crop production [66].

2.1.7 Quality of organic materials and its decomposition rate

Material that is partially decomposed is called humus or organic matter, material that is not yet decomposed is known as organic material. The

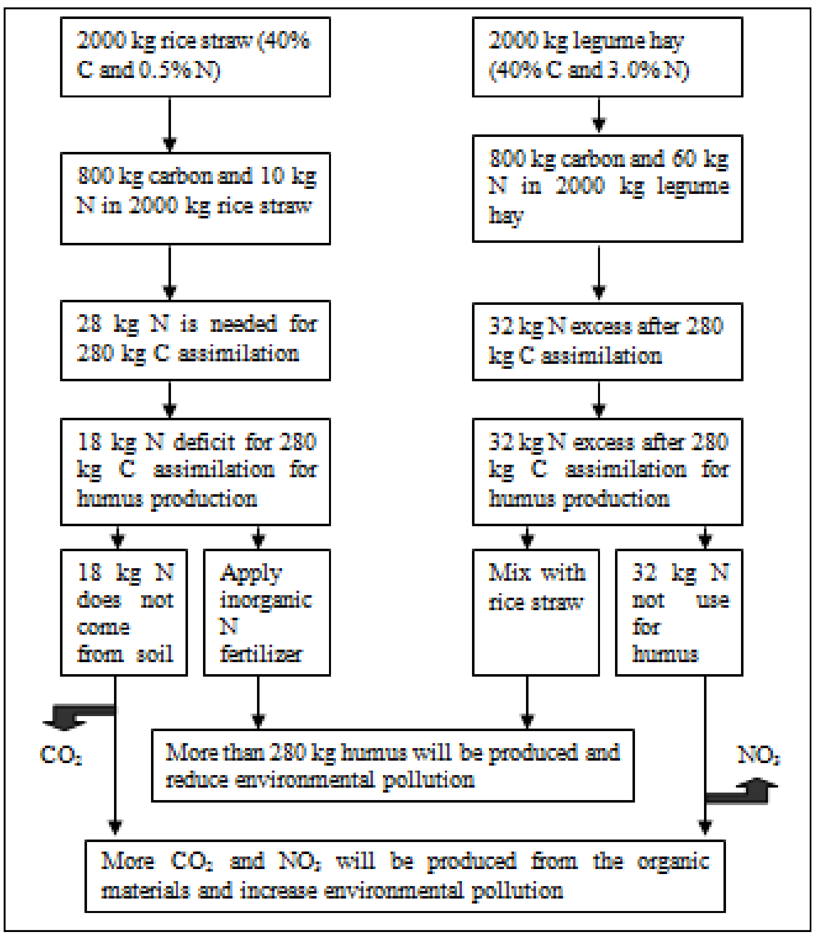

Fig. 8. Conceptual model for increasing humus from organic materials using balanced N fertilizer

Table 2. Carbon – nitrogen ratio in major fresh organic materials

Name of crop/plant		C:N	Name of crop/plant		C:N
Wheat	:	1:40	Mungbean	:	
Grasses	:	1:20 to 1:40	Poultry manure	:	
Coniferous and heath	:	1:30 to 1:40	Cowdung	:	
Rice straw	:		Soil organic matter	:	10:1
Rice root	:		Sawdust	:	100-400:1
Corn stover		60:1			

soil chemist would tell us that the organic matter has a carbon nitrogen ratio (C:N) of about 10:1, while the organic material accumulating in a deciduous forest has a carbon-nitrogen ratio of about 1:300 or 1:400. So, fresh residues decompose faster than soil organic matter. Grasses hold the narrow carbon nitrogen ratio from 1:20 to 1:40 (Table 2). Based on the carbon nitrogen ratio, decomposition rate of grass land is higher than forest surface soils. In general, grass and deciduous litters tend to mineralize fairly easily and give rise to more decompose forms of humus whereas heath and coniferous residues with their more highly lignified nature decompose only slowly and tend to form more humus. The decomposition rate of organic materials composition is in the following order sugars-starches and proteins> hemicelluloses> cellulose>fats, waxes>lignin. Amongst the common forest litters, ease of mineralization decreases in the order: ash = lime = maple < oak = beech <<spruce [67]. The C:N ratio of different organic materials is presented (Table 2).

The organic material decomposition trend depends on the ratio of carbon and nitrogen. Wheat, grass, coniferous as well as saw dust contain high C:N ratio. So, its decomposition slowed due lack of nitrogen. So, the decomposition of wheat, grass, coniferous derived organic materials is slowed due to lack of sufficient nitrogen. The N, P and K contents in different organic materials are presented (Fig. 9). The highest N was found in sesame oil cake on the other hand, the lowest nitrogen content was observed in rice straw.Poultry manure is the best nutrients source for good crop production as well as improves soil quality by supplying more organic materials [68]. So, it should be needed frequent additions of small quantities of fresh organic materials rather than to practices of maintaining the organic matter content at any particularly high level. The different decomposition rates of the above- and below-ground C sources might constitute another mechanism explaining the higher soil organic carbon (SOC) formation efficiency of root litter versus aboveground litter. Root biomass is more suberized than the above-ground tissues. In a number of ecosystems suberins were found to significantly contribute to new soil C formation with a longer turn-over rate than above-ground lipids [69]. However, root suberin and other exudates are released closed to the soil minerals that protect SOC from microbial decomposition.

Mineralization of carbon and nitrogen in soil follows a similar pattern. Soil carbon change rate predicts using a simple model [70]. The low microbial activities at low temperature led to slow decomposition of organic matter resulting, thereby, in higher stability of organic carbon and other nutrients in the soil.

$$\frac{\mathrm{dC}}{\mathrm{dt}} = \mathrm{a} - \mathrm{kC}$$

Where k is the decomposition constant, C is the carbon content of a given mass of soil at time t and a is the accretion constant reflecting the amount of C added to the soil through agricultural operations e.g. crop residue return, application of compost and farmyard manure, dung from grazing cattle etc. Researchers reported that correlation (r = -0.924) was found between the decomposition rate of organic matter and the lignin content [71]. The trend of organic matter accumulation using different organic materials over 50 years results. The highest and intermediate organic matter accumulation ability was found in composted materials and woody materials. The low amount of organic matter accumulation was observed in crop residues, livestock manure and excess sludge.

During the initial stages of decomposition unprotected, monomeric compounds are lost as well as some cellulose, resulting in an accumulation of lignin in particulate organic matter associated with fine-sand fractions (Fig. 10) [36]. Polysaccharides are usually more rapidly lost than other soil fractions are often depleted in coarse soil organic matter fractions.

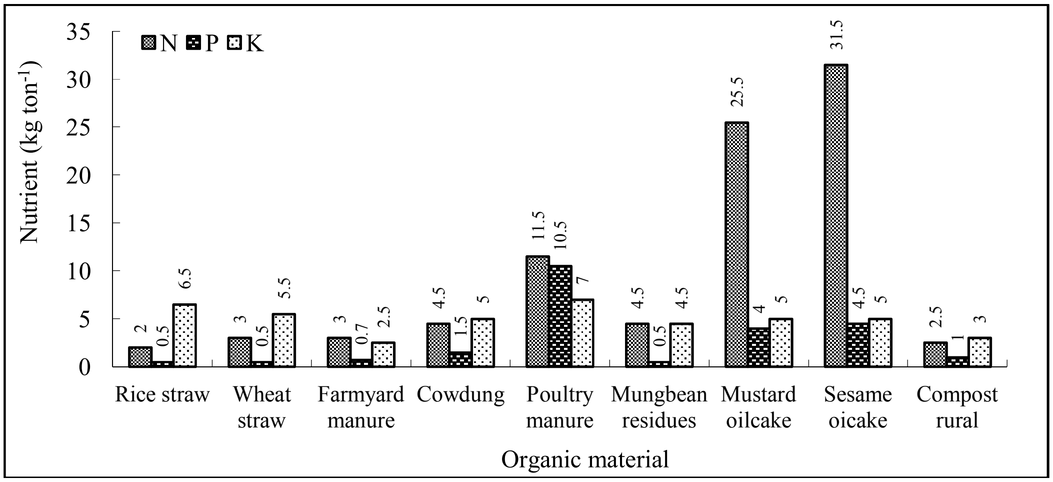

Fig. 9. Nutrient supply from different organic materials

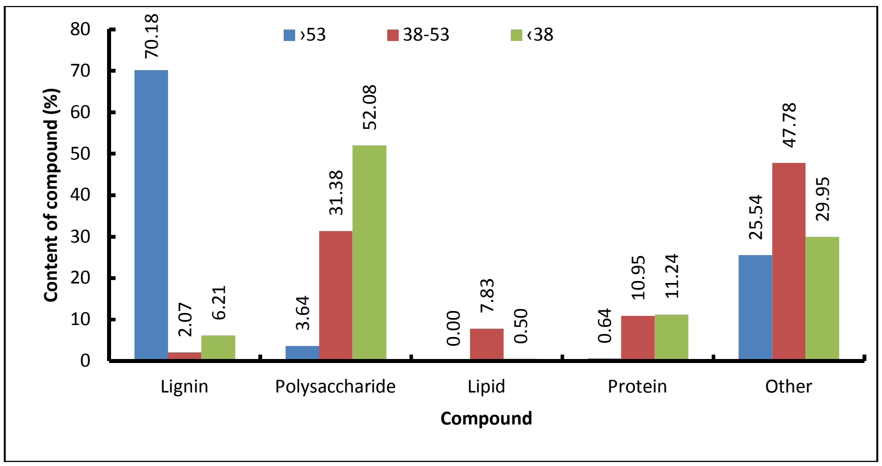

Fig. 10. Distribution of molecular C compounds in different size (μm) classes

2.1.8 Soil microorganisms, temperature, drainage and moisture

Soil management techniques are cooled soil by mulch or shade, wetter soil by irrigation, increase fertility by fertilization, increase subsoil pH by deep liming, fracture subsoil pans by subsoiling, deeper rooting by tolerant cultivars and last of all reduced aeration by limited tillage [72]. Neutral soils are more conducive to decomposition organic matter than acidic or alkaline soils due to the highest microbial population. Carbon dioxide is released largely from the microbial decay or burning of plant litter and soil organic matter [73]. China's terrestrial ecosystems absorbed 28-37 per cent of its cumulated fossil carbon emissions during the 1980s and 1990s [74]. The number of microorganism participates in mineralization of soil organic matter increases dramatically in arable land compared to undisturbed land soils. The residues on the soil surface slow the carbon cycle because they are exposed to fewer micro-organisms, resulting in the production of humus and liberating less CO_2 to the atmosphere. Conventional tillage stimulates the heterotrophic microbiological activity through soil aeration, resulting in increased mineralization rate. Reduced or zero tillage controls heterotrophic microbiological activity because the pore atmosphere is richer in CO_2/O_2, and facilitates the activity of the humifiers [75,76]. Carbon stocks in soils are seriously hampered by high temperature and dry condition in tropical and subtropical regions and biological reactions usually exhibit Q_{10} values ranging from 2 to 3 [77]. An increase in this apparent Q_{10} in response to rising temperature is expected to have a positive feedback to global warming [78].

Nevertheless, the magnitude of this feedback is uncertain. If global warming from anthropogenic carbon dioxide (CO_2) stimulates the decomposition of SOC, the extra CO_2 efflux may accelerate the warming trend, forming a positive feedback. Tree leaves as mulch during a hot summer day kept the soil 8°C cooler than in an adjoining plot with no leaves. When the temperature is too low or too high that time fungi and bacteria cannot grow and the rate of organic matter decomposition is slow. Soil temperature indirectly influenced the SOC concentration by affecting soil microbial activity. In the temperature ranges of 23°- 48°C, decomposition of plant residue is usually accelerated with the increase of temperature. Maximum decomposition rates are reached within a range of 48°- 58°C. Above 58°C, decomposition rates generally decline [79] due to lack of optimum population of organic material decomposers. In general, the quantity of humus accumulated in the soil decreases with an increase in temperature if moisture conditions remain constant. On the other hand, with uniform temperatures the amount of humus in the soil increases with an increase in moisture supply (Fig. 11). If adequate moisture is present, grass can use nitrogen as rapidly as it becomes available as a result, grass can supplement more organic materials to increase C stocks in soil.

The decomposition of organic matter occurs more slowly in poorly aerated soils, where oxygen is limiting or absent, compared with well-aerated soils. In this regard, organic matter accumulates in wet soil environments. Permanently waterlogged soil, one of the major structural parts of plants, lignin, does not decompose at all. Increasing the water content of soils may reduce rates of decomposition in temperate regions [80] but may increase the potential for the production of CH_4. The ultimate consequences of extremely wet or swampy conditions are the development of organic soils, with organic matter contents of more than 30 percent. Wetland soils sequestrate 0.2 Gt C yr^{-1} [81]. When the soils are drained artificially for agricultural or other uses, the soil organic matter decomposes rapidly. Crop residue mulching is a system of maintaining a protective cover of vegetative residues such as straw, maize stalks, palm fronds as well as stubble on the soil surface. The effective plant cover can reduce erosion of land [82]. Mulching adds organic matter to the soil, reduces weed growth, and virtually eliminates erosion during the period of mulch when used as surface mulch, organic matter keeps soils warmer in winter and cooler in summer. Researchers have demonstrated that litter placement on the soil surface increased the ratio of fungi to bacteria - the reason being that fungi have a higher carbon assimilation efficiency than bacteria [83]. Increasing the availability of water enhances biomass production, soil biological activity, plant residues and roots that provide organic matter. In temperate regions, well drain and aerated soils, oxidative decomposers are active and easily break down added organic materials [84]. On the other hand, poorly aerated or anaerobic soils act more slowly as well as anaerobic decomposition is a much slower process. Carbon stocks in the soil are in the following order low microbial activity>high microbial activity, low temperature>high temperature, poorly drained>well drained and moistened>dry, temperate>tropical.

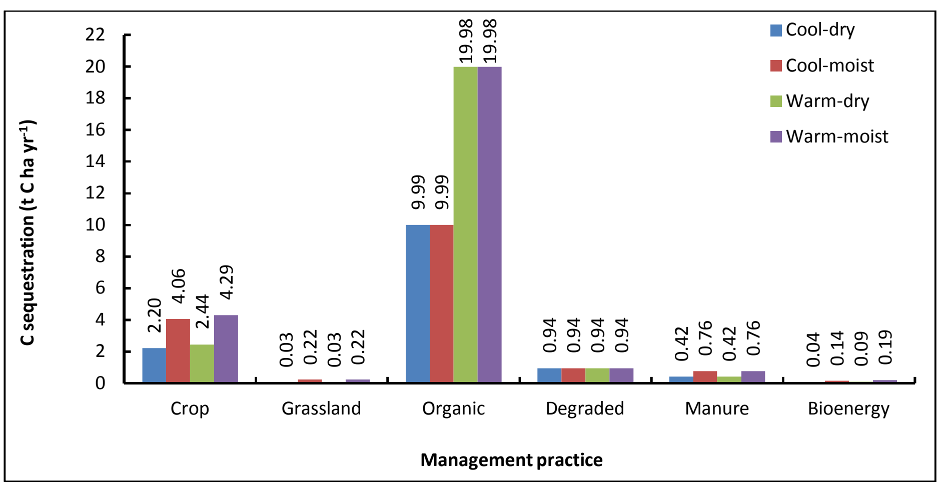

Fig. 11. Effect of different management practices on C sink in soil

2.1.9 Biochar additions

Biochar is a carbon-rich solid produced from biomass using a thermochemical conversion process known as pyrolysis. A range of temperatures can be used in pyrolysis, with lower temperatures/longer residence times favoring solid biochar formation on the other hand higher temperatures/shorter residence times producing a greater proportion of gases, liquid bio-oil and less char [85]. Biochar amendments can impact soil C storage and net CO_2 removals from the atmosphere in three different ways. Biochars produced as a co-product of biofuel pyrolysis processes, when added to soils, most of the biochar mass (80–95%) is highly resistant to microbial decay, with a mean residence time of 100s of years or more [86]. Biochar addition can influence plant productivity, and hence C inputs to the soil in the form of plant residues. Impact of biochar addition on plant productivity can vary widely depending on the characteristics of the biochar and soil-plant characteristics. Research results suggest that biochar additions generally have neutral or positive effects on plant growth, with small increases on average in temperate cropping systems and larger increases in tropical systems, particularly on acid nutrient-poor soils [87]. Aside from impacts on soil carbon storage, a number of studies suggest that biochar amendments may decrease soil N_2O emissions, which would further contribute to greenhouse gas mitigation. A recent meta-analysis by Verhoeven et al. [88] reported the average reductions of N_2O emissions of 9–12% while an earlier global assessment [89] suggested that greater average reductions of almost 50%, compared to non-biochar amended soils. Biochar amendments as a CO_2 mitigation strategy they estimated a climate change mitigation potential of 1.8 Gt C per year [90].

Based on the discussion, it is possible to increase 4‰ carbon a year the quantity of carbon contained in soils at 0-40 cm soil depth, soil management practices (2.2 Gt C yr^{-1}) [91], check deforestation process (1.6 Gt C yr^{-1}) [92] as well as increase wetland C sequestration (0.2 Gt C yr^{-1}) [81] which can help to halt carbon dioxide enrichment (4.0 Gt C yr^{-1}) in the atmosphere.

3. CONCLUSION

Unplanned conversion of lands to agricultural production causes a sharp decrease in carbon stored in soil. Soil is an important factor to sequestrate the significant amount of carbon. Histosol, clayey and fine particle size have good capacity to sequestrate C in soil. Land use change with effective cover crops, refraining from burning crop residues, reduced or zero tillage and forestation on uncovered hilly areas and control deforestation are good options for offsetting CO_2 in the atmosphere. Increased forage by grazing rather than by harvesting, applying poultry and animal manure or other carbon-rich wastes and applying plant materials from off farm areas to enrich organic matter in soil. The application of fertilizers especially nitrogen and irrigation usually results in an increase in crop growth as well as a corresponding increase in root development take place for building up active organic matter in soil. Reducing or eliminating tillage, keeping the soil saturated with water, keeping the soil cool with vegetative cover or mulch and lastly, practices uneconomic for farmers—potentially overcome by changes in regulations or subsidies help to sequestrate carbon in soil. Biochar can impact soil C storage and net CO_2 removals from the atmosphere in three different ways such as longer residence time of C, plant productivity and reduce N_2O emission. Wetland soil, effective management practices and control deforestation sequestrate 0.2, 2.0 and 1.6 Gt C yr^{-1}, respectively. Based on these information, it is possible to increase 4‰ carbon a year the quantity of carbon contained in soils at 0-40 cm soil depth to halt carbon dioxide enrichment (4.0 Gt C yr^{-1}) in the atmosphere.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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