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# Enhancing Carbon Sequestration Using Organic Amendments and Agricultural Practices

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## Abstract

Carbon sequestration (CS) is an important strategy for the mitigation of climate change (CC) as well as for improving the soil fertility of agricultural soils. Carbon sequestration in crop lands and rangelands requires a certain amount of organic matter (OM) presence in the soil called soil organic matter (SOM). Organic amendments like animal and poultry manures, the incorporation of different crop residues, different types of compost, sugarcane bagasse, peat soils, different wood chips, biochar and good agricultural practices like cover crops, nutrient management, mulching, zero and no-tillage techniques, soil biota management and mulching are effectively used for this purpose. These enhance the SOM and improve the soil's physical and chemical properties which help to sequester more C in soil which ultimately contributes towards CS and CC mitigation.

**Keywords:** carbon sequestration, amendments, biochar, agricultural practices, tillage

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## 1. Introduction

There is an increase in atmospheric C concentration by 31% which is  $270 \pm 30$  Pg since industrial uprising due to the change in land use patterns. Depletion of SOM has contributed up to  $78 \pm 12$  Pg in the atmosphere. Agricultural soils have lost two-thirds of the original SOC with a cumulative loss of  $30\text{--}40$  Mg C ha<sup>-1</sup>. Atmospheric C removal and storing it in the soils is one of the best options. From soils, agricultural soils are thought to be a major sink and can sequester more and more quantities of C if we adopt agroforestry. It has received widespread credit due

to its advantages of helping in agricultural sustainability CC mitigation [1]. The CS potential of agroforestry systems is estimated between 12 and 228 Mg ha<sup>-1</sup>. So, based on the Earth's total suitable area for crop production, which is 585–1215 × 10<sup>6</sup> ha, a total of 1.1–2.2 Pg C can be sequestered in the agricultural soils in the next 50 years [2]. Overall, the agriculture sector has a great potential for CS in the soil as well as in crop plants. Changes in agricultural practice and managements can also result in enhanced CS in them. It is presumed that if we change the management practice, it will result in decreased crop yields but the net C flux can be greater

Sr. No.	Term	Definition	Reference
1	Carbon sequestration	It is the processes by which C is removed from the atmosphere and stored in the sinks like ocean, forest and crops, soils and geologic formations.	[11]
2	Agroforestry	It is a combination of two words, agriculture and forestry in which perennial trees and shrubs are grown in combination with agricultural crops.	[12]
3	Mulching	It is a detached vegetation covering wheat straw, compost or may be plastic sheets which are spread around plants to secure them from excessive evaporation, cold stress and promoting SOM contents in soil.	[13]
4	Crop residues	Detached vegetative parts of crop plants that are intentionally left to decay in agricultural fields after crop harvesting.	[14]
5	Crop rotation	It is the systematic planting of different crops in a specific order for several years in the same agricultural field.	[15]
6	Nutrient management	It is the combination of strategies which links soil, crop and weather factors and irrigation for ideal nutrient use efficiency to crops.	[16]
7	Zero tillage	A tillage system in which soil disturbances through ploughing is not being done.	[17]
8	Conservation tillage	If we leave crop residues of previous crop on fields to improve SOM, reducing soil erosion and runoff.	[18]
9	Biochar	It is carbonized biomass obtained from sustainable sources and sequestered in soils and can also be obtained by pyrolysis synthetically.	[19]
10	Cover crops	Crop which is grown for the benefit of the soil rather than the crop yield.	[20]
11	Compost	Material which largely consists of decayed organic matter and is used for fertilizing and conditioning of agricultural soil.	[21]
12	Cropping intensity	It is the fraction of the cultivated area that is harvested.	[22]
13	Bagasse	It is a dry pulp like material which is left when we extract juice from sugar cane.	[23]
14	Animal manure	Animals excreta collected from livestock farms and barnyards used to enrich the soil.	[24]
15	Peat moss	It is also called bog moss or sphagnum moss, a plant very rich in organic matter and used to enhance SOM.	[25]

**Table 1.** Some terms used in the chapter and their definitions.

under the new system. It will only happen when crop demand remains the same and additional lands are brought into production. Conversely, if increasing crop yields lead to land abandonment, the overall C savings from changes in management will be greater than when soil CS alone is considered [3]. Application of organic amendments and N fertilizer incurs C emissions to the atmosphere, which must be deducted by increasing SOM. Application of manures is important for maintaining agricultural soil health [4, 5].

When agricultural waste lands are vegetated, C is increased in them and can accumulate SOM in them. This accumulation reverses C losses from soils when these lands are converted to perennial vegetation. Maximum rates of CS during the early stage of perennial trees is  $100\text{gCm}^{-2}\text{yr}^{-1}$  while average rates are like forests and grasslands, that is, 33.8 and  $33.2\text{gCm}^{-2}\text{y}^{-1}$ , respectively [6]. Carbon sequestration (CS) potential by agroforestry is estimated up to 9, 21, 50, and  $63\text{Mg C ha}^{-1}$  in semiarid, sub-humid, humid and temperate regions, respectively. For small land holdings, CS potential ranges from 1.5 to  $3.5\text{Mg C ha}^{-1}\text{yr}^{-1}$ . Another advantage of agroforestry is soil property enhancement which also enhances the CS in plants and soils. Agroforestry systems are important C sinks but intensively managed agroforestry practice in combination with annual crops is like conventional agriculture which does not contribute in CS [7]. Agricultural practices like CT is effective in enhancing CS [8]. The global potential of CS through agroforestry and CT is around  $0.9 \pm 0.3\text{Pg C year}^{-1}$  offsetting 25–75% of the annual C emissions. It is a truly win-win strategy which restores degraded soils, enhances biomass production, purifies surface and ground waters and reduces C from the atmospheric [9, 10] (Table 1).

## 2. Agriculture practices which involve CS

Agricultural practices help in sequestering C in soils such as zero or reduced tillage, crop residue incorporation in fields, nutrient management, preventing OM loss, supplying nutrients and maintaining soil microbes, soil erosion control, vegetation or revegetation, cover cropping, green manuring, crop rotations, agro-forestry, soil rehabilitation, reclamation and use of salt-affected soils for forest plantations and crop production.

### 2.1. Zero tillage and conservation agriculture

Zero tillage is the type of conservation agriculture which does not disturb the soil comprising minimum soil disturbance, crop residues, cover crops and their diversification; this is also promoted for reducing soil disturbance and improving SOM and its sustainability as well as it also mitigates the CC through CS up to  $0.16\text{--}0.49\text{Mg C ha}^{-1}\text{yr}^{-1}$ . Increase in SOC concentration from CA induces improvement in the soil's physical and chemical attributes which ultimately contribute to increase the sustainability and CC mitigation through CS [26]. In Brazil, the government is trying to increase the agricultural area under zero tillage from 32 to 40 million ha by 2020 to mitigate C emissions. It was calculated that average annual CS is  $1.61\text{--}1.48\text{Mg C ha}^{-1}\text{yr}^{-1}$  in Brazil for the 8 years from 2003 to 2011. So, converting 8 million ha of cropland to zero tillage can sequester an estimated soil C storage of about  $8\text{Tg C yr}^{-1}$  in 10–15 years [27].

In Haryana, India, conventional and zero tillage techniques were tested for the efficiency of CS; results showed that nearly USD 97.5 ha<sup>-1</sup> can be earned extra by adopting zero tillage as zero tillage reduces the tillage implement costs, labor and fuel costs by spending USD 76 ha<sup>-1</sup> and 97.5 USD earnings show that shifting from conventional to zero tillage reduces cost and additionally, sequester C emission by 1.5 Mg C ha<sup>-1</sup> season<sup>-1</sup> [28, 29]. Zero tillage generates considerable benefits up to US D 97 ha<sup>-1</sup>; it also increases the crop yield by 5–7%, saving costs up to USD 52 ha<sup>-1</sup> [30–32].

## 2.2. Conservation tillage

Soil organic matter (SOM) is considered as C pool as well as its source while it decomposes. It decomposes when conventional tillage (CoT) is done. To check the effectiveness of conservation tillage in SOM retention, three scenarios of conservation tillage in model were used, that is, 27%; the current usages are 57 and 76%. The SOM content for major field crops up to 30 cm was 5304–8654 Tg C with 1710–2831 Tg C at 0–8 cm depth and 1383–2240 Tg C at 8–15 cm depth [33]. Changes in the SOC are greatly influenced by long-term tillage practices. For example, soil from 0 to 60 cm after 25 years of CT showed 5% higher soil bulk density for conservation tillage as compared to CoT practices. Analysis also showed that CS and storage was significantly higher in CT soil than CoT. So, it was concluded that CT practices increased SOM and CS as compared to CoT [34, 35]. It is a fact that interest in C storage in soils has gained a lot of interest in the last few years, especially C with its potential to help alleviate or offset some of the negative effects of the increase in greenhouse gases in the atmosphere. Several questions still exist about what management practices can optimize CS in the soil. Primary method is to conserve SOM by not ploughing. As in a study involving different tillage practices like CT, ZT, NT and CoT, it showed that CS throughout the profile was significantly affected by tillage practices. Conservation, ZT and NT showed that there is the greatest potential of CS while applying ZT, NT and CoT [36]. Conservation tillage is highly recommended in crop lands as a means of enhancing CS in these soils. Carbon sequestration can be increased by  $3.15 \pm 2.42$  t ha<sup>-1</sup> by adopting CT [37].

## 2.3. Nutrient management

Agricultural soils can be a sink for atmospheric C concentrations by CS. It is accomplished by the formation of SOM or humus which is limited by the availability of nutrients such as nitrogen (N). Optimization of N can be a good mean for CS. Practices that enhance N in soil are no or reduced tillage and increased crop intensity. Nitrogen additions are important for increasing biomass yield and hence crop residues' decomposition in soil which increases SOM concentration. Practices like CT and increased cropping intensity and crop rotations yield more quantity of crop residues, increasing N availability and CS. Croplands have the potential of sequestering C from 8 to 298 Tg C yr.<sup>-1</sup> [38]. Soil organic matter and N are directly influenced by tillage, residue return and N fertilization management practices [39], and that is why, intensive use of N fertilizers is employed to achieve higher economic value of high-grain yields and is generally perceived to bring about CS and by increasing the inputs of crop residues [40]. To determine the effects of N, tillage and crop rotation on SOM, long-term

tillage and rotation studies were conducted. Conventional techniques and ZT were applied and C and N were determined from soils at depths of 0–2.5, 2.5–7.5, 7.5–15 and 15–30 cm. It was revealed that compared with CT, NT had greater organic C, N and SOM. Increases in SOM were directly related to the tillage practice and N fertilizer application [41].

#### **2.4. Cropping system and intensity**

Soils represent a C pool of approximately 1500 Gt. Any modification or change of land use or land management can induce variations in soil C stocks [42]. Intense cropping systems always cause depletion of SOM but applying crop residues, balanced fertilization with NPK and use of organic amendments can increase CS levels to 5–10Mgha<sup>-1</sup>yr.<sup>-1</sup>. As these amendments also contain 10.7–18% C in them, they also help in CS [43].

In agricultural systems, there is a need for the optimization of C and N by cropping intensity and system to sequester C in the form of SOM which, in addition, gives stable soil structure, more yield and economic benefits [44]. Here, one challenge is to analyze the mechanism, capacity and longevity of C stabilization in agricultural lands by cropping intensity and systems. It is estimated that across 10 cropping systems, annual soil CS rates range up to 0.56 Mg C ha<sup>-1</sup> yr.<sup>-1</sup> [45]. Continuous and intense crop production accumulates 10–17% more SOM and N [46]. Increases in CS in soil can be attained by improved soil fertility, extensive cropping systems with shifting cultivation cropped fallows and cover crops [47]. Tillage, land cover, nutrients and cropping system management can contribute in CS up to 30–105 million metric tons of C (MMTC) yr.<sup>-1</sup>. Cropping intensity and rotations have the potential to sequester 14–29 MMTC yr.<sup>-1</sup>. By adopting these strategies, biomass production is increased and so, the C usage in the plants is increased and more C is sequestered in the plant and soil. If nutrient inputs combined the above strategies, this CS amount can be doubled [48]. Increase in SOM can be seen under long-term maize-wheat-cowpea cropping system up to 1.83 Tg C yr.<sup>-1</sup> [49].

#### **2.5. Mulching**

Carbon concentration and SOM is increased by adding mulch, and crop residues are widely applied in the form of mulch for CS and crop protection against cold stress. Mulch can increase CS in agricultural soils up to 8–16 Mg ha<sup>-1</sup> yr.<sup>-1</sup> and additionally, the soil's physical and chemical properties are also improved. Total SOM by using mulch increased from 1.26 to 1.50% [50]. Mulch also plays a key role in supplying nutrients, playing a role in the C and N cycle and the sink of C. It can significantly increase SOM and CS in the topsoil layer of 0–5 cm. This variation in the CS is attributed to the mulch rates. As more is the mulch and time after applying mulch, more will be the CS rate. For example, there will be 41% more CS after 4 years of mulching and 52% more CS after 11 years of mulching [51, 52].

#### **2.6. Residues and nutrient management**

Crop residues and nutrients especially N help in sequestering C in soils up to 21.3%–32.5% and simultaneously improve soil quality and plant growth [53]. Total SOM stocks are improved



by crop residues which suggests the substitution of SOM by fresh SOC derived from crop residues from 3.5 to 5.5 Mg C ha<sup>-1</sup> [54]. The use of crop residue as a source of CS and keeping the soil in good quality helps in nutrient management and conservation. In the USA, a total of 367 × 10<sup>6</sup> Mg year<sup>-1</sup> crop residues from 9 cereal crops, 450 × 10<sup>6</sup> Mg year<sup>-1</sup> for 14 cereals and legumes and 488 × 10<sup>6</sup> Mg year<sup>-1</sup> for 21 crops are produced. The amount of total crop residue production in the world is 2802 × 10<sup>6</sup> Mg year<sup>-1</sup> from cereal crops and 3758 × 10<sup>6</sup> Mg year<sup>-1</sup> from 27 food crops which can sequester 40–60% of total agricultural C emissions through their incorporation in the fields [55].

## 2.7. Soil biota management

Biological CS is accomplished by microbial activities. Mechanisms of CS by microbes need to be developed based on experiments and field investigations to predict the CS potential and C cycling under potential global change scenarios [56, 57]. Microbes improve the physical, chemical and biological soil properties in RT or NT areas. The evaluation of the soil microbial and biochemical environment greatly in these areas aids predictions of C availability in soil and plants to quantify CS. Where microbial communities are higher, C and N were 1.32–1.82 [58, 59]. Carbon sequestration was recorded higher up to 49.9 g C kg<sup>-1</sup> in soils which were rich in soil microbes like fungi and soil bacteria [60].

## 2.8. Cover crops

The use of cover crops for the maintenance and restoration of SOM and soil productivity is a popular option [61]. Planting cover crops is a promising option to sequester C in cropping systems by the implementation of recommended management practices. The highest CS rate up to 5.3 t C ha<sup>-1</sup> yr.<sup>-1</sup> is observed by cover cropping of olive orchards, vineyards and almond orchards. Soil CS rate tends to be the highest during the first years after the change of the management and progressively attains equilibrium. Soil CS rates in cover cropping are much higher than that of fields with low or no cover cropping which suggests that the adoption of cover cropping is a sustainable and efficient measure to mitigate CC [62].

## 2.9. Soil fertility management

Rice-fallow-rice is one of the dominant cropping systems which has received attention to improve SOM by using organic amendments. Understanding the contributions of organic amendments in CS is important for the estimation of CS, their nutrient supply potential and their role in it. In different organic amendments, poultry manure is found to be more efficient in increasing C and other nutrients in soils and microbial activities which contribute to CS in the rice-rice cropping system [63, 64]. Raw adzuki bean (*Vigna angularis* (Willd.) Ohwi and Ohashi) and wheat (*Triticum aestivum* L.) straw residues can supply C into fields by 499 ± 119 kg C ha<sup>-1</sup> [65]. The Mekong Delta, Vietnam, produces 21 Mt. of rough rice (*Oryza sativa* L.) and an estimated 24 Mt. of rice straw annually. The spread of these crop residues in this area can increase CS and SOM, significantly reducing GHG emissions [66]. Crop residue decomposition acceleration can enhance the SOM [67].

### 3. Organic amendments

#### 3.1. Animal manure

Animal manure is the source of C and the addition of animal manure to different crop fields has impacts on C contents [68]. Different researchers conducted the experiments in Germany to check the soil's C levels. The experiment showed that the annual application rate of 200 Mg ha<sup>-1</sup> yr.<sup>-1</sup> of manure to the crop field shows a high level of SOM with respect to adjacent fields [69]. Powlson reported that the mean annual SOC sequestration rates of three long-term (>49) years of manure applications ranged from 10 to 22 kg C ha<sup>-1</sup> yr.<sup>-1</sup> t<sup>-1</sup> of dry solids, while SOC sequestration rates with shorter-term experiments (8–25 years of farmyard manure, cattle slurry and boiler litter) were from 30 to 200 kg C ha<sup>-1</sup> yr.<sup>-1</sup> t<sup>-1</sup> of dry solids [70]. The experiment was conducted to improve the soil quality and crop productivity. Improved soil properties refer to better C management. Animal manure also increases the salt concentration of the soil. The long-term application of manure increases the SOM significantly [71]. In another study, the farm yard manure was applied to the rice-wheat cropping system with NPK fertilizers and results showed significantly an increase in C sequestration in farm yard manure-applied plots than NPK-applied plots [72]. The same experiment was conducted on the maize-wheat cropping system, but in this experiment, the farm yard manure is applied with green manure and indicates that green manure sequesters more C [73]. It was also observed that the high application of N has the potential to sequester C almost at the rate of 1.0–1.4 Mg ha<sup>-1</sup> yr.<sup>-1</sup> [74].

#### 3.2. Crop residues

The researchers investigated that the annual production of crop residues is about  $3.4 \times 10^9$  tones worldwide. If 15% of the total residue is applied to the soil, it will increase the C contents of soil. The crop residues are the remains of the agricultural crops. The intensive agriculture system increases the crop residue production significantly. This may increase the SOM and soil aggregation and hence C storage [75]. The degradation of crop residue depends upon its composition. For example, it is difficult for microorganisms to start the degradation of the substances which contain a high content of lignin. There three mechanisms, which are classified by different researchers based on the stabilization of SOM, include chemical, biochemical and physical stabilization [76]. Agricultural practices such as the addition of crop residues increase the SOM as well as nutrients contents in the soil by integrated nutrient management [77]. Most studies focus on the fact that the change of crop residue traits has positive effects of the soil CS in organic farming system [78].

#### 3.3. Composting

Composting is the systematic and controlled breakdown of different types of organic matter including animal manure, woody material and other organic waste. The C content is available in the form of plant uptake in the composting. When the compost matures, 50% of C is available in the form of humic substances [79] and is thought to be more stable practically [80]. In the



long-term application of compost, about 8 years or 5 years, a mean  $60 \text{ kg C ha}^{-1} \text{ yr.}^{-1} \text{ t}^{-1}$  of dry solids were monitored [81]. The compost applied in different plots and the soil organic C stock increased significantly compared with the initial stock [82]. It is a win-win condition to increase C storage in the soil as well as plant growth and yield by chemical fertilization. The compost application at the rate of  $10 \text{ Mg ha}^{-1} \text{ yr.}^{-1}$  results in higher CS. This clear cut indicates that composting not only increases the net primary production but also the C content of the soil [83].

### 3.4. Bagasse

The application of different types of biomass in soil is the best technique to enhance CS in the agricultural sites. The application of bagasse as a biomass in the field showed that bagasse has the potential to sequester C at about  $1200\text{--}1800 \text{ t C year}^{-1}$  [84]. The application of biochar produced from bagasse is a very authentic organic amendment to soil for retaining its water content [85]. Another study suggested that Bagasse can be converted into B and applied in the soil and it has the potential to sequester C. The porous and high surface area is efficient for the sequestration of C from the atmosphere. Bagasse (B) produced at  $600^\circ\text{C}$  showed the most adsorption of C ( $73.55 \text{ mg g}^{-1}$  at  $25^\circ\text{C}$ ) [86]. The use of bagasse ash is investigated in an experiment. Different ashes like bagasse and rice husk ash were investigated on wheat soil and the soil organic C content and enzymatic activity were monitored. Bagasse ash increases the soil organic contents at the rate of  $525 \text{ kg ha}^{-1} \text{ y}^{-1}$  while rice husk ash has no increase of SOM. Bagasse ash increases the soil dehydrogenase and cellulose activity. Long-term investigations are needed to check the effect of ash effects on the soil's physical, chemical and biological properties [87].

### 3.5. Wood chips

The world is under threat due to drastic effects of CC, energy access and availability of food. Wood is mostly used as a fuel to cook food and considered as a renewable energy source. Bamboo plantation can sequester C and fix it by producing high biomass. This biomass can be used to generate chips and pellets and as the alternative of fuel; as a result, it can sequester approximately  $1.78 \text{ kg of C}$  [88]. Another research was conducted and wood chips and straw were applied in the soil and the results showed that nitrogen mineralization and nitrification rates were higher significantly in the soil-applied wood chips. The bad thing is that when we applied wood chips in the soil, nitrogen deficiency occurs and then an additional supplement of nitrogen is required [89]. Carbon contents of early woods are higher than late woods [90]. It is produced from wood-based biomass at a low pyrolysis temperature ( $400^\circ\text{C}$ ) suitable for enhancing the cation exchange capacity, whereas B produced from wood-based biomass at a high pyrolysis temperature ( $800^\circ\text{C}$ ) can enhance nitrate adsorption [85].

### 3.6. Biochar

Biochar (B) is usually obtained by the breakdown of crop residues, wood chips, at a low temperature range ( $350\text{--}600^\circ\text{C}$ ) in the atmosphere having very little or no oxygen. If the condition remained optimum during the process of B formation including temperature and oxygen, then almost  $>50\%$  of the C is retained by the B with respect to original biomass [91]. It is resistive to

microbial attack and hence when applied to the soil will remain stable for thousands of years and thus reduce the release of terrestrial C to the atmosphere in the form of CO<sub>2</sub> [92]. It has long-term benefits including increase in soil pH [93], increases in crop yield, maintaining the cation exchange capacity, nutrient retention and water-holding capacity. Biochar also reduces the emissions of others greenhouse gases like methane and nitrous oxides [94]. Increased concentration of nitrogen oxides in the atmosphere affects the plant growth by necrosis, slow photosynthetic rate and increased sensitivity of the plants. Gases usually affect the plants by entering them through the stomata of plants [95]. The B has been classified into two classes on the basis of degradation. Class 1 has the potential to store C in soil to about 21.3% and class 2 has potential of about 32.5%. The presence of alkali metals in the B reduces their stability. The B can store 0.55 Pg CO<sub>2</sub> yr.<sup>-1</sup> in soils over long time use [96]. The findings suggest that the application of B to soil is profitable amendments if the B price is low enough [97]. The response of B at different pH levels was investigated and found that acidic medium emits more carbon dioxide than the alkaline medium. The enhancement of copiotrophic bacteria like gemmatimonadetes and bacteroidetes and the decrease of oligotrophic bacteria increase the C emission in the acidic medium of soil [98]. Biochar-based C management networks have the potential to mitigate CC but the quality of B should be appropriate [99] (**Table 2**).

The studies in China indicate that cultivated and forest soils have the CS potential around 38.5–77 Mt., respectively [107, 108]. The research shows that due to the increase of temperature from South to North, there is also a decrease of soil organic carbon (SOC) [109].

In Belgium in different studies, the C stock was found to be around 319 Mt. and this is due to the increase in mean elevation from Northeast coast to Southeast, and as a result, it leads to a decrease in temperature and an increase in precipitation. Carbon stock is higher in Southeast than Northeast. The C contents in topsoil were found to be 48 t C ha<sup>-1</sup> in Luvisols while 113 t C ha<sup>-1</sup> in Cambisols soil types [110].

Strategy	Area	CS rate (t C ha <sup>-1</sup> )	Observational time	Reference
Organic manure	China	0.62	14–40 y	[100]
Organic matter plus in-organic fertilizer	China	0.62–0.69	03–25 y	[101]
Animal manure	Belgium	0.45	20 y	[102]
Fertilizer plus crop residues	Indonesia	0.52 ± 0.16	40 y	[103]
Inorganic fertilizers	South Korea	0.32 ± 0.29	8 y	[103]
Different crop residues	Nigeria	0.24	18 y	[104]
Crop stubbles	Australia	0.19 ± 0.08	–	[105]
Inorganic fertilizer	South Korea	0.32 ± 0.29	8 y	[103]
Crop residue	Nigeria	0.24	18 y	[104]
Crop stubbles retention	Australia	0.19 ± 0.08	4–40	[105, 106]

**Table 2.** Different strategies and their carbon sequestration potential.

It was found by Indonesian scientists that total SOM was higher if the high clay and silt content was found in soil. The other factors like low pH, rainfall and higher altitude were found responsible for higher soil organic content. The organic content of peatland soil was estimated to be about 33.7 Gt of the 20.9 M ha area of peat soils [111].

Agricultural land of South Korea is about 174 Mt. (1 m depth) for the storage of carbon. Soil organic carbon stocks in grass and agricultural lands were as large as 88 and 68 t C ha<sup>-1</sup>, respectively [112].

A study in Nigeria also revealed that 20–60 t ha<sup>-1</sup> is found in top 0.3 m soil layer and a total of 118 Mg C ha<sup>-1</sup> can be found in the top 1 m. Humid forest zone contains more C than any other zone [113], and the C stock of Australian topsoils was found to be around 25 Gt because of great land mass as well as low temperature [114].

## 4. Conclusions

Greenhouse effect was the natural phenomena, but humans are responsible for the escalation of it leading to the global warming and climate change (CC). Due to climate change, the natural environment is facing different types of unexpected and high-intensity weather events. Climate change mitigation or the solution of all the above problems lies in the reduction of the C concentrations in the atmosphere. There are many sinks for CS including forests, soil, oceans and crop plants. Soil CS and crop production is a better, economical and reliable option because it captures C as well as grows plants which provide food to us. C sequestration in crop lands and rangelands requires certain amounts of organic matter (OM) presence in the soil called soil organic matter (SOM). Organic amendments like animal and poultry manures, the incorporation of different crop residues, different types of compost, sugarcane bagasse, peat soils, different wood chips, B and good agricultural practices like cover crops, nutrient management, mulching, zero and no-tillage techniques, soil biota management and mulching are effectively used for this purpose. These enhance the soil organic matter and improve the soil's physical and chemical properties that help to sequester more C in the soil, which ultimately contributes towards CS and CC mitigation.

## Abbreviations

B	biochar
C	carbon
SOM	soil organic matter
CS	carbon sequestration
CT	conservation tillage

ZT	zero tillage
CoT	conventional tillage
N	nitrogen
SOC	soil organic carbon
CA	conservation agriculture

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## References

- [1] Lal R. Soil carbon sequestration to mitigate climate change. *Geoderma*. 2004;**123**:1-22
- [2] Albrecht A, Kandji ST. Carbon sequestration in tropical agroforestry systems. *Agriculture, Ecosystems & Environment*. 2003;**99**:15-27
- [3] West TO, Marland G. Net carbon flux from agriculture: Carbon emissions, carbon sequestration, crop yield, and land-use change. *Biogeochemistry*. 2003;**63**:73-83
- [4] Schlesinger WH. Carbon sequestration in soils. *Science*. 1999;**284**:2095
- [5] Baker JM, Ochsner TE, Venterea RT, Griffis TJ. Tillage and soil carbon sequestration—What do we really know? *Agriculture, Ecosystems & Environment*. 2007;**118**:1-5
- [6] Post WM, Kwon KC. Soil carbon sequestration and land-use change: Processes and potential. *Global Change Biology*. 2000;**6**:317-327
- [7] Montagnini F, Nair PKR. Carbon sequestration: An underexploited environmental benefit of agroforestry systems. In: Nair PKR, Rao MR, Buck LE, editors. *New Vistas in Agroforestry: A Compendium for 1st World Congress of Agroforestry*. Dordrecht: Springer Netherlands; 2004. pp. 281-295
- [8] West TO, Marland G. A synthesis of carbon sequestration, carbon emissions, and net carbon flux in agriculture: Comparing tillage practices in the United States. *Agriculture, Ecosystems & Environment*. 2002;**91**:217-232
- [9] Lal R. World crop residues production and implications of its use as a biofuel. *Environment International*. 2005;**31**:575-584

- [10] Silver WL, Ostertag R, Lugo AE. The potential for carbon sequestration through reforestation of abandoned tropical agricultural and pasture lands. *Restoration Ecology*. 2000;**8**:394-407
- [11] Lal R. Soil carbon sequestration impacts on global climate change and food security. *Science*. 2004;**304**:1623-1627
- [12] King K. The history of agroforestry. *Agroforestry*. USA: KLGWER Academic Publishers; 1987. pp. 1-11
- [13] Mulumba LN, Lal R. Mulching effects on selected soil physical properties. *Soil and Tillage Research*. 2008;**98**:106-111
- [14] Bannari A, Pacheco A, Staenz K, McNairn H, Omari K. Estimating and mapping crop residues cover on agricultural lands using hyperspectral and IKONOS data. *Remote Sensing of Environment*. 2006;**104**:447-459
- [15] Liebman M, Dyck E. Crop rotation and intercropping strategies for weed management. *Ecological Applications*. 1993;**3**:92-122
- [16] Havlin JL, Kissel DE, Maddux LD, Claassen MM, Long JH. Crop rotation and tillage effects on soil organic carbon and nitrogen. *Soil Science Society of America Journal*. 1990;**54**:448-452
- [17] Govaerts B, Sayre KD, Deckers J. Stable high yields with zero tillage and permanent bed planting? *Field Crops Research*. 2005;**94**:33-42
- [18] Holland J. The environmental consequences of adopting conservation tillage in Europe: Reviewing the evidence. *Agriculture, Ecosystems & Environment*. 2004;**103**:1-25
- [19] Lehmann J, Joseph S. *Biochar for Environmental Management: Science, Technology and Implementation*. USA: Routledge; 2015
- [20] Snapp S et al. Evaluating cover crops for benefits, costs and performance within cropping system niches. *Agronomy Journal*. 2005;**97**:322-332
- [21] Haug R. *The Practical Handbook of Compost Engineering*. USA: Routledge; 2018
- [22] Peterson G, Halvorson A, Havlin J, Jones O, Lyon D, Tanaka D. Reduced tillage and increasing cropping intensity in the Great Plains conserves soil C. *Soil and Tillage Research*. 1998;**47**:207-218
- [23] Mohan D, Singh KP. Single-and multi-component adsorption of cadmium and zinc using activated carbon derived from bagasse—An agricultural waste. *Water Research*. 2002;**36**:2304-2318
- [24] Kumar K, Gupta S, Baidoo S, Chander Y, Rosen C. Antibiotic uptake by plants from soil fertilized with animal manure. *Journal of Environmental Quality*. 2005;**34**:2082-2085
- [25] Crum H, Planisek S. *A Focus on Peatlands and Peat Mosses*. USA: University of Michigan Press; 1992



- [26] Powlson DS, Stirling CM, Thierfelder C, White RP, Jat ML. Does conservation agriculture deliver climate change mitigation through soil carbon sequestration in tropical agro-ecosystems? *Agriculture, Ecosystems & Environment*. 2016;**220**:164-174
- [27] Corbeels M, Marchão RL, Neto MS, Ferreira EG, Madari BE, Scopel E, Brito OR. Evidence of limited carbon sequestration in soils under no-tillage systems in the Cerrado of Brazil. *Scientific Reports*. 2016;**6**:21450
- [28] Aryal JP, Sapkota TB, Jat ML, Bishnoi DK. On-farm economic and environmental impact of zero-tillage wheat: A case of North-west India. *Experimental Agriculture*. 2014;**51**:1-16
- [29] Erenstein O, Farooq U, Malik RK, Sharif M. On-farm impacts of zero tillage wheat in South Asia's rice-wheat systems. *Field Crops Research*. 2008;**105**:240-252
- [30] Erenstein O, Laxmi V. Zero tillage impacts in India's rice-wheat systems: A review. *Soil and Tillage Research*. 2008;**100**:1-14
- [31] Erenstein O. Adoption and Impacts of Zero Tillage as a Resource Conserving Technology in the Irrigated Plains of South Asia. Vol. 19. CIMMYT; 2007
- [32] Landers JN, Sant'Anna De c Barros G, Rocha MT, Manfrinato WA, Weiss J. Environmental impacts of zero tillage in Brazil—A first approximation. In: García-Torres L, Benites J, Martínez-Vilela A, Holgado-Cabrera A, editors. *Conservation Agriculture: Environment, Farmers Experiences, Innovations, Socio-economy, Policy*. Netherlands, Dordrecht: Springer; 2003. pp 341-350
- [33] Kern JS, Johnson MG. Conservation tillage impacts on national soil and atmospheric carbon levels. *Soil Science Society of America Journal*. 1993;**57**:200-210
- [34] Deen W, Kataki PK. Carbon sequestration in a long-term conventional versus conservation tillage experiment. *Soil and Tillage Research*. 2003;**74**:143-150
- [35] Sheehy J, Regina K, Alakukku L, Six J. Impact of no-till and reduced tillage on aggregation and aggregate-associated carbon in Northern European agroecosystems. *Soil and Tillage Research*. 2015;**150**:107-113
- [36] Varvel GE, Wilhelm WW. No-tillage increases soil profile carbon and nitrogen under long-term rainfed cropping systems. *Soil and Tillage Research*. 2011;**114**:28-36
- [37] Luo Z, Wang E, Sun OJ. Can no-tillage stimulate carbon sequestration in agricultural soils? A meta-analysis of paired experiments. *Agriculture, Ecosystems & Environment*. 2010;**139**:224-231
- [38] Christopher SF, Lal R. Nitrogen management affects carbon sequestration in North American cropland soils. *Critical Reviews in Plant Sciences*. 2007;**26**:45-64
- [39] Dolan MS, Clapp CE, Allmaras RR, Baker JM, Molina JAE. Soil organic carbon and nitrogen in a Minnesota soil as related to tillage, residue and nitrogen management. *Soil and Tillage Research*. 2006;**89**:221-231
- [40] Khan SA, Mulvaney RL, Ellsworth TR, Boast CW. The myth of nitrogen fertilization for soil carbon sequestration. *Journal of Environmental Quality*. 2007;**36**:1821-1832. All

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- [41] Havlin JL, Beaton JD, Tisdale SL, Nelson WL. *Soil Fertility and Fertilizers: An Introduction to Nutrient Management*, vol. 515. Upper Saddle River, NJ: Pearson Prentice Hall; 2005
- [42] Bernoux M et al. Cropping systems, carbon sequestration and erosion in Brazil, a review. *Agronomy for Sustainable Development*. 2006;**26**:1-8
- [43] Mandal B et al. The potential of cropping systems and soil amendments for carbon sequestration in soils under long-term experiments in subtropical India. *Global Change Biology*. 2007;**13**:357-369
- [44] Drinkwater LE, Wagoner P, Sarrantonio M. Legume-based cropping systems have reduced carbon and nitrogen losses. *Nature*. 1998;**396**:262
- [45] Kong AYY, Six J, Bryant DC, Denison RF, van Kessel C. The relationship between carbon input, aggregation, and soil organic carbon stabilization in sustainable cropping systems. *Soil Science Society of America Journal*. 2005;**69**:1078-1085
- [46] Sherrod LA, Peterson GA, Westfall DG, Ahuja LR. Cropping intensity enhances soil organic carbon and nitrogen in a no-till agroecosystem. *Soil Science Society of America Journal*. 2003;**67**:1533-1543
- [47] Hutchinson JJ, Campbell CA, Desjardins RL. Some perspectives on carbon sequestration in agriculture. *Agricultural and Forest Meteorology*. 2007;**142**:288-302
- [48] Follett RF. Soil management concepts and carbon sequestration in cropland soils. *Soil and Tillage Research*. 2001;**61**:77-92
- [49] Purakayastha TJ, Rudrappa L, Singh D, Swarup A, Bhadraray S. Long-term impact of fertilizers on soil organic carbon pools and sequestration rates in maize-wheat-cowpea cropping system. *Geoderma*. 2008;**144**:370-378
- [50] Kahlon MS, Lal R, Ann-Varughese M. Twenty two years of tillage and mulching impacts on soil physical characteristics and carbon sequestration in Central Ohio. *Soil and Tillage Research*. 2013;**126**:151-158
- [51] Saroa GS, Lal R. Soil restorative effects of mulching on aggregation and carbon sequestration in a Miamian soil in central Ohio. *Land Degradation & Development*. 2003;**14**:481-493
- [52] Duiker SW, Lal R. Crop residue and tillage effects on carbon sequestration in a Luvisol in central Ohio. *Soil and Tillage Research*. 1999;**52**:73-81
- [53] Windeatt JH, Ross AB, Williams PT, Forster PM, Nahil MA, Singh S. Characteristics of Bs from crop residues: Potential for C sequestration and soil amendment. *Journal of Environmental Management*. 2014;**146**:189-197
- [54] Van De Vreken P, Gobin A, Baken S, Van Holm L, Verhasselt A, Smolders E, Merckx R. Crop residue management and oxalate-extractable iron and aluminium explain

- long-term soil organic carbon sequestration and dynamics. *European Journal of Soil Science*. 2016;**67**:332-340
- [55] Lal R. Residue management conservation tillage and soil restoration for mitigating greenhouse effect by CO<sub>2</sub>-enrichment. *Soil and Tillage Research*. 1997;**43**:81-107
- [56] Jiao N et al. Mechanisms of microbial carbon sequestration in the ocean—Future research directions. *Biogeosciences*. 2014;**11**:5285-5306
- [57] Wang CJ, Pan GX, Tian YG, Li LQ, Zhang XH, Han XJ. Changes in cropland topsoil organic C with different fertilizations under long-term agro-ecosystem experiments across mainland China. *Science China. Life Sciences*. 2010;**53**:858-867
- [58] Doran JW. Soil microbial and biochemical changes associated with reduced tillage. *Soil Science Society of America Journal*. 1980;**44**:765-771
- [59] Six J, Frey S, Thiet R, Batten K. Bacterial and fungal contributions to carbon sequestration in agroecosystems. *Soil Science Society of America Journal*. 2006;**70**:555-569
- [60] Bailey VL, Smith JL, Bolton H. Fungal-to-bacterial ratios in soils investigated for enhanced C sequestration. *Soil Biology and Biochemistry*. 2002;**34**:997-1007
- [61] Olson K, Ebelhar SA, Lang JM. Long-term effects of cover crops on crop yields, soil organic carbon stocks and sequestration. *Open Journal of Soil Science*. 2014;**4**:284
- [62] Vicente-Vicente JL, García-Ruiz R, Francaviglia R, Aguilera E, Smith P. Soil carbon sequestration rates under Mediterranean woody crops using recommended management practices: A meta-analysis. *Agriculture, Ecosystems & Environment*. 2016;**235**:204-214
- [63] Rahman F, Rahman MM, Rahman GKMM, Saleque MA, Hossain ATMS, Miah MG. Effect of organic and inorganic fertilizers and rice straw on carbon sequestration and soil fertility under a rice–rice cropping pattern. *Carbon Management*. 2016;**7**:41-53
- [64] Cheng W et al. Changes in the soil C and N contents, C decomposition and N mineralization potentials in a rice paddy after long-term application of inorganic fertilizers and organic matter. *Soil Science and Plant Nutrition*. 2016;**62**:212-219
- [65] Koga N, Hayashi K, Shimoda S. Differences in CO<sub>2</sub> and N<sub>2</sub>O emission rates following crop residue incorporation with or without field burning: A case study of adzuki bean residue and wheat straw. *Soil Science and Plant Nutrition*. 2016;**62**:52-56
- [66] Arai H, Hosen Y, Pham Hong VN, Thi NT, Huu CN, Inubushi K. Greenhouse gas emissions from rice straw burning and straw-mushroom cultivation in a triple rice cropping system in the Mekong Delta. *Soil Science and Plant Nutrition*. 2015;**61**:719-735
- [67] Nakajima M et al. Modeling aerobic decomposition of rice straw during the off-rice season in an Andisol paddy soil in a cold temperate region of Japan: Effects of soil temperature and moisture. *Soil Science and Plant Nutrition*. 2016;**62**:90-98
- [68] Stewart CE, Paustian K, Conant RT, Plante AF, Six J. Soil C sequestration: Concept, evidence and evaluation. *Biogeochemistry*. 2007;**86**:19-31

- [69] Blair N, Faulkner RD, Till AR, Korschens M, Schulz E. Long-term management impacts on soil C, N and physical fertility-Part II: Bad Lauchstadt static and extreme FYM experiments. *Soil and Tillage Research*. 2006;**91**:39-47
- [70] Powlson DS, Whitmore AP, Goulding WT. Soil C sequestration to mitigate climate change: A critical re-examination to identify the true and the false. *European Journal of Soil Science*. 2011;**62**:42-55
- [71] Guo ZC, Zhang ZB, Zhou H, Rahman MT, Wang DZ, Guo XS, Li LJ, Peng XH. Long-term animal manure application promoted biological binding agents but not soil aggregation in a Vertisol. *Soil and Tillage Research*. 2018;**180**:232-237
- [72] Naresh RK, Gupta RK, Minhas PS, Rathore RS, Ashish and D, Purushottam. Climate change and challenges of water and food security for smallholder farmers of Uttar Pradesh and mitigation through C sequestration in agricultural lands: An overview. *International Journal of Chemical Studies*. 2017
- [73] Kukal SS, Rasool R, Benbi DK. Soil organic C sequestration in relation to organic and inorganic fertilization in rice-wheat and maize-wheat systems. *Soil and Tillage Research*. 2009;**102**:87-92
- [74] Liebig MA, Varvel GE, Doran JW, Wienhold BJ. Crop sequence and nitrogen fertilization effects on soil properties in the western Corn Belt. *Soil Science Society of America Journal*. 2002;**66**:596-601
- [75] Novelli LE, Caviglia OP, Piñeiro G. Increased cropping intensity improves crop residue inputs to the soil and aggregate-associated soil organic C stocks. *Soil and Tillage Research*. 2017;**165**:128-136
- [76] Christensen BT. Physical fractionation of soil and structural and functional complexity in organic matter turnover. *European Journal of Soil Science*. 2001;**52**(3):345-353
- [77] Fang Y, Nazaries L, Singh BK, Singh PB. Microbial mechanisms of C priming effects revealed during the interaction of crop residue and nutrient inputs in contrasting soils. *Global Change Biology*. 2018;**24**(7):2775-2790
- [78] Pablo GP, Andreas G, Helene BJ, Lijbert B, Filipe C, Helena C, Jean-Christophe C, Gerlinde DD, Tina DH, Arnaud F, Katarina H, Sandra L, Nicolas L, Martina L, Paul M, Martínez-García LB, da Silva PM, Adrian M, Eduardo N, Filipa R, Sarah S, José PS, Rubén M. Crop traits drive soil C sequestration under organic farming. *Journal of Applied Ecology*. 2018;**00**:1-10
- [79] Inbar Y, Chen Y, Hadar Y. Humic substances formed during the composting of organic matter. *Soil Science Society of America Journal*. 1990;**54**:1316-1323
- [80] Post WM, Kwon KC. Soil C sequestration and land-use change: processes and potential. *Global Change Biology*. 2000;**6**:317-327
- [81] Wallace P. Compost use in agriculture consolidated report phase 2. Grant Scape and the Applied Research Forum. London: Routledge, Taylor and Francis Group; 2007



- [82] Farina R, Testani E, Campanelli G, Leteo F, Napoli R, Canali S, Tittarelli F. Potential C sequestration in a Mediterranean organic vegetable cropping system. A model approach for evaluating the effects of compost and agro-ecological service crops (ASCs). *Agricultural Systems*. 2018;**162**:239-248
- [83] Baldi E, Cavani L, Margon A, Quartieri M, Sorrenti G, Marzadori C, Toselli M. Effect of compost application on the dynamics of C in a nectarine orchard ecosystem. *Science of the Total Environment*. 2018;**637-638**:918-925
- [84] Kameyama K, Shinogi Y, Miyamoto T, Agarie K. Estimation of net C sequestration potential with farmland application of bagasse charcoal: Life cycle inventory analysis through a pilot sugarcane bagasse carbonisation plant. *Soil Research*. 2010;**48**:586-592
- [85] Kameyama K, Iwata Y, Miyamoto T. B amendment of soils according to their physico-chemical properties. *Japan Agricultural Research Quarterly*. 2017;**51**:117-127
- [86] Creamer AE, Gao B, Zhang M. C dioxide capture using B produced from sugarcane bagasse and hickory wood. *Chemical Engineering Journal*. 2014;**249**:174-179
- [87] Benbi DK, Thind HS, Sharma S, Brar K, Toor AS. Bagasse ash application stimulates agricultural soil C sequestration without inhibiting soil enzyme activity. *Communications in Soil Science and Plant Analysis*. 2017;**48**:1822-1833
- [88] Patel B, Gami B, Patel P. C Sequestration by Bamboo Farming on Marginal Land and Sustainable Use of Wood Waste for Bioenergy: Case Studies from Abellon Clean Energy. Singapore: Springer Singapore; 2017. pp. 451-467
- [89] Margenot AJ, Griffin DE, Alves BSQ, Rippner DA, Li C, Parikh SJ. Substitution of peat moss with softwood B for soil-free marigold growth. *Industrial Crops and Products*. 2018;**112**:160-169
- [90] Lamloom SH, Savidge RA. A reassessment of C content in wood: variation within and between 41 North American species. *Biomass and Bioenergy*. 2003;**25**:381-388
- [91] Laird DA. The charcoal version: A win-win scenario for simultaneously producing bio-energy, permanently sequestering C, while improving soil and water quality. *Agronomy Journal*. 2008;**100**:178-181
- [92] Lehmann J. Bio-energy in the black. *Frontiers in Ecology and Environment*. 2007;**5**:381-387
- [93] Hecht SB. Agroforestry in the Amazon Basin: Practice, theory and limits of a promising land use. In: Hecht SB, editor. *Amazonia: Agriculture and Land Use Research*. Proc. Int. Conf., Cali, Colombia; 1982. pp. 331-372
- [94] Rondon M, Ramirez JA, Lehmann J. Charcoal additions reduce net emissions of greenhouse gases to the atmosphere. In: *Proceedings of the 3rd USDA Symposium on Greenhouse Gases and C Sequestration*; March 21-24, 2005; Baltimore, USA. 2005. pp. 28
- [95] Zeeshan N, Nasir MS, Nasir A, Saifullah, Farooqi ZR, Naveed K. Air contamination and its impact on plants, humans and water of Pakistan—A review. *Journal of Applied Environmental and Biological Sciences*. 2016;**6**(8), 32-39



- [96] Windeatt JH, Ross AB, Williams PT, Forster PM, Nahil MA, Singh S. Characteristics of biochars from crop residues: Potential for carbon sequestration and soil amendment. *Journal of Environmental Management*. 2014;**146**:189-197
- [97] Galinato SP, Yoder JK, Granatstein D. The economic value of B in crop production and C sequestration. *Energy Policy*. 2011;**39**:6344-6350
- [98] Sheng Y, Zhu L. B alters microbial community and C sequestration potential across different soil pH. *Science of The Total Environment*. 2018;**622-623**:1391-1399
- [99] Belmonte BA, Benjamin MFD, Tan RR. Bi-objective optimization of B-based C management networks. *Journal of Cleaner Production*. 2018;**188**:911-920
- [100] Wang X, Feng Y, Liu J, Lee H, Li C, Li N, Ren N. Sequestration of CO<sub>2</sub> discharged from anode by algal cathode in microbial carbon capture cells (MCCs). *Biosensors and Bioelectronics*. 2010;**25**:2639-2643
- [101] Jin L, Li Y, Gao Q, Liu Y, Wan Y, Qin X, Shi F. Estimate of C sequestration under cropland management in China. *Scientia Agricultura Sinica*. 2008;**41**:734-743. in Chinese with English summary
- [102] Buysse P, Roisin C, Aubinet M. Fifty years of contrasted residue management of an agricultural crop: impacts on the soil C budget and on soil heterotrophic respiration. *Agriculture, Ecosystems and Environment*. 2013;**167**:52-59
- [103] Minasny B, McBratney AB, Hong SY, Sulaeman Y, Kim MS, Zhang YS, Kim YH, Han KH. Continuous rice cropping has been sequestering C in soils in Java and South Korea for the past 30 years. *Global Biogeochemical Cycles*. 2012:26-34
- [104] Raji BA, Ogunwole JO. Potential of soil C sequestration under various land use in the sub-humid and semi-arid savanna of Nigeria: Lessons from long-term experiments. *International Journal of Soil Science*. 2006;**1**(1):33-43
- [105] Sanderman J, Farquharson R, Baldock J. Soil C sequestration potential: A review for Australian agriculture. A report prepared for the Department of Climate Change and Energy Efficiency CSIRO National Research Flagships; 2010
- [106] Lam SK, Chen D, Mosier AR, Roush R. The potential for C sequestration in Australian agricultural soils is technically and economically limited. *Scientific Report*. 2013;**3** (Article number: 2179)
- [107] Tsai CC, Chen ZS, Hseu ZY, Duh CT, Guo HY. Organic carbon storage and management strategies of the forest soils on the forest soil survey database in Taiwan. In: Chen ZS, Agus F, editors. In: *Proceedings of International Workshop on Evaluation and Sustainable Management of Soil Carbon Sequestration in Asian Countries*; Sep 28-29, 2010; Bogor, Indonesia. 2010. pp. 85-102
- [108] Jien SH, Hseu ZY, Guo HY, Tsai CC, Chen ZS. Organic carbon storage and management strategies of the rural soils on the basis of soil information system in Taiwan. In: Chen ZS, Agus F, editors. In: *Proceedings of International Workshop on Evaluation and*

Sustainable Management of Soil Carbon Sequestration in Asian Countries; Sep 28-29, 2010; Bogor, Indonesia. 2010. pp. 125-137

- [109] Tsui CC, Tsai CC, Chen ZS. Soil organic carbon stocks in relation to elevation gradients in volcanic ash soils of Taiwan. *Geoderma*. 2013;**209**:119-127
- [110] National Inventory Report (NIR). Belgium's greenhouse gas inventory (1990-2014). National Inventory Report submitted under the United Nations Framework Convention on Climate Change. Brussels: VMM, VITO, AWAC, IBGE, IRCEL, ECONOTEC; 2016. 360 pp
- [111] Wahyunto DA, Agus F. Distribution, properties, and carbon stock of Indonesian Peatland. In: Chen ZS, Agus F, editors. In: Proc. of Int. Workshop on Evaluation and Sustainable Management of Soil Carbon Sequestration in Asian Countries (ISRI-FFTC-NIAES, Bogor); Sept. 28-29, 2010; Bogor, Indonesia. 2010. pp. 187-204
- [112] Hong SY, Minasny B, Zhang YS, Kim YH, Jung KH. Digital soil mapping using legacy soil data in Korea. In: Proceedings of the 19th World Congress of Soil Science, Soil Solutions for a Changing World; 1-6 August 2010; Brisbane, Australia. 2010
- [113] Akpa SIC, Odeh IOA, Bishop TFA, Hartermink AE, Amapu IY. Total soil organic carbon and carbon sequestration potential in Nigeria. *Geoderma*. 2016;**271**:202-215
- [114] Viscarra Rossel RA, Webster R, Bui EN, Baldock JA. Baselinemap of organic carbon in Australian soil to support national carbon accounting and monitoring under climate change. *Global Change Biology*. 2014;**20**:2953-2970

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