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Farmer's Perception towards Mitigating Climate Change through Adoption of Soil Carbon Sequestration Practices: A Review Analysis

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Climate change is one of the most severe global environmental issues. Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases (F) are the principal greenhouse gases (GHGs) whose atmospheric concentrations are escalating. According to [1], agricultural soils have the ability to mitigate GHG emissions by 89% through the sequestration of carbon and an additional 2% and 9% through the mitigation of N2O and CH4, respectively. The process of capturing and long-term stabilisation of CO_2 in the soil is known as soil carbon sequestration. Increased food production, better soil health, diversified ecosystem services, and reduced environmental footprints

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are all the benefits of practices increasing soil organic carbon (SOC). These techniques include planting woods, managing nutrients by using compost, sludge and green manure, and mulching [2]. Additionally, they have the ability to reduce GHG emissions by up to 8% by mitigating around 18 Mg C ha^{-1} C year $^{-1}$ (0-15 cm soil layer). Farmers and society as a whole may benefit from this approach [3]. Supporting campaigns and initiatives to boost soil C sequestration is crucial, both on a policy level and through programmes. Additional studies needs to be done to determine the benefits of C sequestration on soil quality precisely, which encourages farmers to adopt more C-positive agricultural practices that improve productivity, as well as water and air quality [4].

Keywords: Soil carbon sequestration; carbon sequestration practices; green house gas (GHG); mitigation; perception; adoption.

1. INTRODUCTION

The whole terrestrial life relies on the multiple functions and ecosystem services provided by soil, a significant component of land. Accelerated erosion, salinization, elemental imbalance, acidification, depletion of soil organic carbon (SOC), reduction in soil biodiversity, and degeneration of soil structure and tilth are the main contributors to soil degradation, which is the loss of the soil's capacity to support functions and offer ecosystem services. Social, economic, political, and cultural variables have a significant impact on the positive feedbacks between soil degradation and climate change. Poverty, despair and the disintegration of society are all closely tied to the effects of soil erosion and climate change. Since majority of the population directly rely on agriculture and natural ecosystems for their livelihoods, developing nations like India are more vulnerable to climate change. It is technically possible to sequester carbon and offset anthropogenic emissions, improve the environment, and increase and maintain agronomic productivity by restoring degraded and desertified soils, converting marginal agricultural areas to rangeland and forest land, and adopting recommended management practices. Due to agriculture and its associated deforestation, biomass burning, soil tillage, cultivation of paddy rice (Oryza sativa), and domestication of cattle, the terrestrial biosphere and soils have been the source of GHGs (i.e., CO_2, CH_4, and N_2O) for thousands of years [5]. According to [6], agricultural soils may account for around 89% of the GHG mitigation potential through C sequestration and have an additional 2% and 9% mitigation potential for N_2O and CH_4.This leads to an estimated 5–14% reduction in emissions over the course of 5–10 decades (with agricultural systems having the ability to store up to 1400–2900 Mt CO_2 equivalent annually [7]. Because of their capacity to store substantial quantities of organic C, soils have been a primary focus of increasing soil C storage [8]. According to [7], this leads to an estimated 5–14% reduction in emissions over the course of 5–10 decades, with agricultural systems having the ability to store up to 1400–2900 Mt CO_2 equivalents annually. Because of their capacity to store substantial quantities of organic C, soils have been a primary focus of increasing soil C storage [8].

The irreversible spread of desert landforms and landscapes to regions where they were not present recently is known as desertification [9]. In addition to any potential effects of climate change, long-term and persistent mismanagement by extractive practices also contributes to soil deterioration and desertification. According to reports, the Amazon Basin's tropical wet forest is being replaced by savanna (grass) vegetation as a result of changes in land use, fire regimes, and climate change [10]. Erosion and salinization, two of the main processes of desertification, are also impacted by climate change. By tillage, wind, gravity, raindrop splash, surface run-off, stream movement, coastal processes, and chemical dissolution, soil can be physically removed. Run-on and inundation, sedimentation, non-point source pollution, and the release of greenhouse gases (GHGs) into the atmosphere all contribute to the off-site consequences of erosion. Accelerated erosion has enormous regional and worldwide agronomic, economic, and environmental implications. The already minimal amount of SOC stored in these soils may decrease as the dryland tropics become more gradually desertified [11]. Additionally, due to desertification, the GHG emissions from these fragile and ecologically sensitive ecosystems may change.

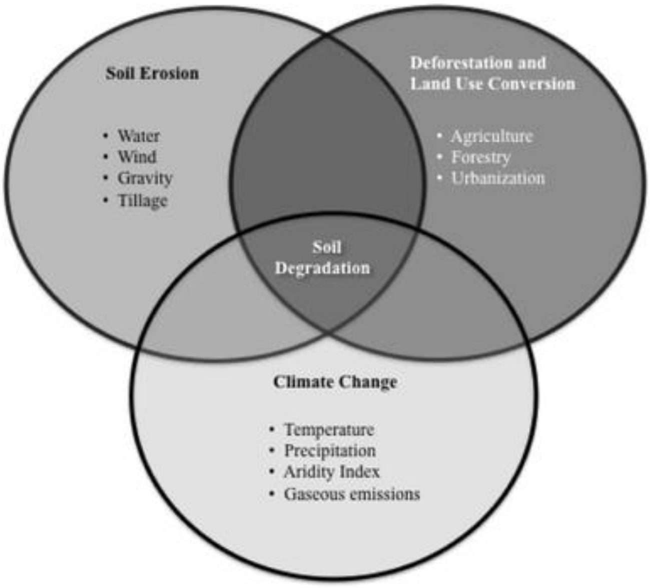

Fig. 1. Interaction of soil degradation with soil erosion, climate change and deforestation/ land use conversion [5]

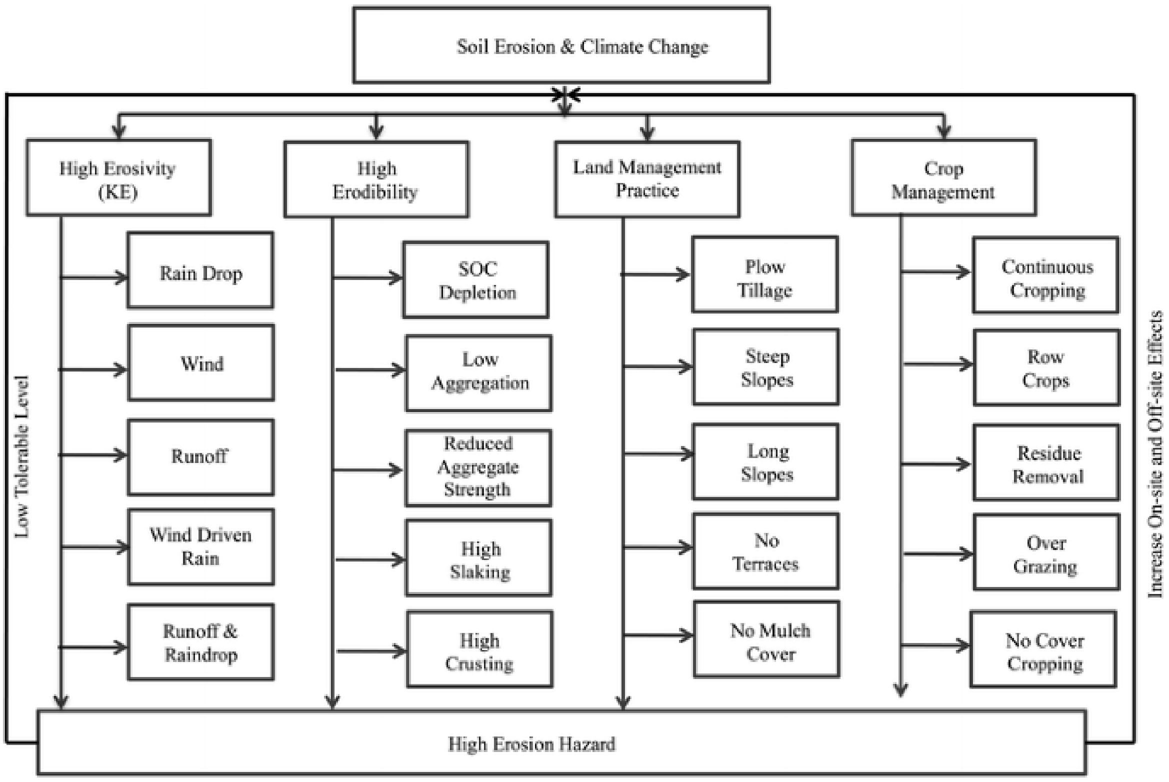

Fig. 2. Determinants of soil erosion and climate change [5]

KE= Kinetic Energy

Climatic erosivity, soil erodibility, and crop and land management techniques all affect the risk of soil erosion. All of these factors may be affected by climate change, which will also significantly increase the erosion risk. Increased wind speed and erosivity, increased rainfall intensity and kinetic energy, increased run-off velocity and shearing, and greater sediment carrying capacity would all result from more frequent and more intense extreme events. Additionally, the erosivity of wind-driven rain and shallow overland flow affected by droplets is greater than that of rain without wind and laminar overland flow. As aggregate formation and strength decline due to an increase in slaking brought on by a fall in SOC concentration, soil erodibility rises [5]. Hence ongoing efforts have been made to encourage sustainable land use through the adoption of practices that could boost agricultural output, income, and the sustainable use of natural resources [12]; for instance, through establishing Sustainable Land management (SLM) practices and restoring deteriorated land [13,14]. However, despite the use of such measures, a considerable improvement in agricultural productivity has not noticed since the agricultural land continues to be degraded. Because SLM practices have not been fully adopted and, when they have, they have not been properly carried out [14]. One of the low cost SLM technologies that have several advantages, including improving soil fertility and raising farm output, is the adoption of soil carbon enhancing practices [15]. Hence these practices increase farmer income and ensure food security.

2. SOIL CARBON SEQUESTRATION PRACTICES FOR FARMER'S ADOPTION

The technique of capturing and permanently storing CO_2 in a stable form inside the soil is known as soil carbon sequestration. The following six soil C management strategies were suggested by [16] to increase SOC: (1) minimal soil disturbance; (2) maintenance of permanent ground cover; (3) intensification of nutrient recycling mechanisms; (4) creation of a positive nutrient balance; (5) enhancement of biodiversity; and (6) reduction in losses of water and nutrients. He felt that a C-management strategy should have potential for lowering GHG emissions in addition to being able to boost SOC content. Carbon management practices are aimed at increasing the ecosystem C balance by applying more carbon into the soil (for example, by planting crops), increasing below- and above-ground biomass (for example, through forestry and agroforestry), sequestering SOC (for all ecosystems), and also lowering C losses from the soil [17], SOC stocks in soil can be maintained by avoiding poor land use, using management strategies, and restoring degraded land [17,18]. Therefore, implementing Recommended Management Practices (RMPs) on agricultural soils can improve water quality, the environment, food security and agro-industries while reducing the rate of atmospheric CO_2 enrichment. RMP adoption results in measured soil C sequestration rates ranging from 50 to 1000 kg/ha/year. The global potential for SOC sequestration through these methods is 0.9–0.3 Pg C/year, which may counteract a quarter to a third of the predicted 3.3 Pg C/year yearly rise in atmospheric CO_2. The potential for soil C sequestration to accumulate over 25 to 50 years is 30 to 60 Pg. There is no doubt that the practices utilized to store carbon in the soil are advantageous. Because they contribute in soil restoration, increased biomass production, water purification (both surface and ground), and a decrease in atmospheric CO_2 enrichment by balancing emissions from fossil fuels [5].

Table 1. Comparison between traditional and Recommended Management Practices (RMP's) in relation to soil organic carbon sequestration [2]

S. No	Traditional methods	Recommended management practices
1	Biomass burning and residue removal	Residue returned as surface mulch
2	Conventional tillage and clean cultivation	Conservation tillage, no till and mulch farming
3	Bare/idle fallow	Growing cover crops during the off season
4	Continuous monoculture	Crop diversions with high diversity
5	Low input subsistence farming and soil fertility mining	Judicious use of farm input
6	Intensive use of chemical fertilizers	Integrated nutrient management with compost, bio-solids and nutrient cycling, precision farming
7	Intensive cropping	Integrating trees and livestock with crop production
8	Surface flood irrigation	Drip, furrow or sub irrigation
9	Indiscriminate use of pesticides	Integrated Pest Management
10	Cultivating marginal soils	Conservation reserve program, restoration of degraded soils through land use change

3. CARBON SEQUESTRATION PRACTICES BY FARMERS - REVIEW AND RESULTS

3.1 Tillage and Land Levelling

The possibility of zero tillage to increase soil carbon storage has been frequently reported [19,20,21]. Zero tillage and reduced tillage demand less energy, which results in less GHG emissions [22,23]. In Zero tillage-based wheat and maize systems, GHG emissions were decreased by 1.5 Mg CO_2-e ha^{-1} $year^{-1}$ [22,24]. Zero/No-tillage combined with crop residue retention in the field or usage as mulch aids in enhancing water and fertilizer use efficiency and sequestering a very considerable amount of atmospheric CO_2 [25]. When compared to conventional tillage, No-Tillage (NT) considerably enhanced the plow layer SOC stocks [26]. The transition from conventional to no-tillage practices effectively protects soils, improves their quality or slows the rate at which soil organic matter depletes and increases cropping system's resilience [27]. When compared to conventional tillage, soils sequestered considerably more SOC across the entire profile (0-50 cm soil depth), with a more prominent effect at 0-15 cm soil depth [28]. Due to traditional land-levelling practices, the majority of agricultural areas in South Asia are not properly levelled [29,30]. The effect is felt for a long period of time, although soil aggregates are stabilized under reduced and zero tillage practices, which physically prevent C from mineralization [31-33]. According to [34], proper land levelling increases crop growth and yield, as well as the effectiveness of input utilization. By enhancing water and nitrogen use efficiency, Precision Land Levelling (PLL) is known to reduce GHG emissions [35]. Laser Land Levelling (LLL) makes a substantial contribution to CC adaptation and mitigation [36]. A dual contribution is made to CC mitigation. Reduced demand for irrigation, which results in a 163,600 MT CO_2eq reduction in fuel use and GHG emissions annually, as well as reduced demand for tillage operations, which saves an additional 19,500 MT CO_2e annually [27]. Age, climatic context, slope gradient, and terracing land use were important determinants for SOC sequestration [37].

3.2 Crop Residue and Irrigation Management

Crop residue return, or the biomass that is returned after harvesting, has beneficial effects on SOC, yet the degree to which it is effective depends on the tillage practices used [38,39]. The soil carbon sequestration is increased when residues are left on the soil surface [40-42]. According to [40], the C sequestration is positively correlated with the amount of residue return. Improved crop cultivars, paddy-upland rotation, employing legumes in rotation, and optimum fertilizer application are few of the management practices for increasing crop residue return to the soil [18,43]. Retaining crops can lower the need for fertilizer [44,45], which may minimize GHG emissions. Since biochar can prevent the release of CO_2 by stabilizing decaying organic matter and can last in soil for hundreds or even thousands of years, it has the potential to reduce global GHG emissions by 12% [46]. Biochar is a synthetic product made from crop residues and other organic sources. [47] projected a decrease in SOC in the soils with no residues since there wasn't enough accessible C produced from residues for microbial use. When compared to the conventional tillage system, a rice-wheat system would be a bigger sink of organic carbon with residue application under the no-tillage system than with or without residue application [28]. The numerous farmers switching to no-till farming in the Corn Belt may result in a significant sink for atmospheric CO_2 depending on how much crop residue is returned to the soil [48]. [49] confirmed the potential of irrigation to increase soil C stocks. The irrigated fields (IRR) showed increased C inputs and larger SOC stocks than the dryland cultivated fields (DRY) [50]. Soil acts as a sink for global C, which can be influenced by the water regime and organic matter (OM) management in field [49]. [51] indicated that long-term irrigated farming can significantly increase SOC. Farming practices that improve Nitrogen and Water Use Efficiency (NUE and WUE) reduce soil disturbance and erosion, increase plant biomass, and together affect N availability and SOC stock [52]. By improving Net Primary Productivity (NPP) and by ensuring addition of biomass to soil, improved water management improves C sequestration [18,53]. According to estimates by [54], better water management might reduce greenhouse gas emissions by 1.14 t CO_2-e ha^{-1} $year^{-1}$. Through increased microbial activity, drip irrigation with repeated wetting-drying cycles may encourage soil CO_2 emission [55]. Micro-irrigation/fertigation lowers the Global Warming Potential (GWP) by reducing N losses as well [56]. The C footprint of pumping water is reduced through reduced irrigation [57].

3.3 Manure and Nutrient Management

From 70% of the total manure generated in the early 1970s to 30% in the early 1990s, India's availability of manure as a source of nutrients and C in agricultural practices has decreased [44]. In India, dung production totals 335 Mt annually, of which 225 Mt remain for agriculture usage. According to [45], this only represents one-third of the FYM that the nation needs to have in order to fully realize its total C sequestration potential. Compost and other organic manures can improve soil C stocks [14], but they may also raise CO_2 emissions [46]. By providing enzyme-producing microbes such as C and N substrates, organic manure application can promote SOM [47], thus enhancing the structure and diversity of the microbial community [48]. NPK treatment alone sequestered C at a rate of 0.16 Mg C ha^{-1} $year^{-1}$, whereas application of NPK along with FYM sequestered C at a rate of 0.33 Mg C ha^{-1} $year^{-1}$ [45]. Even in a hot, semi-arid region, FYM combined with Integrated Nutrient Management (INM) may enhance soil SOC [49]. In an extensive study, [50] observed soil C accumulation in a triple-cereal cropping system (rice, rice, and wheat) with organic (FYM or compost) amendment. The addition of organic material raised SOC in a rice-wheat cropping system by 18 to 62% as compared to NPK [51]. Similar results were found by [52] who found that adding FYM to rice-wheat cropping systems in India and Nepal increased SOC accumulation from 0.08 to 0.98 Mg C ha^{-1} yr^{-1}. When manures were added to various types of soil, some researchers observed greater GHG fluxes (CH_4 and N_2O emissions) [53,54]. [55] found that a soybean-wheat cropping system with an organic amendment increased SOC stocks, N_2O and CO_2 emissions, but the yearly GWP was reduced.

The application of N fertilizer from the right source, at the right dose, right time, and in the right place enhances crop yield, N use efficiency, and SOC storage, and mitigates GHG emissions [56]. Optimum and balanced doses of nutrients maximize crop yields, resulting in relatively more C inputs from both above and below-ground plant biomass to the soil [4]. ‘Nutrient Expert’-based management reduced on average 13% of GHG emissions from rice, wheat, and maize compared with farmer’s fertilizer practices [57,21]. Enhanced fertility management can improve SOC content at the rate of 0.05–0.15 Mg ha^{-1} $year^{-1}$ [2]. Crop production, N use efficiency, SOC storage, and GHG emissions are all improved by administering N fertilizer from the appropriate source, at the right dose, at the right time, and in the right place [56]. Maximising crop yields with optimal and balanced nutrient dosages causes significantly greater C inputs from both above- and below-ground plant biomass to the soil. [4]. When compared to farmer's fertilizer practices, "Nutrient Expert"-based management decreased GHG emissions from rice, wheat, and maize by an average of 13% emissions from rice, wheat, and maize compared with farmer’s fertilizer practices [Improved fertility control can raise SOC content by 0.05-0.15 Mg ha^{-1} $year^{-1}$ [2]. According to a meta-analysis by [58], N fertilization encourages SOC storage in agricultural soils everywhere over the world. In the opinion of [59], the impacts of balanced fertilization on crop development resulted in a favourable influence on soil C sequestration. Due to the higher C input associated with increased primary production and crop residues returned to the soil, balanced fertilization (N120 P30 K30) improved SOC concentration in rice-wheat and maize-wheat cropping systems [60]. The Government of India has launched a "Soil Health Management (SHM)” programme under the National Mission for Sustainable Agriculture [61] to enhance soil health and soil productivity through balanced fertilization. Through the careful use of chemical fertilizers, including secondary- and micro-nutrients, along with organic manures and bio-fertilizers, the SHM programme seeks to achieve Integrated Nutrient Management (INM). According to the SHC-based suggestions, crop yield increased by 5-6% and chemical fertilizer use was reduced by 8–10% [62].

3.4 Crop Variety and Pest Management

In lower soil profiles, crops and crop cultivars with deep roots can store more [63]. Growing deep-rooted crops also improves SOC stocks [4,39], reduces nitrate leaching to groundwater and thereby reduces N_2O emission [64,65], and extracts nutrients and moisture from deeper soil layers [66]. The need for tillage may be greatly reduced by deep-rooted perennial crops as well [39]. According to [67], plants that possess improved root architecture can enhance soil structure, hydrology, drought tolerance, and N usage efficiency [68,69] are more examples of plants with enhanced root design. [70] contrasted the amount of assimilated C from traditional and new wheat varieties that were transmitted underground and stabilized in the soil. According to the authors, older wheat cultivars containing greater root biomass transferred more assimilated C down the soil profile than more recent cultivars. A new "Rhizo-Engine framework" stressing a comprehensive strategy for exploring plant root impacts on SOC sequestration and the vulnerability of SOC stocks to climate and land-use changes was recently developed by [71]. According to [72], the mycorrhizal fungi can boost C sequestration by "enhanced weathering" of silicate rocks via vigorous interactions. While the use of pesticides improves the amount of carbon dioxide (CO_2) capture via higher crop yield, it also increases the amount of greenhouse gases (GHGs) emitted during the manufacturing, distribution, and application of synthetic pesticides [73]. According to [28], Integrated Pest Management (IPM) can boost crop yields while reducing pesticide usage. IPM can increase agricultural yields by more than 40% while lowering the requirement for pesticides by 31%, according to [74]. According to research, any pest management techniques that minimize foliar spraying are capable of lowering greenhouse gas emissions [75]. Climate-Smart Pest Management (CSPM) is a cross-sectoral approach to managing pests [76]. Its aim is to decrease crop losses brought on by pests, enhances ecosystem services, lowers GHG emissions, and increases the resilience of the agricultural system [77].

3.5 Crop Rotation and Fallow Management

According to studies by [78] and [50], the inclusion of a dual- or multi-purpose legume (grain, green manure, and forage) in a rotation is likely to balance the inputs of organic and inorganic fertilizers and its impact on SOC stocks. In legume-cereal crop rotations, legumes with the ability to fix atmospheric nitrogen increase biomass production, crop residue inputs, and ultimately the total SOC [79,80]. SOC in agricultural soils can be improved by reducing overgrazing (which reduces Net Primary Production and increases CH_4 flow and animal respiration), balancing SOM decomposition through manures, crop residues, and litter, and increasing the mean annual Net Primary Production (NPP) [81]. Increasing soil biodiversity can result in higher SOC stocks and more stabilised SOC [82,83,84]. According to [85], the incorporation of grain sorghum, instead of continuous soybean farming boosted soil organic C and N levels and that cultivating high residue crops coupled with minimal tillage could increase production. In accordance with [86], a cover crop used to cover the ground surface during the fallow season prevents nutrients leaching from the soil profile and supplies nutrients to the primary crops. According to [86], by using cover crops, SOC loss was decreased. To increase soil fertility, especially soil C, in intensive double-cropping areas, a short-duration cover crop like Sesbania can be cultivated [87]. According to [86], growing cover crops on 25% of the world's farmland could reduce greenhouse gas emissions in agriculture by 8%. A decrease in N_2O emissions has also been attributed to cover crops [88,89]. In warm and humid areas, cover crops and fallow rotation may mitigate a net loss of 0.98 Mg C ha^{-1} during a 7-year period, according to [40]. Creating borders of permanent vegetation along the edges of the field is another way to provide continuing live cover for agricultural soils [86]. When cover cropping is incorporated into the system, the potential impact of no-tillage on boosting SOC increases significantly [82]. According to [90] and [91], rhizodeposition and the addition of root litter boost SOC stocks, and this is greater with perennial crops than with annuals. In opinion of [92] agroforestry, in which crop cultivation is blended with growing trees and occasionally with grazing cattle, has the largest capacity to hold carbon, ranging from 4.3 to 6.3 MT CO_2-e ha^{-1} $year^{-1}$ [93-106].

4. CARBON SEQUESTRATION PRACTICES – FARMER'S PERCEPTION

Farmers choose carbon pathways because they also have other benefits, most notably improving soil structure. They want to enhance soil health and, as a bonus, maybe sequester carbon. According to [107], the farmers would require localized models that could address their management issues and assess complicated mixtures of practices. Less than 35% of respondents in an Australian survey believed that carbon farming is a suitable method of lowering Australia's greenhouse gas emissions. The study also indicated that experience with the negative effects of climate change had an impact on respondent's chances of adopting carbon farming [108]. Another study that looked at the adoption of climate-mitigative practices in Alberta found that beliefs about climate change had no bearing on adoption choices and that many farmers had already adopted these practices due to co-benefits rather than because they agreed with the climate science. The main element encouraging farmers to adopt soil carbon sequestration technologies may be the higher production profitability. Most smallholder farmers raise both crops and livestock, and they traditionally feed their livestock with crop residue. In these situations, despite the obvious production gains, farmers are hesitant to leave residues on the surface. Farmers have seldom ever adopted methods for soil and water conservation [109]. In addition to productivity and profit, smallholders have a variety of household livelihood goals [109] that go beyond those two. Since they believe that adopting novel practices may increase the risk to their household's food security, many smallholders are risk averse and avoid doing so [110]. Despite having a solid understanding of the principles and techniques of carbon sequestration, most farmers lack this knowledge [109]. Although the authors acknowledge that some members of this population are skeptical about man-made global warming, they warn that attempts to convince them to embrace legislative requirements related to climate change could cause cognitive dissonance and cause them to reject the mandates [111]. However, some research has connected concern about climate change to readiness of adopting conservation agriculture habits [112]. There has never been a prior evaluation of farmer's stated preferences for a particular carbon payment scheme. Prior to the establishment of government conservation programmes that encourage the adoption of practices that ameliorate climate change or well-developed carbon commodity markets for carbon, it will not be possible to evaluate revealed preferences for such payment systems [113].

5. CONCLUSION

Around 18 Mg C ha^{-1} $year^{-1}$ (0–15 cm soil layer) might be mitigated by soil management practices, which could make up for an 8% reduction in GHG emissions [4]. When farmers adopt soil carbon enhancing agricultural practices, development and innovation occur frequently [114]. In order to increase food security, it is necessary to accelerate the adoption of land management practices that improve SOC. The farmers require a lot of support because the current methods for providing them with knowledge, resources, and incentives to encourage the adoption of sound technical practices are insufficient [4]. The improvement of knowledge and abilities through training and the provision of extension services could provide farmers with the necessary skills and raise the necessary awareness of a wide range of practices and technologies that sequester carbon. Therefore, knowledge and understanding of the issues that limit small-scale farmer's decisions to embrace these practices are necessary. Farmers certainly require more information about these practices, and the best way to solve this is through collaborative efforts by researchers, agents from the private sector, policymakers, extensionists, traders, and other stakeholders [115]. The productivity effects of carbon farming practices must be efficiently promoted and practices must be simple to incorporate into current agricultural systems, in order to boost involvement [116]. By developing innovation systems that can adapt technologies to local conditions, soil carbon sequestration can be scaled up successfully. Experience with both commercial and noncommercial agricultural systems demonstrates the necessity of a functional network of farmer groups, machinery developers, extension agents, local businesses, and researchers in an innovation systems approach. Decentralized learning hubs within various farming systems and agro-ecological zones should be created for this aim. The various partners in the research and extension process have to be organized in these hubs to have frequent communication and information exchange. Rather than making lower intensity efforts on a large scale, operations should be centered in a few selected sites typical of specific farming systems due to the complex nature of carbon sequestration development and extension. Regional networks for soil carbon sequestration are created through research and training to support and encourage research as well as the growth of innovative systems and technologies. In addition to dismantling the traditional processes, research at the hubs offers an illustration of how carbon sequestration practices work. In order to develop a comprehensive understanding of soil carbon sequestration and its adaptability to various ecosystems, cropping systems, and farmer circumstances, the hubs should be connected to the strategic science platforms run by international centres and national research organizations [109] To expand our understanding, we require a new generation of research to evaluate the potential of novel management strategies for C sequestration and its long-term stabilization. Additionally, it is necessary to pursue both short-term and long-term policy efforts that can provide incentives through the corresponding government initiatives and the involvement of the farming community [115].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Smith P, Martino D, Cai Z, Gwary D, Janzen H, Kumar P, McCarl B, Ogle S, O'Mara F, Rice C, Scholes B. Policy and technological constraints to implementation of greenhouse gas mitigation options in agriculture. Agriculture, Ecosystems & Environment. 2007 Jan 1;118(1-4):6-28
2. Lal R. Soil carbon sequestration in India. Climatic Change. 2004 Aug;65(3):277-96.
3. Anonymous. The Potential of Carbon Sequestration in the Soil. No. 013. UN Environment. Foresight Brief. 2019 Available:https://wedocs.unep.org/20.500.11822/28453
4. Jat ML, Chakraborty D, Ladha JK, Parihar CM, Datta A, Mandal B, Nayak HS, Maity P, Rana DS, Chaudhari SK, Gerard B. Carbon sequestration potential, challenges, and strategies towards climate action in smallholder agricultural systems of South Asia. Crop and Environment. 2022 Mar 1;1(1):86-101.
5. Lal R. Climate change and soil degradation mitigation by sustainable management of soils and other natural resources. Agricultural Research. 2012 Sep;1:199-212.
6. Smith P, Martino D, Cai Z, Gwary D, Janzen H, Kumar P, McCarl B, Ogle S, O'Mara F, Rice C, Scholes B. Policy and technological constraints to implementation of greenhouse gas mitigation options in agriculture. Agriculture, Ecosystems & Environment. 2007 Jan 1;118(1-4):6-28.
7. Chan KY, Cowie A, Kelly G, Singh B, Slavich P. Scoping paper: Soil organic carbon sequestration potential for agriculture in NSW. NSW Department of Primary Industries. 2008 Sep.
8. Banger K, Kukal SS, Toor G, Sudhir K, Hanumanthraju TH. Impact of long-term additions of chemical fertilizers and farm yard manure on carbon and nitrogen sequestration under rice-cowpea cropping system in semi-arid tropics. Plant and soil. 2009 May;318:27-35
9. Le Houérou HN. Man-made deserts: Desertization processes and threats. Arid land research and management. 2002 Jan 1;16(1):1-36.
10. Veldman JW, Putz FE. Grass-dominated vegetation, not species-diverse natural savanna, replaces degraded tropical forests on the southern edge of the Amazon Basin. Biological Conservation. 2011 May 1;144(5):1419-29.
11. Hulme M, Kelly M. Exploring the links between desertification and climate change. Environment: Science and Policy for Sustainable Development. 1993 Aug 1;35(6):4-5.
12. Liniger HP, Studer RM, Hauert C, Gurtner M. Sustainable land management in practice: guidelines and best practices for sub-Saharan Africa. FAO; 2011.
13. Bewket W. Soil and water conservation intervention with conventional technologies in northwestern highlands of Ethiopia: Acceptance and adoption by farmers. Land use policy. 2007 Apr 1;24(2):404-16.
14. Motavalli P, Nelson K, Udawatta R, Jose S, Bardhan S. Global achievements in sustainable land management. International Soil and Water Conservation Research. 2013 Jun 1;1(1):1-0.
15. Bekele W, Drake L. Soil and water conservation decision behavior of subsistence farmers in the Eastern Highlands of Ethiopia: a case study of the Hunde-Lafto area. Ecological economics. 2003 Oct 1;46(3):437-51.
16. Lal R, Follett RF, Stewart BA, Kimble JM. Soil carbon sequestration to mitigate climate change and advance food security. Soil science. 2007 Dec 1;172(12):943-56.
17. Paustian K, Lehmann J, Ogle S, Reay D, Robertson GP, Smith P. Climate-smart soils. Nature. 2016 Apr 7;532(7597):49-57.
18. Soussana JF, Lutfalla S, Ehrhardt F, Rosenstock T, Lamanna C, Havlík P, Richards M, Chotte JL, Torquebiau E, Ciais P, Smith P. Matching policy and science: Rationale for the '4 per 1000-soils for food security and climate'initiative. Soil and Tillage Research. 2019 May 1;188:3-15.
19. 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 Feb 24;6(1):21450.

20. Francaviglia R, Di Bene C, Farina R, Salvati L. Soil organic carbon sequestration and tillage systems in the Mediterranean Basin: A data mining approach. Nutrient Cycling in Agroecosystems. 2017 Jan;107:125-37.
21. Virto I, Barré P, Burlot A, Chenu C. Carbon input differences as the main factor explaining the variability in soil organic C storage in no-tilled compared to inversion tilled agrosystems. Biogeochemistry. 2012 Apr;108:17-26.
22. 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. 2015 Jan;51(1):1-6.
23. Grace PR, Harrington L, Jain MC, Philip Robertson G. Long-Term Sustainability of the Tropical and Subtropical Rice–Wheat System: An Environmental Perspective. Improving the Productivity and Sustainability of Rice-Wheat Systems: Issues and Impacts. 2003 Jan 1;65:27-43.
24. Parihar CM, Jat SL, Singh AK, Ghosh A, Rathore NS, Kumar B, Pradhan S, Majumdar K, Satyanarayana T, Jat ML, Saharawat YS. Effects of precision conservation agriculture in a maize-wheat-mungbean rotation on crop yield, water-use and radiation conversion under a semiarid agro-ecosystem. Agricultural Water Management. 2017 Oct 1;192:306-19.
25. Hussain S, Hussain S, Guo R, Sarwar M, Ren X, Krstic D, Aslam Z, Zulifqar U, Rauf A, Hano C, El-Esawi MA. Carbon sequestration to avoid soil degradation: A review on the role of conservation tillage. Plants. 2021 Sep 24;10(10):2001.
26. Zhu K, Ran H, Wang F, Ye X, Niu L, Schulin R, Wang G. Conservation tillage facilitated soil carbon sequestration through diversified carbon conversions. Agriculture, Ecosystems & Environment. 2022 Oct 1;337:108080.
27. Mehra P, Baker J, Sojka RE, Bolan N, Desbiolles J, Kirkham MB, Ross C, Gupta R. A review of tillage practices and their potential to impact the soil carbon dynamics. Advances in agronomy. 2018 Jan 1;150:185-230.
28. Ghimire R, Adhikari KR, Chen ZS, Shah SC, Dahal KR. Soil organic carbon sequestration as affected by tillage, crop residue, and nitrogen application in rice–wheat rotation system. Paddy and Water Environment. 2012 Jun;10:95-102
29. Jat ML, Chandna P, Gupta R, Sharma SK, Gill MA. Laser land leveling: A precursor technology for resource conservation. Rice-Wheat consortium technical bulletin series. 2006;7:48.
30. Ladha JK, Kumar V, Alam MM, Sharma S, Gathala M, Chandna P, Saharawat YS, Balasubramanian V. Integrating crop and resource management technologies for enhanced productivity, profitability, and sustainability of the rice-wheat system in South Asia. Integrated crop and resource management in the rice–wheat system of South Asia. 2009:69-108.
31. Six J, Ogle SM, Jay Breidt F, Conant RT, Mosier AR, Paustian K. The potential to mitigate global warming with no- tillage management is only realized when practised in the long term. Global change biology. 2004 Feb;10(2):155-60.
32. Kumari M, Chakraborty D, Gathala MK, Pathak H, Dwivedi BS, Tomar RK, Garg RN, Singh R, Ladha JK. Soil aggregation and associated organic carbon fractions as affected by tillage in a rice–wheat rotation in North India. Soil Science Society of America Journal. 2011 Mar;75(2):560-7.
33. Merante P, Dibari C, Ferrise R, Sánchez B, Iglesias A, Lesschen JP, Kuikman P, Yeluripati J, Smith P, Bindi M. Adopting soil organic carbon management practices in soils of varying quality: Implications and perspectives in Europe. Soil and Tillage Research. 2017 Jan 1;165:95-106.
34. Aryal JP, Mehrotra MB, Jat ML, Sidhu HS. Impacts of laser land leveling in rice–wheat systems of the north–western indo-gangetic plains of India. Food Security. 2015 Jun;7(3):725-38.
35. Jat ML, Singh Y, Gill G, Sidhu H, Aryal JP, Stirling C, Gerard B. Laser assisted precision land leveling: Impacts in irrigated intensive production systems of South Asia. Advances in soil science. 2015:323-52.
36. Gill G. An assessment of the impact of laser-assisted precision land levelling technology as a component of climate-smart agriculture in the state of Haryana, India.
37. Chen D, Wei W, Daryanto S, Tarolli P. Does terracing enhance soil organic carbon sequestration? A national-scale data analysis in China. Science of the

Total Environment. 2020 Jun 15;721: 137751.

38. Zhang HL, Lal R, Zhao X, Xue JF, Chen F. Opportunities and challenges of soil carbon sequestration by conservation agriculture in China. Advances in agronomy. 2014 Jan 1;124:1-36.
39. Zhao X, Liu SL, Pu C, Zhang XQ, Xue JF, Ren YX, Zhao XL, Chen F, Lal R, Zhang HL. Crop yields under no-till farming in China: A meta-analysis. European Journal of Agronomy. 2017 Mar 1;84:67-75.
40. Lou Y, Xu M, Wang W, Sun X, Zhao K. Return rate of straw residue affects soil organic C sequestration by chemical fertilization. Soil and Tillage Research. 2011 May 1;113(1):70-3.
41. Wang X, Yang H, Liu J, Wu J, Chen W, Wu J, Zhu L, Bian X. Effects of ditch-buried straw return on soil organic carbon and rice yields in a rice–wheat rotation system. Catena. 2015 Apr 1;127:56-63.
42. Zhao X, Liu BY, Liu SL, Qi JY, Wang X, Pu C, Li SS, Zhang XZ, Yang XG, Lal R, Chen F. Sustaining crop production in China's cropland by crop residue retention: A meta- analysis. Land Degradation & Development. 2020 Apr 15;31(6):694-709.
43. Wang X, He C, Liu B, Zhao X, Liu Y, Wang Q, Zhang H. Effects of residue returning on soil organic carbon storage and sequestration rate in China’s croplands: A meta-analysis. Agronomy. 2020 May 13; 10(5):691.
44. Jat HS, Datta A, Sharma PC, Kumar V, Yadav AK, Choudhary M, Choudhary V, Gathala MK, Sharma DK, Jat ML, Yaduvanshi NP. Assessing soil properties and nutrient availability under conservation agriculture practices in a reclaimed sodic soil in cereal-based systems of North-West India. Archives of Agronomy and Soil Science. 2018 Mar 21;64(4):531-45.
45. Prade T, Kätterer T, Björnsson L. Including a one-year grass ley increases soil organic carbon and decreases greenhouse gas emissions from cereal-dominated rotations–a Swedish farm Case Study. Biosystems Engineering. 2017 Dec 1; 164:200-12.
46. Levitan, D., 2009. Refilling the carbon sink: biochar's potential and pitfalls. Yale Environ. 360
47. Chowdhury S, Farrell M, Butler G, Bolan N. Assessing the effect of crop residue removal on soil organic carbon storage and microbial activity in a no-till cropping system. Soil Use and Management. 2015 Dec;31(4):450-60.
48. Duiker SW, Lal R. Crop residue and tillage effects on carbon sequestration in a Luvisol in central Ohio. Soil and Tillage Research. 1999 Sep 1;52(1-2):73-81.
49. Yeasmin S, Assaduzzaman, Kabir MS, Anwar MP, Islam AM, Hoque TS. Influence of Organic Amendments on Soil Carbon Sequestration Potential of Paddy Soils under Two Irrigation Regimes. Sustainability. 2022 Sep 28;14(19): 12369.
50. Gillabel J, Denef K, Brenner J, Merckx R, Paustian K. Carbon sequestration and soil aggregation in center-pivot irrigated and dryland cultivated farming systems. Soil Science Society of America Journal. 2007 May;71(3):1020-8.
51. Wu L, Wood Y, Jiang P, Li L, Pan G, Lu J, Chang AC, Enloe HA. Carbon sequestration and dynamics of two irrigated agricultural soils in California. Soil Science Society of America Journal. 2008 May;72(3):808-14.
52. Meena RS, Kumar S, Yadav GS. Soil carbon sequestration in crop production. Nutrient dynamIcs for Sustainable Crop Production. 2020:1-39.
53. Sykes AJ, Macleod M, Eory V, Rees RM, Payen F, Myrgiotis V, Williams M, Sohi S, Hillier J, Moran D, Manning DA. Characterising the biophysical, economic and social impacts of soil carbon sequestration as a greenhouse gas removal technology. Global Change Biology. 2020 Mar;26(3):1085-108.
54. Aryal JP, Sapkota TB, Rahut DB, Jat ML. Agricultural sustainability under emerging climatic variability: the role of climate-smart agriculture and relevant policies in India. International Journal of Innovation and Sustainable Development. 2020;14(2):219-45.
55. Guo S, Qi Y, Peng Q, Dong Y, He Y, Yan Z, Wang L. Influences of drip and flood irrigation on soil carbon dioxide emission and soil carbon sequestration of maize cropland in the North China Plain. Journal of Arid Land. 2017 Apr;9:222-33.
56. Guardia G, Cangani MT, Andreu G, Sanz-Cobena A, García-Marco S, Álvarez JM, Recio-Huetos J, Vallejo A. Effect of inhibitors and fertigation strategies on GHG emissions, NO fluxes and yield in irrigated maize. Field crops research. 2017 Mar 15;204:135-45.

57. Nouri H, Stokvis B, Galindo A, Blatchford M, Hoekstra AY. Water scarcity alleviation through water footprint reduction in agriculture: the effect of soil mulching and drip irrigation. Science of the total environment. 2019 Feb 25;653:241-52.
58. FAO. Fertilizer use by crop. Food Agric. Organ; 2006. Available:https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwiK38Pom9KAAxW52TgGHb8nBZIQFnoECA8QAQ&url=https%3A%2F%2Fwww.researchgate.net%2Fprofile%2FAnoop_Srivastava7%2Fpost%2FWhere_can_I_find_data_on_how_much_of_certain_types_of_fertilizers_Nitrogen_Solutions_Urea_etc_specific_states_use%2Fattachment%2F59e05cd9b53d2fe117b57970%2FAS%253A548886122110976%25401507876057345%2Fdownload%2Ffpnb17.pdf&usg=AOvVaw047gAx9bMsPFi3y2E7kcjF&opi=89978449
59. Pathak H, Jain N, Bhatia A, Mohanty S, Gupta N. Global warming mitigation potential of biogas plants in India. Environmental Monitoring and Assessment. 2009 Oct;157:407-18.
60. Ray RL, Griffin RW, Fares A, Elhassan A, Awal R, Woldesenbet S, Risch E. Soil CO2 emission in response to organic amendments, temperature, and rainfall. Scientific Reports. 2020 Apr 3;10(1):5849.
61. Zhen Z, Liu H, Wang N, Guo L, Meng J, Ding N, Wu G, Jiang G. Effects of manure compost application on soil microbial community diversity and soil microenvironments in a temperate cropland in China. PloS One. 2014 Oct 10;9(10):e108555.
62. Hedlund K. Soil microbial community structure in relation to vegetation management on former agricultural land. Soil Biology and Biochemistry. 2002 Sep 1;34(9):1299-307.
63. Anantha KC, Majumder SP, Padhan D, Badole S, Datta A, Mandal B, Gade KR. Carbon dynamics, potential and cost of carbon sequestration in double rice cropping system in semi arid southern India. Journal of Soil Science and Plant Nutrition. 2018 Jun;18(2):418-34.
64. Regmi AP, Ladha JK, Pathak H, Pasuquin E, Bueno C, Dawe D, Hobbs PR, Joshy D, Maskey SL, Pandey SP. Yield and soil fertility trends in a 20-year rice–rice–wheat experiment in Nepal. Soil Science Society of America Journal. 2002 May;66(3):857-67.
65. Gami S, Ladha J, Pathak H, Shah M, Pasuquin E, Pandey S, Hobbs P, Joshy D, Mishra R. Long-term changes in yield and soil fertility in a twenty-year rice-wheat experiment in Nepal. Biology and Fertility of Soils. 2001 Jul;34:73-8.
66. Duxbury JM. Long-term yield trends in the rice-wheat cropping system: results from experiments and northwest India. Journal of Crop Production. 2001 Jan 1;3(2):27-52.
67. Bhattacharyya P, Roy KS, Neogi S, Adhya TK, Rao KS, Manna MC. Effects of rice straw and nitrogen fertilization on greenhouse gas emissions and carbon storage in tropical flooded soil planted with rice. Soil and Tillage Research. 2012 Aug 1;124:119-30.
68. Khalil M, Rosenani A, Van Cleemput O, Boeckx P, Shamshuddin J, Fauziah C. Nitrous oxide production from an ultisol of the humid tropics treated with different nitrogen sources and moisture regimes. Biology and Fertility of Soils. 2002 Aug;36:59-65.
69. Lenka S, Lenka NK, Singh AB, Singh B, Raghuwanshi J. Global warming potential and greenhouse gas emission under different soil nutrient management practices in soybean–wheat system of central India. Environmental Science and Pollution Research. 2017 Feb;24:4603-12.
70. Snyder CS, Bruulsema TW, Jensen TL, Fixen PE. Review of greenhouse gas emissions from crop production systems and fertilizer management effects. Agriculture, Ecosystems & Environment. 2009 Oct 1;133(3-4):247-66.
71. Pampolino MF, Witt C, Pasuquin JM, Johnston A, Fisher MJ. Development approach and evaluation of the Nutrient Expert software for nutrient management in cereal crops. Computers and Electronics in Agriculture. 2012 Oct 1;88:103-10.
72. Ladha JK, Reddy CK, Padre AT, van Kessel C. Role of nitrogen fertilization in sustaining organic matter in cultivated soils. Journal of Environmental Quality. 2011 Nov;40(6):1756-66.
73. Benbi DK, Brar JS. A 25-year record of carbon sequestration and soil properties in intensive agriculture. Agronomy for sustainable development. 2009 Jun;29: 257-65.
74. Kukal SS, Benbi DK. Soil organic carbon sequestration in relation to organic and

inorganic fertilization in rice–wheat and maize–wheat systems. Soil and Tillage Research. 2009 Jan 1;102(1):87-92.

75. NMSA. National Mission for Sustainable Agriculture. Integrated Nutrient Management Division;. 2017 Available:https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwii0cDfndKAAxXYzTgGHY8EBXIQFnoECA0QAQ&url=https%3A%2F%2Fnmsa.dac.gov.in%2F&usg=AOvVaw0cxdKs0pkyUqGmmriB-Is6&opi=89978449.
76. Srinivasarao C, Kundu S, Lakshmi CS, Rani YS, Nataraj KC, Gangaiah B, Laxmi MJ, Babu MV, Rani U, Nagalakshmi S, Manasa R. Soil health issues for sustainability of South Asian Agriculture. EC Agric. 2019;5(6):310-26.
77. Kell DB. Large-scale sequestration of atmospheric carbon via plant roots in natural and agricultural ecosystems: why and how. Philosophical Transactions of the Royal Society B: Biological Sciences. 2012 Jun 5;367(1595):1589-97.
78. Abalos D, Brown SE, Vanderzaag AC, Gordon RJ, Dunfield KE, Wagner- Riddle C. Micrometeorological measurements over 3 years reveal differences in N2O emissions between annual and perennial crops. Global Change Biology. 2016 Mar;22(3):1244-55.
79. Crews TE, Rumsey BE. What agriculture can learn from native ecosystems in building soil organic matter: a review. Sustainability. 2017 Apr 11;9(4):578.
80. Lorenz K, Lal R. Soil organic carbon sequestration in agroforestry systems. A review. Agronomy for Sustainable Development. 2014 Apr;34:443-54.
81. Gregory AS, Webster CP, Watts CW, Whalley WR, Macleod CJ, Joynes A, Papadopoulos A, Haygarth PM, Binley A, Humphreys MW, Turner LB. Soil management and grass species effects on the hydraulic properties of shrinking soils. Soil Science Society of America Journal. 2010 May;74(3):753-61.
82. Kamoshita A, Babu RC, Boopathi NM, Fukai S. Phenotypic and genotypic analysis of drought-resistance traits for development of rice cultivars adapted to rainfed environments. Field crops research. 2008 Oct 1;109(1-3):1-23.
83. McKenzie BM, Bengough AG, Hallett PD, Thomas WT, Forster B, McNicol JW. Deep rooting and drought screening of cereal crops: a novel field-based method and its application. Field Crops Research. 2009 Jun 26;112(2-3):165-71.
84. Van de Broek M, Ghiasi S, Decock C, Hund A, Abiven S, Friedli C, Werner RA, Six J. The soil organic carbon stabilization potential of old and new wheat cultivars: a 13 CO 2-labeling study. Biogeosciences. 2020 Jun 11;17(11):2971-86.
85. Dijkstra FA, Zhu B, Cheng W. Root effects on soil organic carbon: a double- edged sword. New Phytologist. 2021 Apr;230(1): 60-5.
86. Verbruggen E, Struyf E, Vicca S. Can arbuscular mycorrhizal fungi speed up carbon sequestration by enhanced weathering?. Plants, People, Planet. 2021 Sep;3(5):445-53.
87. Agriculture and Agri-Food Canada's (AAFC). Next Policy Framework (NPF), 2017. pp.241–252. Available:https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjMgrenn9KAAxXz-zgGHbtVDcgQFnoECBMQAQ&url=https%3A%2F%2Fwww.gov.nl.ca%2Fffa%2Ffiles%2F21593_WWH-Next-Policy-Framework-Agriculture_V1Nov-16.pdf&usg=AOvVaw0F6-xNhY66oHoPjM2cOJek&opi=89978449
88. Pretty J, Pervez Bharucha Z. Integrated pest management for sustainable intensification of agriculture in Asia and Africa. Insects. 2015 Mar 5;6(1):152-82.
89. Heimpel GE, Yang Y, Hill JD, Ragsdale DW. Environmental consequences of invasive species: greenhouse gas emissions of insecticide use and the role of biological control in reducing emissions. PLoS One. 2013 Aug 20;8(8):e72293.
90. FAO. Climate-smart pest management. Food and agriculture organization. Practice Brief Climate-Smart Agriculture. 2010. Available: http://www.fao.org/3/BU464EN/bu464en.pdf
91. Heeb L, Jenner E, Cock MJ. Climate-smart pest management: building resilience of farms and landscapes to changing pest threats. Journal of Pest Science. 2019 Jun 1;92(3):951-69.
92. Bhandari AL, Ladha JK, Pathak H, Padre AT, Dawe D, Gupta RK. Yield and soil nutrient changes in a long-term rice-wheat rotation in India. Soil Science Society of America Journal. 2002 Jan;66(1):162-70.

93. Shah Z, Shah SH, Peoples MB, Schwenke GD, Herridge DF. Crop residue and fertiliser N effects on nitrogen fixation and yields of legume–cereal rotations and soil organic fertility. Field Crops Research. 2003 Jun 20;83(1):1-1.
94. Shah Z, Ahmad SR, Rahman HU, Shah MZ. Sustaining rice-wheat system through management of legumes. II Effect of green manure legumes and N fertilizer on wheat yield. Pakistan Journal of Botany. 2011 Aug 1;43:2093-7.
95. Jansson C, Wullschleger SD, Kalluri UC, Tuskan GA. Phytosequestration: Carbon biosequestration by plants and the prospects of genetic engineering. Bioscience. 2010 Oct 1;60(9):685-96.
96. Chenu C, Angers DA, Barré P, Derrien D, Arrouays D, Balesdent J. Increasing organic stocks in agricultural soils: Knowledge gaps and potential innovations. Soil and Tillage Research. 2019 May 1;188:41-52.
97. Lange M, Eisenhauer N, Sierra CA, Bessler H, Engels C, Griffiths RI, Mellado-Vázquez PG, Malik AA, Roy J, Scheu S, Steinbeiss S. Plant diversity increases soil microbial activity and soil carbon storage. Nature Communications. 2015 Apr 7;6(1):6707.
98. Steinbeiss S, BEßLER HO, Engels C, Temperton VM, Buchmann N, Roscher C, Kreutziger Y, Baade J, Habekost M, Gleixner G. Plant diversity positively affects short-term soil carbon storage in experimental grasslands. Global Change Biology. 2008 Dec;14(12):2937-49.
99. 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 Mar;54(2):448-52.
100. Poeplau C, Don A. Carbon sequestration in agricultural soils via cultivation of cover crops–A meta-analysis. Agriculture, Ecosystems & Environment. 2015 Feb 1;200:33-41.
101. Kundu DK. Sustaining Productivity of Rice Soils under Changing Climate: Issues and Options Related to Nitrogen Availability. Journal of the Indian Society of Soil Science. 2014;62:S143-54.
102. Eory V, MacLeod M, Topp CF, Rees RM, Webb J, McVittie A, Wall E, Borthwick F, Watson CA, Waterhouse A, Wiltshire J. Review and update the UK agriculture MACC to assess the abatement potential for the 5th carbon budget period and to 2050: Final report submitted for the project contract “Provision of services to review and update the UK agriculture MACC and to assess abatement potential for the 5th carbon budget period and to 2050.
103. Pellerin S, Bamière L, Angers D, Béline F, Benoît M, Butault JP. How can French agriculture contribute to reducing greenhouse gas emissions?. Energy. 2013;19:12.
104. Cheng W, Parton WJ, Gonzalez- Meler MA, Phillips R, Asao S, McNickle GG, Brzostek E, Jastrow JD. Synthesis and modeling perspectives of rhizosphere priming. New Phytologist. 2014 Jan;201(1):31-44.
105. Dignac MF, Derrien D, Barré P, Barot S, Cécillon L, Chenu C, Chevallier T, Freschet GT, Garnier P, Guenet B, Hedde M. Increasing soil carbon storage: mechanisms, effects of agricultural practices and proxies. A review. Agronomy for sustainable development. 2017 Apr;37:1-27.
106. Biardeau L, Crebbin-Coates R, Keerati R, Litke S, Rodríguez H. Soil health and carbon sequestration in US croplands: A policy analysis. United States Department of Agriculture and the Berkeley Food Institute; 2016 May.
Available:http://food. berkeley. edu/wp-content/uploads/2016/05/GSPPCarbon_03 052016 _FINAL. pdf
107. Mattila TJ, Hagelberg E, Söderlund S, Joona J. How farmers approach soil carbon sequestration? Lessons learned from 105 carbon-farming plans. Soil and Tillage Research. 2022 Jan 1;215:105204.
108. Dumbrell NP, Kragt ME, Gibson FL. What carbon farming activities are farmers likely to adopt? A best–worst scaling survey. Land Use Policy. 2016 Jul 1;54:29-37.
109. Govaerts B, Verhulst N, Castellanos-Navarrete A, Sayre KD, Dixon J, Dendooven L. Conservation agriculture and soil carbon sequestration: between myth and farmer reality. Critical Reviews in Plant Science. 2009 Apr 3;28(3):97-122.
110. Binswanger HP. Attitudes toward risk: Experimental measurement in rural India. American Journal of Agricultural Economics. 1980 Aug;62(3):395-407.
111. Davidson DJ, Rollins C, Lefsrud L, Anders S, Hamann A. Just don’t call it climate change: climate-skeptic farmer adoption of

climate-mitigative practices. Environmental Research Letters. 2019 Mar 18;14(3): 034015.

112. Roesch-McNally GE, Gordon Arbuckle J, Tyndall JC. What would farmers do? Adaptation intentions under a Corn Belt climate change scenario. Agriculture and Human Values. 2017 Jun;34:333-46.
113. Gramig BM, Barnard JM, Prokopy LS. Farmer beliefs about climate change and carbon sequestration incentives. Climate Research. 2013 Mar 26;56(2):157-67.
114. Koirala B, Dutta JP, Dhakal SC, Pant KK. Level of adoption and factor affecting the level of adoption sustainable soil management practices in Ramechhap district, Nepal. Am. J. Agric. For. 2015; 3(2):21-4.
115. Karanja Ng’ang’a S, Jalang’o DA, Girvetz EH. Adoption of technologies that enhance soil carbon sequestration in East Africa. What influence farmers’ decision?. International Soil and Water Conservation Research. 2020 Mar 1;8(1):90-101.
116. Kragt ME, Blackmore L, Capon T, Robinson CJ, Torabi N, Wilson KA. What are the Barriers to Adopting Carbon Farming Practices?. 2014 Dec 21.

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