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12. Agriculture Practices to Reduce In-Field Greenhouse Gas Emissions

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Abstract:

Population growth and climate change together pose a serious threat to the availability, accessibility, and security of food in emerging nations. The result of past overexploitation of natural resources is the climate as it is today. Even the agricultural sector contributed to it by transforming the naturally diverse nature into a cultivated, uniform area. Through a disciplined review of the literature, an effort is made to understand the concept and to pinpoint the linked ideas. The global temperature raised and there was less fresh water available as a result of increased greenhouse gas emissions. Agricultural practices that emit carbon dioxide, methane, and nitrous oxides into the atmosphere include burning litter, anaerobic decomposition of organic matter, rice grown in flooding areas, etc. The effect is typically lessened by conservation agriculture, intercropping system, cover crop, crop rotation, effective cropping systems, good crop residue management, and increased nutrient usage efficiency. Precision farming, the use of slow release fertilisers, effective water management in rice fields, the use of dung and energy crops, requirement for specific agroforestry and grazing management practices, and the replacement of fossil fuels with *crop residues all significantly reduce greenhouse gas emissions. Biochar, a product of the pyrolysis of plant and animal biomass, increases soil fertility, lowers pollution, and promotes agricultural residue recycling in addition to sequestering carbon. Henceforth, for India's agricultural production systems to be viable into the future there is a need to reduce the in-field greenhouse gases emissions through climate smart agriculture practices.*

Keywords:

Carbon sequestration, Climate change, Climate smart agriculture practices, Conservation agriculture, Greenhouse gas emission.

12.1 Introduction:

Global climate change is accelerating. As a result, catastrophic weather occurrences like droughts, floods, heat waves and others are becoming more frequent. The primary contributor to these occurrences is the growing temperature of Earth's atmosphere, which is brought on by rising emissions of climate-relevant greenhouse gases (GHGs), which trap heat in the atmosphere. Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are three major GHGs (Figure 12.1). These GHGs are the most potent gases which trap the outgoing long wave solar radiations and are the most probable reason for the global climate change. The major sources of these most dreadful greenhouse gases as given in Table 1 indicated the potential for their reduction.

Table 12.1: Major sources of greenhouse gases and their global warming potential

Gases	Global warming potential for a 100-year time horizon	Natural causes	Anthropogenic sources
Carbon Dioxide (CO_2)	1	Oceanic-atmosphere exchange, animal respiration, soil microbial respiration, plants, and volcanic eruptions.	Combustion of fossil fuels (coal, natural gas, and oil), deforestation, and the cultivation of land, agricultural and animal leftovers.
Methane (CH_4)	21	Wetlands, termite activity, and the ocean	landfills, paddy fields, enteric emission from ruminants, and the production and use of fossil fuels, and methanogenic archaea by anaerobic mineralization.
Nitrous oxide (N_2O)	310	Oceans and soils under natural vegetation	Intensification in agriculture, increased use of synthetic fertilizers, inefficient use of irrigation water, the deposit of animal wastes (urine and dung) from grazing animals, ineffective application of animal manures and techniques increasing soil organic N mineralization.

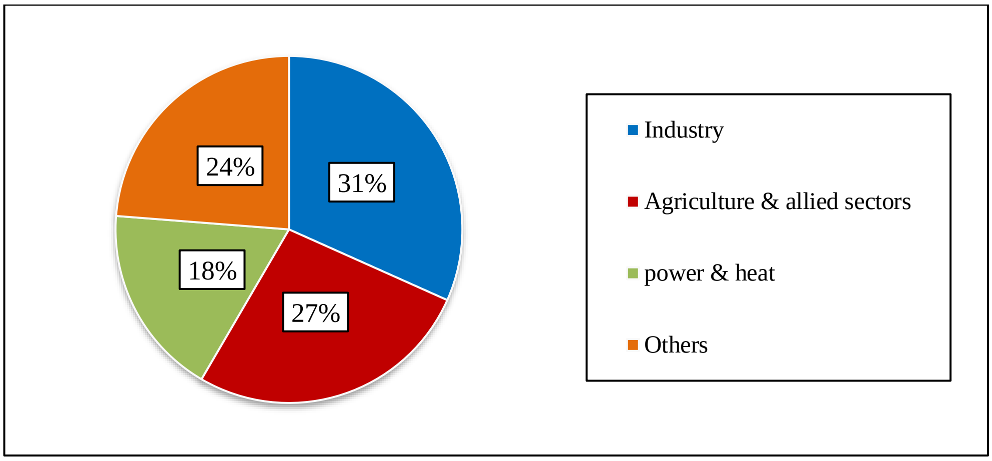

Figure 12.1: Contribution of different Sectors in Greenhouse Gases Emission

Agriculture contributes significantly to greenhouse gas emissions that drive climate change and is a direct victim of it. According to [1], 37.6% of the world's land area is covered by agricultural lands, and this sector is a substantial source of GHG emissions.

CO_2, CH_4, and N_2O are the main trace gas types that contribute most to the global warming impact. Agricultural soil management (such as tillage), the use of synthetic and organic fertilizers, dairy management, the burning of fossil fuels for agricultural operations, and crop residues burning are all factors that contribute to agricultural GHG emissions (Figure 12.2). According to [2], agriculture may be the source of 52% and 84%, respectively, of the world's anthropogenic CH_4 and N_2O emissions. Certainly, advanced approaches are needed to minimize agricultural emissions of CH_4 and N_2O since they have substantially larger global warming potentials than CO_2 based on per unit mass and a 100-year time frame.

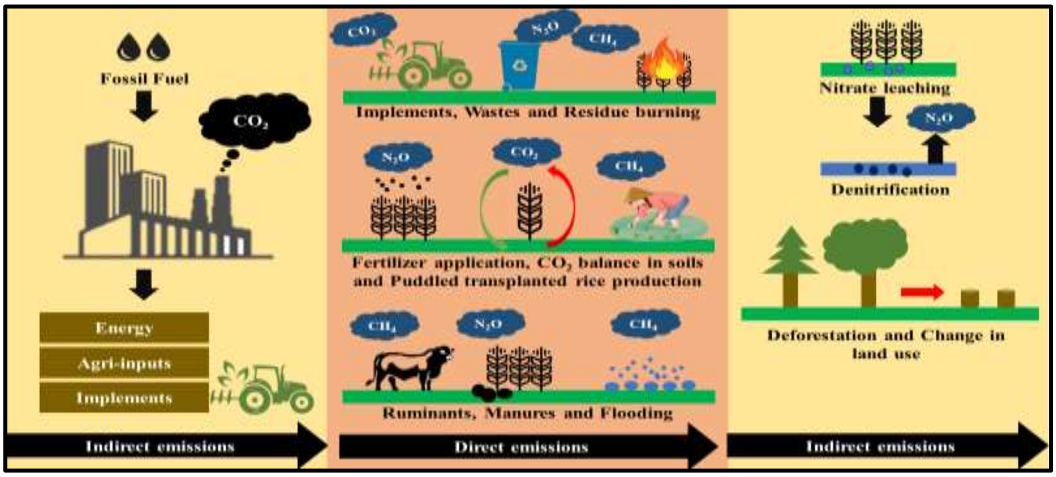

Figure 12.2: Representation of direct and indirect GHG emissions from crop production

Human settlement in previously uninhabited areas results in the conversion of natural ecological systems to agricultural production, which results in the loss of 20–40% of the soil organic carbon (SOC) after cultivation, with the majority of that loss happening during the first couple of years [3]. This conversion also increases levels of GHG emissions. According to a recent estimate, since agriculture began roughly 12,000 years ago, 133 billion tonnes of SOC, or about 8% of the total worldwide SOC stock, have been lost from the top two meters of soil, with the rate of loss sharply increased since the beginning of the industrial era [4]. According to the study, farmland suffered a bigger overall proportion of SOC loss than grazing land, despite grazing on more than twice as much land overall. This suggests that while agriculture has a better ability to boost SOC gain, grazing land has a greater capacity to increase SOC storage overall.

Since the soil and vegetation retain approximately three times the amount of organic carbon of the atmosphere [5], slight variations in the organic carbon stock in the soil and vegetation may have a significant impact on the global carbon dioxide concentration. As a result, significant attempts must be created to improve SOC storage in terrestrial environments and to decrease GHG emissions from these systems. In managed systems, management practices including not burning agricultural waste after harvest and using compost, charcoal, and animal dung to improve organic C input to the soil can boost SOC storage.

The fact that agriculture is a major source of GHGs and much of the carbon in the soil gets lost through cultivation. But the agricultural sector offers a significant opportunity to reduce anthropogenic sources of greenhouse gas emissions and boost soil carbon storage.

If permanent vegetation can be sustained, soil carbon storage could rise, benefiting from the C cycle becoming more closed in the system and the soil being able to capture more carbon. For instance, agricultural management practices can be enhanced in order to reduce disturbance to the soil by reducing the frequency and extent of cultivation as a way to minimize soil C loss and to increase soil C storage.

By strategically applying fertilizers, one can increase fertilizer nitrogen use efficiency (NUE) and decrease nitrogen loss, including gaseous and leached forms of nitrogen loss [6]. Additionally, management actions can be implemented to reduce the burning of agricultural biomass. Climate-smart agriculture (CSA) management practices, which include the strategic use of synthetic and organic fertilizers, conservation tillage, use of cover crops, and the addition of lime, biochar, and nitrification inhibitors to agricultural fields, can help to reduce GHG emissions from agriculture [7].

According to the [8], CSA is defined as a systematic approach for designing agricultural policies that can provide sustainable food security. Based on this concept, a variety of agricultural techniques can be created to aid in enhancing both environmental and food security at the same time in relation to global change. Since soil can act as a sink or source of CO_2 and influence climate change if we can strengthen the carbon sink and remove more CO_2 from the atmosphere by implementing CSA, we will be in an advantageous position in not only battling the adverse impacts of climate change but also reducing emission of greenhouse gases emission and enhancing soil quality and health, which includes nutrient and water retention, and increasing agricultural productivity [9].

12.2 Agriculture Practices to Reduce In-field Green House Gas Emissions:

There are various areas in agriculture which contribute differently to the GHG emissions (Figure 12.3.). Thus, it is very important to prioritize those areas for reduction of GHG emissions.

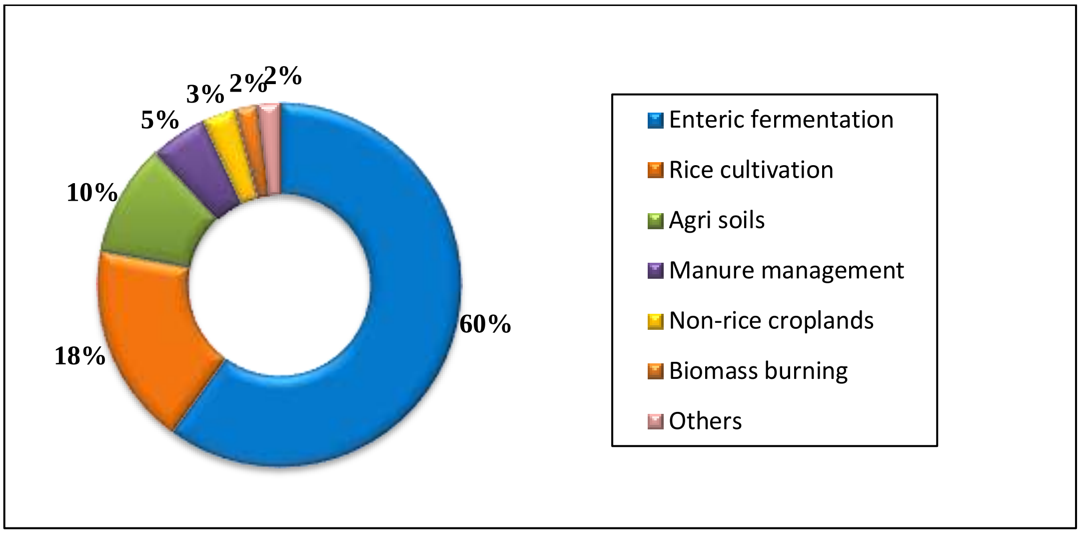

Figure 12.3: Contribution of different agriculture sectors to greenhouse gas emissions

Agriculture has the ability to reduce GHG emissions at a low cost by changing agricultural methods and management techniques. Different agriculture practices focuses on enhanced risk management, improving information flows, and encouraging local institutions to increase the community's adaptive capacity to climate change [10]. The following are some agricultural practices that help to reduce in-field greenhouse gas emissions:

12.2.1 Adoption of Conservation Tillage Practices:

Contrarily, conservation tillage (CT) systems focus on retaining and managing crop residue while minimizing disturbance to the soil by limiting any field preparation operations to a shallow depth and preventing soil inversion [11]. They include non-inversion tillage, eco-tillage, minimal tillage, mulch tillage, reduced tillage, zone tillage, or no-tillage. A minimum of 30% of the earlier crop residues should still be visible on the soil surface, according to CT [12].

Adopting CT can increase soil organic matter (SOM), lower CO_2 emissions, and improve SOC sequestration, especially when combined with agricultural residue retention. When compared to conventional ploughing, conservation tillage has been proven to produce more soil that is present in macro-aggregates and more carbon that is connected with micro-aggregates [13]. Increased biological activity in such soils is the source of the increased aggregate strength under CT management [14], and residues that leave on the soil surface provide additional protection, slowing down the degradation of the top soil particles [15].

Compared to normal tillage, no-tillage greatly lowered the release of methane from fields of rice. By increasing soil bulk density and inhibiting the breakdown of organic matter, no-tillage reduces the volume percentage of big pores and methane emissions. Conservation tillage has a higher near-surface soil C content than conventional tillage because it keeps more plant remains on the soil surface, especially in cool, humid climates [16]. In comparison with residues that are thoroughly mixed into the soil through standard tillage practices, the degradation of plant residues may occur more slowly under these circumstances due to the reduced soil-residue contact. Conservation agriculture has the ability to increase the use efficiency of resources that are renewable, including water, air, fossil fuels, and soil through the adoption of resource-conserving technologies like zero or minimum tillage with direct planting, permanent or semi-permanent residue cover, and rotations of crops. By maintaining the base of available resources and reducing GHG emissions, the technologies can enhance the sustainability of agriculture. By carbon accumulation inside the small macro aggregates and micro aggregates at the 5–15 cm depth, tillage intensity and frequency were reduced, increasing soil carbon [17].

12.2.2 Agronomic Practices:

Intercropping, as a traditional multi-cropping system, has been well proven to improve crop production and fertilizer use efficiency by utilizing niche crop and seasonal differentiation, as well as advantageous relationships between species when handled properly [18]. Intercropping thus becomes critical for achieving the dual goals of boosting crop yields and lowering GHG emissions [19]. Many researches have shown that a cereal-legume system reduces soil CO_2 and N_2O emissions when compared with monoculture [20]. Soil physicochemical properties and microbial community diversity are changed with increased crop diversification, resulting in changes in soil N_2O emissions [21]. Intercropping regimens that use various legume species and cultivars might also cause differences in N_2O emissions [22]. In contrast to typical monocropping, maize farming, nitrogen fixation of legume crops and nitrogen transport between maize and legume crops greatly altered the nitrogen cycle in intercropping systems. Maize-peanut intercropping was observed to reduce soil N_2O emissions by 13% when compared to maize monoculture [23]. This could be linked to increased nitrogen utilization efficiency in cereal-legume intercropping.

Cover crops are a common agronomic strategy that can reduce nutrient losses, such as soil inorganic N, and improve carbon dioxide (CO_2) sequestration. Legumes, grasses, mustards, or mixer of those species can be cultivated as cover crops to increase soil quality, reduce harmful soil erosion, increase soil structure and fertility, control pests, and reduce the loss of nutrients from the root zone [24]. In comparison to winter fallows, a combination of cereal rye (*Secale cereale* L.) and hairy vetch (*Vicia villosa* Roth) drilled into crop stubble every year increased soil organic carbon, nutrient retention, and water aggregate stability, according to research by [25]. By absorbing nitrogen and storing it in their biomass, a number of cover crop species have been demonstrated to reduce soil N-NO_3 levels [26].

This reduces the amount of nitrogen that can enter rivers or be released to the atmosphere via gaseous pathways. Because the reduction in soil water would not favour circumstances of denitrification via which N_2O might be formed, cover crops can also reduce N_2O production by absorbing soil moisture in their living plant tissue [27]. Following cover crop suppression, the mineralization or immobilization of the residue N would be made possible by the breakdown of cover crop residues in the presence of oxygen. Use of crop rotation is another mitigating strategy discovered to lower N_2O emissions. A corn-soybean rotation lowered N_2O emissions by 35% compared to continuous corn, and it also increased yield by 20% [28].

The key to lowering the system's total footprint is to grow crops with minimal production input requirements and those that produce a lot of straw and roots for the soil to absorb carbon. According to [29], switching from the conventional double-rice system of cultivation to a more diversified structure that included upland crops lowered irrigation water consumption in the dry season by about 70% and lowered CH_4 emissions by 97% without having adverse economic impact. System carbon footprints can be decreased by up to 250% in more intensive systems with less frequent summer-fallow in the rotation. When summer-fallow is replaced with fodder or grain legume as opposed to an approach with a high frequency of summer-fallow, farming income can more than quadruple [30].

In the summer fallow-cereal cropping system, where substantial increases in inputs of carbon were accomplished using currently available legume species, green manuring played a significant role in increasing soil carbon levels [31].

Increasing cropping frequency in order to minimize bare fallow was also found to improve soil carbon sequestration [32], including perennial forages like lucerne (Medicago sativa L.). Due to larger belowground biomass carbon input and ongoing root growth compared to annual cropping systems [33], increased dryland soil carbon sequestration and biological soil quality were achieved by increasing microbial biomass and activity [34].

Additionally, building agroforestry systems, or the production of crops, livestock, and tree biomass on the same plot of land, can successfully boost SOC sequestration [35]. This is done by planting trees with high roots-to-aboveground biomass ratios and trees that fix nitrogen. It consists of woody species-filled riparian zones and buffer strips as well as shelter belts. Planting trees may also boost soil carbon sequestration. The standing stock of carbon above ground is typically greater than the equivalent land use without plants. To increase carbon sequestration rates and the mechanisms causing SOC to stabilize in soil profiles, detailed agroforestry management techniques are required.

12.2.3 Reduce Enteric Fermentation Through New Technologies:

Approximately one-third of all anthropogenic CH_4 emissions worldwide are produced by livestock, primarily ruminants like cattle and sheep [36]. Eructation is used to expel the methane, which is predominantly produced by enteric fermentation. Because N is excreted in urine and faeces, all cattle produce N_2O emissions from manure. In order to lessen these CH_4 and N_2O emissions, try the following:

- **Improved feeding practices-** Feeding more concentrates which often replace forages can lower methane emissions. [37] recommend improving pasture quality by including specific oils or oilseeds in the diet to increase animal productivity and decrease the amount of energy lost as CH_4 as well as optimising protein intake to lower nitrogen excretion and N_2O emissions [38].

- **Specific agents and dietary additives-** Antibiotics called ionophores contribute to reducing methane emissions. Halogenated substances suppress methanogenic bacteria, although they can also have adverse effects like lower intake and their effects are frequently transient. Probiotics, like yeast culture, have only had minor, negligible impacts, but choosing strains particularly for their capacity to reduce methane could lead to better outcomes [39]. Fumarate and malate, two precursors of propionate, serve as substitute hydrogen acceptors to lessen methane synthesis [40]. Propionate precursors are pricey nevertheless because the response is only evoked at large doses [41]. Bovine somatotropin (bST) and hormonal growth implants can lower emissions per kilogram of the animal product even if they do not explicitly suppress the creation of CH_4.
- **Longer-term management changes and animal breeding-** Methane production per unit of animal product is frequently decreased by improving productivity through breeding and better management techniques, such as a decrease in the total number of replacement heifers [42]. Meat-producing animals become slaughter weight earlier and have lower lifetime emissions thanks to increased efficiency.

12.2.4 Soil Amendments for Reducing GHG Emissions:

Mulches- Mulch will alter the amount of carbon (C) and other minerals that are available to microbial communities, which will have an impact on soil GHG emissions. In addition to controlling the temperature of the soil systems, mulches preserve soil moisture [43]. However, too much straw applied to the soil's surface can hinder seed germination, necessitating the administration of additional fertilizer to make up for any N that may become immobilized during the crucial early period of growth [44]. When it comes to CO_2 emissions, mulching typically causes an increase because labile C is added to the mulch, and the rate of CO_2 emissions rises as the rate of mulch addition increases. In comparison to adding no mulch, adding mulch can immobilise mineral N in the soil, lower the availability of NH_4 for nitrification and NO_3 for denitrification, and therefore minimise N_2O emissions.

Biochar- The cycling of C and N is one of soil properties that can be altered by adding biochar. According to numerous reports, applying biochar can lower N_2O emissions [45]. By aiding the final stage of denitrification and increasing the production of N_2 rather than N_2O, biochar lowers N_2O emissions [46]. A significant amount of crop residues are produced in farming operations, and the return of crop residues in the raw state vs after the crop residue has been transformed to biochar can have a significant impact on the emissions of all three trace gases.

12.2.5 Improved Manure Management:

Livestock urine and manure are substantial producers of methane and nitrous oxide when decomposed under anaerobic conditions. When the nitrogen in animal manure is nitrified and then denitrified, nitrous oxide is created [47]. When manure is kept in big heaps or settlement ponds to handle the waste from numerous animals kept in a small space (such as dairy farms, cattle feedlots, pigteries, and poultry farms), anaerobic conditions sometimes develop [48]. Aeration and composting of manure stockpiles lower methane emissions. Nitrous oxide emissions can be decreased by adding urease inhibitors to manure heaps.

Urease inhibitors are chemical additives that slow down or prevent the conversion of urea found in animal urine and manure to nitrous oxide [49].

12.2.6 Fertilizer Management:

Agricultural management practices, such as nitrogen in splits and the use of controlled-release fertilizers have greatly influenced the crop production and nitrogen use efficiency by balancing the nitrogen demand of crops and the nitrogen availability of soils [50]. The effects of these practices on greenhouse gases emissions, particularly in systems of intercropping have not yet been thoroughly assessed. The largest contributor of GHG emissions was discovered to be fertilization with irrigation. Therefore, applying nitrogen in three splits and using a slow-release fertilizer may be an easy and efficient way to increase grain output while lowering GHG emissions [51].

12.2.7 Rice Management and Varieties:

Climate change is a crucial environmental problem for the twenty-first century since it might have a large impact on rice productivity and speed up the paddy ecosystem's greenhouse gas emissions, both of which are extremely concerning for the environment. Due to rice fields' advantageous production, consumption, and transportation systems, CH_4 and N_2O gases are released concurrently into the environment. Because of the enormous pressure that the intensive rice farming system places on rice fields to grow more rice in order to feed the growing global population [52].

Soil fertility is declining, and the ecological balance of the rice paddy is being disrupted by increased CO_2, CH_4, and N_2O fluxes into the atmosphere. Extreme weather conditions like high temperatures, high water vapour or relative humidity, and drought stress may severely stifle beneficial microbial activity, soil nutrients, and water availability to rice plants; as a result, rice yield may decline noticeably while greenhouse gas emissions may rise noticeably [53]. In this situation, field-level farmers should be taught about conservation tillage, water-saving irrigation techniques like alternate wetting and drying, soil amendments with biochar, vermicompost, azolla-cyanobacterial mixture, recommended silicate slag, and phospho-gypsum with minimum NPKSZn fertiliser (IPNS), and more. Another crucial step in lowering methane production is the removal of rice straw from the field before re-flooding [54]. Straw can also be used to grow mushrooms or produce bioenergy, among other useful uses.

Reduce duration of flooding to reduce growth of methane-producing bacteria. In the middle of the growing season, farmers can temporarily lower water levels or sow rice on land that is initially dry rather than flooded [55]. Direct seeded rice is also recommended instead of transplanted rice to reduce the methane emission from the field [56]. The DSR and SRI crops do not require continuous soil submergence, and therefore reduce or totally eliminate methane emission when rice is grown as an aerobic crop. The DSR and SRI have potential to reduce the GWP by about 35-75% compared to the conventional puddled transplanted rice [57]. Grow rice with less methane as well. However, these characteristics have not been developed into the majority of commercial cultivars. A few extant types leak less methane than others, and researchers have demonstrated great experimental promise.

12.2.8 Increase Agricultural Energy Efficiency and Shift to Non-Fossil Energy Sources:

By 2050, agricultural emissions from the usage of fossil fuels will still be at 1.6 Gt CO_2e/year. The methods for mitigating energy emissions are similar to those used to lower them in other industries; they rely on improving efficiency and transitioning to renewable energy sources. On-farm energy use will account for 65 percent of anticipated agricultural energy emissions in 2050. Solar and wind energy may frequently be used to generate electricity and heat, though it will take creative, small-scale solar heating systems to replace on-farm coal. It will be more challenging to reduce the use of diesel fuel by tractors and other large machinery, and it might be necessary to switch to fuel cells that use hydrogen energy produced by solar or wind energy. Alternative technologies could include battery-powered devices and artificial carbon-based fuels produced from renewable electricity. Additionally, since the synthesis of nitrogen fertilizer currently requires a lot of energy, renewable sources of hydrogen might eliminate 85% of the emissions that result from this process. Fortunately, extensive research is being done on the manufacture of hydrogen using electricity from solar energy, and the price of solar electricity has been falling quickly due to the needs of other sectors. Even with efficiency benefits incorporated into our baseline, significant work is still necessary [58].

12.1.9 Focus on Realistic Options to Sequester Carbon in Soils:

Due to the difficulty of reducing agricultural production emissions, significant research and policy emphasis has been focused on techniques to trap carbon in agricultural soils to balance such emissions. There are just two options for increasing soil carbon: add more or lose less. However, new research and experience show that soil carbon sequestration is more difficult to perform than originally anticipated [59]. Ploughing practices that originally appeared to avoid soil carbon losses, such as no-till, now appear to give relatively minor or no carbon benefits when assessed at greater soil depths than earlier reported. No-till tactics must also struggle with negative effects on yields in particular areas, as well as the reality that numerous no-till farmers still plough up soils every few years, releasing much of the carbon gain [60]. Adding mulch or manure to soils are proposed carbon-addition solutions, however, they effectively double-count the carbon that would have influenced carbon storage elsewhere. Allowing crop wastes that would otherwise be used for animal feed to become soil carbon necessitates that the animals' feed comes from other sources, which has a carbon cost because growing that feed often necessitates more agricultural land [61, 62].

12.3 Conclusion:

Good agriculture practices, with an emphasis on climate change adaptation and mitigation, can take many different forms. The climate smart agriculture practices have many roles to play in agricultural sustainability and in reducing in-field GHG emissions, as well as in increasing soil carbon sequestration. Practices such as the use of conservation tillage, crop rotations, application of biochar to the soil, use of soil amendments, nitrification and urease inhibitors, mulching, fertilization management and use of intercropping are all options available to landowners to effectively adapt to and mitigate regional to global climate change. Thus, we have to improve the existing ways to mitigate greenhouse gases through better land based agricultural practices without compromising the food production.

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