EC AGRICULTURE Editor's Choice - 2020

Agrarian Carbon Footprint- A Global Issue

DK Roy
DRPCAU, Pusa, Samastipur, Bihar, India

DK Roy[1]* and Subhra Sahoo[2]

[1]Professor, Department of Agronomy, DRPCAU, Pusa, Samastipur, Bihar, India

[2]Ph.D. Scholar, Department of Agronomy, DRPCAU, Pusa, Samastipur, Bihar, India

***Corresponding Author:** DK Roy, Professor, Department of Agronomy, DRPCAU, Pusa, Samastipur, Bihar, India..

Received: January 05, 2020; **Pubished:** March 24, 2020

Abstract

With the unprecedented increase in natural resource exploitation and uncontrolled population rise, reaching to an irreversible point has led to a major global issue in form of Climate change. Greenhouse gases (GHGs) blamable for the adverse climatic conditions are emitted by a variety of natural as well as anthropogenic sources. Agricultural practices in the course of crop production, food processing and product marketing all generate GHG, contributing to the global climate change. With the rising population, the food demand also increases thus, increasing the proportion of GHG emissions from agricultural sector. Carbon footprint of agriculture in general terms is the sum total of GHGs (in terms of carbon equivalent (C-eq)) emanated during the processes in agrarian sector. Carbon footprints can be estimated by summing the of emissions from (1) the decomposition of crop straw and roots; (2) the manufacture of N and P fertilizers and their rates of application; (3) the production of herbicides and fungicides; and (4) miscellaneous farm field operations. Several activities related to food production such as plowing, tilling, manuring, irrigation, variety of crops, rearing livestock, and related equipment release a significant amount of GHGs that are classified in three tiers of carbon footprinting, separated by hypothetical boundaries. A major proportion of carbon emission through agriculture is from the energy input through machinery, electricity, livestock management, and fossil fuel. Principally, cereals produce higher GHGs than any other crops like vegetables and fruits. Apart from this, land-use modifications in form of conversion of natural ecosystem to agricultural, deforestation, and crop residue burning after harvest pose as significant contributors to higher carbon emission.

This review emphasizes on carbon footprint from agriculture sector, including emission from pre-farm, on-farm and post-farm activities. Various mitigation strategies relating to farming practices are also put forward.

Keywords: *Greenhouse Gases (GHGs); Agrarian Carbon Footprint; Agriculture Sector*

Introduction

The unpredictable shift in weather pattern due to the climate change is a major concern for society in the present day. Thus, in order to prevent the extreme weather variables and create awareness, various records are maintained. As the planet witnesses the effects of climate change, the term carbon footprint gets prominent. The concept of carbon footprint originally relates to the term ecological footprint given by Rees in 1992 [1]. The biologically productive land and sea area required to sustain a given human population, expressed in terms of global hectares is defined as Ecological footprint. Similarly, Wiedmann and Minx [2] explained carbon footprint as a certain amount of gaseous emission that is pertinent to climate change and is linked with human production or consumption activity. Carbon footprint is thus emanation of greenhouse gases (GHGs) from all sources and processes from manufacturing to disposal, related to a particular product or individual or system. Earlier, only CO_2 was considered for carbon footprint estimation, but at present, all the major GHGs emitted such as CO_2, CH_4 and N_2O are taken under consideration in terms of CO_2 equivalent (CO_2-e). As defined by, IPCC [3] CO_2-e is the CO_2 concentration that would cause the same radiative forcing as a given mixture of CO_2 and other forcing components.

Carbon footprint is a component of life-cycle assessment (LCA) that measures GHGs. Carbon footprint is estimated by dividing the whole process tier-wise, separated by hypothetical boundaries. Global warming potential (GWP) of all tiers adds to carbon footprint. With the absence of standards in agriculture system, boundaries are not decided. All the direct on-site emission, such as emission from soil and machinery are considered as Tier 1. Tier 2 consists of indirect farm emissions such as from electricity, and tier 3 includes all the indirect emissions related to manufacturing and transport of agriculture-based chemicals and machinery, etc. Pandey and Agrawal [4] have worked out the formula to calculate carbon footprint:

GWP of tier (kg CO_2-e ha^{-1}) = emission/removal of $CH_4 \times 25$ + emission/removal of $N_2O \times 298$ + emission/removal of CO_2.

Carbon footprint for agriculture = (ΣAgricultural input ∗ GHG emission coefficients)/(Grain yield) [5].

Agricultural sectors have significant contribution towards GHG emission as each practice from industry to farm to house, emit GHGs. With the ever-rising population demand, use of chemicals, electrical energy and use of fossil fuels increases. The rate of natural resources exploitation is much higher, than the input to the soil as carbon sequestration. With time, soil is losing its property to foster life due to various anthropogenic activities such as deforestation, erosion, use of chemicals, and disposal of hazardous wastes.

This review will focus on carbon footprint from agriculture including inputs for uses from energy, fertilizers, organic manure, pesticides and processes that affect carbon emission from agriculture and the probable effective mitigation practices for reducing the carbon footprinting from various agricultural activities.

Carbon footprint from agriculture sector

Total emission from agricultural sector has increased since records (FAOSTAT 2019). One-fourth of total anthropogenic GHG emission is from Agriculture sector along with land-use change [3]. With the increase in world population by 36%, the agricultural land has increased by 42.5% since 1990 to 2014 and emission from agriculture, forestry and land use has increased by 1.1% [6]. Whereas, In India, the increase in population and harvested area was 45.8 and 50.8%, respectively with increase in emission by 11.8% from agriculture, forestry, and land use [6]. Asia solely emits 44% of total agricultural emission followed by America, Africa, Europe, and Oceania [7].

Total energy: Yuosefi., *et al.* [8] calculated the carbon footprint of sunflower cultivation in Iran and reported that sunflower cultivation requires 20.97% renewable energy as human labor, seeds and water for irrigation and 79.03% of non-renewable energy including diesel, pesticides, fertilizers, electricity and machinery, 70.31% direct energy involving human labor, diesel, water for irrigation and electricity and 29.69% indirect energy that involves seeds, fertilizers, pesticides, and machinery.

Globally in the year 2010, 785 million tons of CO_2-e was emitted from the utilization of energy in agriculture using fossil fuel [7]. Use of fossil fuel in agriculture emits GHGs, and the production and transport of fossil fuel also increases the emission of GHGs. In semiarid areas, input of energy contributed only 8% when compared to other agricultural inputs such as fertilizers and pesticides which contributed 82 and 9%, respectively [9]. In Australia, pre-farm processes such as production of fertilizers, pesticides, diesel and electricity in cotton production contributed 25.3%, whereas post-farm processes such as cottonseed drying utilizing LPG, gin machinery utilizing electricity, bale packaging, gin trash treatment and transportation accounted for 26.2% and rest 48.4% were emitted during on-farm processes [10]. Yousefi., *et al.* [8] reported that electricity contributed 78.7% of carbon footprinting. Sah and Devakumar [11] testified emission from the use of electricity from India for the period of 2000 - 2010 was 3%. In India, contribution of irrigation for GHG emission is 1 - 13%, except for wheat and rice [12]. In cotton, 13.9% of the total on-farm carbon footprint (108 kg CO_2e t^{-1} lint) was contributed by irrigation [10]. Land-use change from natural to agricultural land reduced SOC by 60 - 75% that reduced the productivity of plants, reducing the nutrient use efficiency of the plants as well as sequestration of atmospheric carbon [13]. 6 - 17% of total global GHG emission was contributed by conversion of forest land to agricultural land or pastures [14].

Machinery: With the rising demand of population, the use of machinery is increasing and the energy provided to machinery for production, transportation and application, is obtained from fossil fuel that emits GHG. Machinery contributed 67.176 kg CO_2-e ha^{-1} out of 2042.091 kg CO_2-e ha^{-1} total CO_2-e (3.29%) emissions in sunflower production [8]. In Australia, for cotton production, Hedayati., *et al.* [10] calculated carbon footprint of machinery and found it to account for almost 7% (125.5 kg CO_2e t^{-1} lint) in total carbon footprint with 16% on-farm emission from machinery.

Diesel: Diesel consumption occurs during tillage process for transport of fertilizers, pesticides, seeds and other farm equipment and major emissions. Diesel consumption contributes to 12.24% carbon footprint [8].

Chemicals: Fertilizer production, transport and application have significant contribution towards total GHG emission [12]. Synthetic fertilizers are responsible for 13% of total agricultural emission of GHGs [7]. In production process, CO_2 is the major GHG emitted and in the field, N_2O is the major contributor [12]. In sunflower farming, chemical fertilizers contributed 5.77% of the total carbon footprint [8]. Devakumar., *et al.* [9] testified that in semiarid areas of India the contribution of inorganic nitrogenous fertilizers is approximately 72 and 9% from phosphorus and potassium fertilizers. Fertilizers use in cotton production led to 442 kg CO_2-e t^{-1} lint, about 57% from on-farm emission, whereas production of fertilizers led to 267.7 kg CO_2-e t^{-1} lint, contributing 16.7% in total carbon footprint [10]. During 2000 - 2010, N fertilizers contributed 89% of carbon footprint, whereas contribution from phosphorus (4%) and potassium (2%) were very small in India while pesticides accounted for 2% of the total carbon footprint [11].

Crop: Demand of nutrients and management practices had a variable effect on Carbon footprint of different crops. Rice is the most energy demanding crop thus has higher GHG emissions [12]. FAO [15] report suggested that rice cultivation releases 523 million tons of CO_2-e per year that contributed 8.8 - 10% of total agricultural emission globally in 2012. Benbi [16] testified that in 2015, rice cultivation emitted 2917 Gg CO_2-e and wheat emitted 1537 Gg CO_2-e which contributed, respectively, 60 and 31% of total cropland emission in Punjab. In India 21% of total agricultural emission was from rice cultivation [17]. Devakumar., *et al.* [9] scrutinized different crop groups and concluded that cereals and pulses that contributed around 25 and 16%, whereas oilseeds and commercial crops have a highest carbon footprint of 30 and 29%, respectively. Thus, leguminous crops have the highest sustainability index [9]. Oilseed cropping emits higher GHGs than cereals attributing to their high N content [18]. Legumes have 65% less emission than canola and wheat [19]. The studies concluded by Rao., *et al.* [12] and Benbi [16] revealed that large-scale emission of CH_4 recorded the highest carbon footprinting rice. Rao., *et al.* [12] compared carbon footprint of rice, wheat, sorghum, maize, pearl millet, and finger millet, in all states of India, and reported that rice crop has higher energy demand, mainly for irrigation. Millets have low water requirement thus have the lowest carbon footprint. Indian farming is primarily based on water availability and climate conditions of that region that explains reduced carbon footprint of different crops in rainfed areas. Yousefi., *et al.* [8] estimated the carbon footprint of sunflower agroecosystem in Iran and found mean carbon footprint to be 0.875 kg CO_2-e kg^{-1}. Due to regional differences, nutrient requirements, irrigation, and farming practices there's a differences in carbon footprint of the same crop in different regions. Powlson., *et al.* [20] reported a great loss of C as CO_2 due to burning of straw in field and also as the fuel. In India, in 2017, 488 million tons of crop residues was generated and 24% of it get burnt, emitting 211 Tg CO_2-e GHGs, along with other gaseous air pollutants (Ravindra., *et al.* 2019).

Livestock: Carbon footprint from livestock is almost double than from crops. Livestock sector emanates GHGs via enteric fermentation, feed production, transport, and manure application. Energy use from livestock sector contributed 20% of the total emission (Gerber., *et al.* 2013). Chhabra., *et al.* [21] testified 99.8% CH_4 and 0.2% N_2O emission from livestock. Globally, CH_4 is the dominant GHG emitted from livestock sector, contributing 44% of total, whereas N_2O and CO_2 account for approximately similar contribution, i.e. 29 and 27%, respectively (Gerber., *et al.* 2013). Generally, livestock contributed about 66% of total agricultural GHG emissions, in which enteric fermentation accounts for 40%, manure left in pastures accounts for 16%, and manure management share is 7% (FAOSTAT 2014). Gerber., *et al.* (2013) reported that livestock contributed 14.5% of total anthropogenic emission. Feed production and transport contributed 45% and enteric fermentation accounted for 40% of the total emission for livestock sector (Gerber., *et al.* 2013). Beef and dairy cattle hold a larger share of carbon footprint than other ruminants or animals [21]. Production of milk and cattle meat has major contribution in GHG emissions. Feed production, processing, and manure processing from pork and poultry emits large amount of GHGs. INCCA [17] report suggests that enteric fermentation is accountable for 63% of total emission from agriculture sector. Higher carbon footprint of animal feed contributes to the higher carbon footprint of animal-based products.

Mitigation strategies

In the present-day scenario in order to moderate the adverse effects of climate change, it is very important to reduce the carbon footprint of agricultural products. Efficient use of fossil fuel and other non-renewable energy sources in the agriculture, adopting diversified cropping system, enhancing soil carbon sequestration by straw return, plantation, etc., crop rotation system, and limiting deforestation may help to reduce the GHG emissions from agriculture sector.

Crop diversification: Carbon footprint of agricultural crops varies with the diverse agricultural practices adopted species to species. Diversified cropping system increases the productivity lowering the carbon footprint by sequestering carbon and nitrogen leguminous crops [18,19]. One of the major sources of agricultural emission of GHGs is the use of nitrogenous fertilizers during crop cultivation. Crop biomass and N content of the crop are also the deciding factors of carbon footprint. The crop following leguminous crop require less N fertilization, so total carbon footprint is lowered. Hence, the requirement of energy for manufacture and transportation of fertilizers is reduced, leading to low GHG emissions. By using optimum rate of N fertilizers, a reduction of 13.2% in total GHG emission was recorded by Hedayati., *et al* [10]. Sequential cropping also reduced the carbon footprint. Gan., *et al.* [19] testified wheat crop following leguminous crops emitted 20% lower GHGs compared to when cultivated after cereals. Similarly, growing wheat after oilseed, reduced the emission of GHGs by 11% as compared to wheat after cereals.

Summer fallowing: Summer fallowing system increases the crop productivity reducing the carbon footprint of agriculture as it reduces the requirement of N by increases the N availability. Liska., *et al.* [22] reported that residue removal emits higher CO_2 and also causes the loss of SOC, it reduces the emission of N_2O.

Increasing SOC: Conservation tillage, integrated nutrient management, mulching, cover cropping, diverse cropping system, and biochar application are recommended in order to increase SOC [13]. Soil is the sink for organic matter and practices that directly releases terrestrial carbon to atmosphere, such as burning of straw and fossil fuel, leading to loss of SOC and increase the GHG concentration. To reduce carbon footprint, deficit irrigation can be used as it helps to increase SOC that allocates more biomass belowground in order to access more water [23]. Pressurized irrigation systems can also help in reducing the total carbon footprint [10].

Mitigation during rice cultivation: Rotation of rice with aerobic rice or maize in dry season and with rice in wet season can lower the CH_4 emission from rice fields as rotation with maize reduced the emission as maize cropping acted as weak sink for CH_4 and also due to reduction the irrigation water requirement [24]. Yao., *et al.* [25] suggested the production of rice under a ground cover (covered with a thin plastic sheet), thus the moisture level is maintained and direct emission from flooding as well as carbon footprint of irrigation will be reduced while there was an increase in productivity.

Biochar application: Biochar application reduced the GHG emission and also enhanced the crop yield by sequestering carbon in soil [26]. Biochar application in soil causes alteration of soil biota and improves soil characteristics that lead to lower emission of CH_4 and N_2O thus reducing the carbon footprint. Sun., *et al.* [27] speculated that with application of biochar the methanotrophic community was enhanced or the population of methanogens decreased, enhanced N immobilization, decreased denitrification and increased soil pH, leading to reduced CH_4 and CO_2 emission. Xiao., *et al.* [26] suggested reduction in CH_4 and N_2O emission by applying biochar in rice field under controlled irrigation.

Organic farming: Energy use is greatly reduced under organic farming system due to no use of fertilizers and pesticides. Organic farming helps in reducing the total carbon footprint of agriculture by sequestering carbon into soil [10,28]. In organic farming, N_2O emission can be reduced by 50% and CH_4 emission by 70%, by manure composting [14]. Skinner., *et al.* [28] reported that organic farming cuts the N_2O emission by 40.2%. IFOAM [14] report suggested proper management of manure i.e. turning and aeration of manure heaps, keeping manure in closed space, solid and slurry separation and addition of substances reduces the emission and biogas production by biodigesters from manure, thus lowering the emission from manure management.

Biofuel: Use of biofuels instead of fossil fuels is also reported to decrease the carbon footprint of agriculture [23]. The total agricultural carbon footprint was reduced by 8.1% by substituting the electrical energy with solar powered irrigation pumps and also the use of biofuel-based machinery as an alternative for diesel-based reduced the emission by 3.9% [10]. Pawlowski., *et al.* [23] reported growing sugarcane and napier grass under conservation agriculture as a substitute to arable crops, increased SOC and reduced the carbon footprint. Napier grass cultivation has more environmental benefits in terms of reduced GHG emissions, increase in SOC and biofuel production.

Tillage: Tillage disturbs the soil and unveils the organic matter for oxidation and thus loss of SOC occurs. Crop residue mulch with no-tillage significantly enhanced the soil carbon and also stabilizes the new aggregates. Pandey., *et al.* [4] reported that reduced tillage causes increment in total and recalcitrant C pool in rice-wheat system. Crop residues left under no-tillage condition recorded highest rate of carbon sequestration, by reducing the rate of oxidation of organic molecules [4]. The potential of no-tillage to increase the SOC can be influenced by the region and soil condition.

N fertilizer: With limited use and proper application of N fertilizers, emission from soil as well as emission from production and transportation may also be reduced. Several techniques are developed to quantify the required amount of fertilizers such as GreenSeeker and leaf color chart-based urea application. Nath., *et al.* [29] reported by the use of GreenSeeker N_2O emission can be reduced by 11 - 13% in wheat cropping. International Rice Research Institute developed a more efficient technique based on the color of leaf to reduce the excessive use of N fertilizer. This LCC-based urea application method enhances the N use efficiency as well as yield of the crop by reducing the fertilizer-based emission. Bhatia., *et al.* [30] reported by using LCC-based urea application in rice-wheat system, GWP was reduced by 10.5% of rice-wheat system. Jat., *et al.* [31] suggested the use of neem-coated urea. Yao., *et al.* [25] reported that deep placement of urea under ground cover rice production system reduces the GHG emission by 41% as compared to surface application.

Conclusion

Agriculture sector plays the foremost role in impacting the climate change scenario via a higher carbon footprint. Processes involved in production of agricultural input to the processing of agricultural output and emission of GHGs are inexorable. That carbon footprint of pre-farm activities such as manufacture and transportation of fertilizers, pesticides and the machineries is significant. Whereas, the type of crop, water and fertilizer requirement has a considerable effect on the emission from the field. Amongst all crops, rice has the highest carbon footprint due to CH_4 emission and irrigation demand. Again, carbon footprint of livestock sector is reasonably higher due to manure management, feed production, and enteric fermentation. Carbon footprint is decided by the interrelation of the processes; hence, mitigation of emission can be done by using some advanced agronomic practices. Appropriate use of fertilizer, crop rotation, irrigation management, biochar application, reduced tillage frequency, organic farming, etc., are certain recommended measures for mitigation. In order to lessen the carbon footprint, farming practices that enhance SOC stands as the best mitigation strategies. Different techniques as GreenSeeker, LCC-based urea application, neem, and sulfur-coated urea can substantially reduce the carbon footprint of N fertilizers.

Bibliography

1. Rees WE. "Ecological footprints and appropriated carrying capacity: what urban economics leaves out". *Environment and Urbanization* 4.2 (1992): 121-130.
2. Wiedmann T and Minx J. "A definition of 'carbon footprint'". *Ecological Economics Research Trends* 1 (2008): 1-11.
3. IPCC. "Fifth assessment report of the intergovernmental panel on climate change" (2014).
4. Pandey D., *et al*. "Recalcitrant and labile carbon pools in a sub-humid tropical soil under different tillage combinations: a case study of rice-wheat system". *Soil and Tillage Research* 143 (2014): 116-122.
5. Lal R. "Carbon emission from farm operations". *Environment International* 30.7 (2004): 981-990.
6. FAO. "Food and agriculture organization of the United Nations: FAO statistical pocketbook" (2015).
7. FAO. "Food and agriculture organization of the United Nations: News article" (2014).
8. Yousefi M., *et al*. "Water footprint and carbon footprint of the energy consumption in sunflower agro ecosystems". *Environmental Science and Pollution Research* 24.24 (2017): 19827-19834.
9. Devakumar AS., *et al*. "Carbon footprint of crop cultivation process under semiarid conditions". *Agricultural Research* 7.2 (2018): 167-175.
10. Hedayati M., *et al*. "Farm-level strategies to reduce the life cycle greenhouse gas emissions of cotton production: An Australian perspective". *Journal of Cleaner Production* 212 (2019): 974-985.
11. Sah D and Devakumar AS. "The carbon footprint of agricultural crop cultivation in India". *Carbon Management* 9.3 (2018): 213-225.
12. Rao ND., *et al*. "Spatial analysis of energy use and GHG emissions from cereal production in India". *Science of the Total Environment* 654 (2019): 841-849.
13. Lal R. "Sequestering carbon in soils of agro-ecosystems". *Food Policy* 36.1 (2011): S33-S39.
14. IFOAM report (2016).
15. FAO. "FAOSTAT database collections". Food and Agriculture Organization of the United Nations. Rome (2017).
16. Benbi DK. "Carbon footprint and agricultural sustainability nexus in an intensively cultivated region of Indo-Gangetic Plains". *Science of the Total Environment* 644 (2018): 611-623.
17. INCCA (Indian Network for Climate Change Assessment). "India: greenhouse gas emissions 2007". Ministry of environment and forests, government of India (2010).
18. Liu C., *et al*. "Farming tactics to reduce the carbon footprint of crop cultivation in semiarid areas". *Agronomy for Sustainable Development* 36.4 (2016): 69.
19. Gan Y., *et al*. "Strategies for reducing the carbon footprint of field crops for semiarid areas". *Agronomy for Sustainable Development* 31.4 (2011): 643-656.
20. Powlson DS., *et al*. "Does conservation agriculture deliver climate change mitigation through soil carbon sequestration in tropical agro-ecosystems?" *Agriculture, Ecosystems and Environment* 220 (2016): 164-174.
21. Chhabra A., *et al*. "Greenhouse gas emissions from Indian livestock". *Climatic Change* 117.1-2 (2013): 329-344.
22. Liska AJ., *et al*. "Biofuels from crop residue can reduce soil carbon and increase CO_2 emissions". *Nature Climate Change* 4.5 (2014): 398-401.

23. Pawlowski MN., *et al*. "Field-based estimates of global warming potential in bioenergy systems of hawaii: crop choice and deficit irrigation". *PLoS ONE* 12.1 (2017): e0168510.

24. Janz B., *et al*. "Greenhouse gas footprint of diversifying rice cropping systems: Impacts of water regime and organic amendments". *Agriculture, Ecosystems and Environment* 270-271 (2019): 41-54.

25. Yao Z., *et al*. "Urea deep placement reduces yield-scaled greenhouse gas (CH_4 and N_2O) and NO emissions from a ground cover rice production system". *Scientific Reports* 7.1 (2017): 11415.

26. Xiao YN., *et al*. "Biochar improved rice yield and mitigated CH_4 and N_2O emissions from paddy field under controlled irrigation in the Taihu Lake Region of China". *Atmospheric Environment* 200.1 (2019): 69-77.

27. Sun H., *et al*. "Greenhouse gas emissions vary in response to different biochar amendments: an assessment based on two consecutive rice growth cycles". *Environmental Science and Pollution Research* 26.1 (2019): 749-758.

28. Skinner C., *et al*. "The impact of long-term organic farming on soil-derived greenhouse gas emissions". *Scientific Reports* 9.1 (2019): 1702.

29. Nath CP., *et al*. "Greenhouse gases emission, soil organic carbon and wheat yield as affected by tillage systems and nitrogen management practices". *Archives of Agronomy and Soil Science* 63.12 (2017): 1644-1660.

30. Bhatia A., *et al*. "Greenhouse gas mitigation in rice-wheat system with leaf color chart-based urea application". *Environmental Monitoring and Assessment* 184.5 (2012): 3095-3107.

31. Jat SL., *et al*. "Energy auditing and carbon footprint under long-term conservation agriculture-based intensive maize systems with diverse inorganic nitrogen management options". *Science of the Total Environment* 664 (2019): 659-668.