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Carbon Sequestration Potential in Organic Farming

Alagirisamy B[1]* and Shanmugam N[2]

[1]Department of Environmental Sciences, Tamil Nadu Agricultural University, India

[2]Department of Physics, Coimbatore, India

***Corresponding author:** Bharani Alagirisamy Associate Professor, Dept. of Environmental Sciences, Tamil Nadu Agricultural University, Coimbatore, India, Email: bharania2004@rediffmail.com

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Abstract

Organic agriculture is claimed to be the most sustainable approach in food production. It emphasizes recycling techniques and low external input and high external strategies. It relies not only on the fertilizers of organic origin, such as compost, manure, green manure, and bone meal and places emphasis on techniques such as crop rotation and companion planting but also seeds sown through the organic farming. By sequestering carbon dioxide in the soil, agriculture may contribute to the carbon cycle in a positive way. Agriculture has the potential to be a considerable CO2 sink, if good practices, like organic farming, are employed. Organic agriculture offers a unique combination of environmentally-sound practices with low external inputs while contributing to food availability. The potential of organic agriculture to mitigate climate change is mostly claimed on the basis of assumptions concerning the soil carbon sequestration potential of organic management. .Organic farmers could be amplifying their positive climate impact by adopting the best agricultural practices to boost carbon sequestration.

Keywords: Carbon Sequestration; Organic Agriculture; Low External Inputs; Soil Fertility; Carbon Sink

Abbreviations: IPCC: Intergovernmental Panel on Climate Change; CSS: Carbon Capture Storage; RTOACC: Round Table on Organic Agriculture and Climate Change.

Introduction

Organic farming includes environmentally sound practices utilizing low external inputs that help in enhancing carbon sequestration to attain sustainability avoiding usage of synthetic fertilizers, pesticides etc. In this paper we will discuss on the concept of organic farming and carbon sequestration potential in an organic farming system. Organic farming depends on the fertilizers of totally organic origin namely compost, animal manure, green manure etc. and lays emphasis on crop rotation and companion planting. Organic agriculture by definition is the crop production and management system that never uses synthetic fertilizers, genetically modified organisms and pesticides by minimizing pollution of air, water and soil and optimizing the health thereby enhancing the productivity of interdependent communities of plants, animals and people.

Alternately it is a process of removing carbon dioxide from earth's atmosphere and stored in either liquid or solid form. This process can be carried out through forest conservation which directly enhances the storage of carbon thereby reducing the CO2 emissions (suppression of wildfires and reduction in tillage activities). Circulation of carbon from global carbon pool happens by the changes in molecular forms. Uptake of CO_2 from the atmosphere by plants and its by-products cycles carbon between various components of the environment viz., atmosphere, forest soils and oceans. Energy consumption by humans cycles carbon from fossil fuels to the atmosphere. During this flow between ecosystems, the pools through which carbon flows acts either as a source of emitter or sink for its deposition knowing the source sink activity, optimization to draw carbon by the sinks and reduction of carbon in atmosphere will lead to a reversal climate change made by anthropogenic activities. The present situation is alarming to know wherein atmosphere and oceans deposit more of carbon while huge carbon is being lost in soils due to developmental activity, conversion of grasslands, forests to agricultural land and practice of agriculture that decrease the soil organic matter. Carbon sequestration by soils through agriculture contributes for positive carbon cycle which is decided by the management practices applied. If good agriculture practices are followed, where organic inputs are applied will enhance the soil to be a potential CO_2 sink. Organic farming with low external inputs in combination with environmentally friendly practices contributes for safe food availability [1]. In countries like India, organic products have a steady market that offers an opportunity to increase farmers' livelihood and profitability through premium price. Many studies have been done highlighting the importance of organic farming that is being done to mitigate climate change and its adaptation [2,3]. Based on the assumptions of soil organic carbon sequestration potential, organic farming is being advised. Terrestrial carbon sequestration is proposed by scientists as an effective mitigation option because it combines mitigation with positive effects on environmental conservation and soil fertility [4]. Green projects like CDM, UN-REDD etc focuses on forest and degraded lands for terrestrial carbon sequestration. While agricultural soil carbon sequestration is yet to be included in UNFCCC protocols. Voluntary carbon markets partly include agricultural soil management practices.

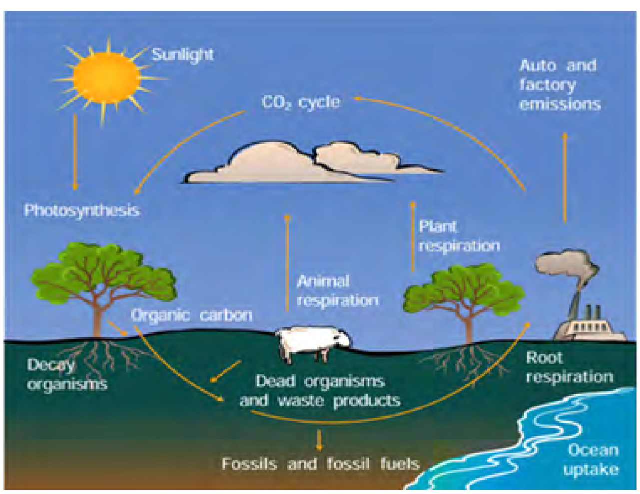

Figure 1: Carbon cycle in the ecosystem involves carbon capture and long term storage of atmospheric carbon dioxide.

Good agriculture practices include crop rotation growing green manures, application of compost, introduction of too many enterprises in the field, biocontrol agents for pest control, crop diversity etc seeking the locally available resources. Application of organic manures instead of mineral fertilizers will lead agriculture in a positive way with regard to soil carbon. According to literatures in the year 2007, about 32 million hectares of land were brought under certified organic category consisting of 1.2 million farmers [5]. The scenario on the developing countries was quite different wherein a huge number of uncertified farmers applied only organic inputs in their lands for sustenance of soil. The reason was due to minimum access to agricultural inputs like mineral fertilizers or pesticides and also difficulty in market accessibility for their produces. Exploring the literature, we could draw conclusions that application of organic manures was able to enhance the soil organic matter that builds the soil health and encourages numerous species of beneficial microorganisms who are the agents for bioavailability of plant nutrients and also as agents for controlling plant diseases mostly soil borne.

It is a known fact that the decomposition of plant residues add to the soil organic matter through supply of nutrients to plant in bioavailable form while restricting the use of synthetic fertilizers that are the major causes for soil and environmental problems. This has led the scientists to declare the International year of soils to be the year 2015 by the UN General Assembly having the theme of "Healthy soils for a healthy life". Thus the word "Organic farming" was found to be a dominant name in countries wherein toxic and synthetic pesticides and fertilizers were not used. This issue was published in the J.I.Rodale's global magazine of Organic Farming and Gardening, USA in 1940's. Rodale was the person who promoted this term organic that included application of composts green manures mulches and cover crops for building the soil health by proper recycling to enhance the organic matter levels which was meant to be the primary management practice.

Organic vs Conventional

Soils with higher organic matter have the capacity to resist erosion caused due to heavy rains and help the soil to capture more of rain water. Soil structure is mainly improved because of soil organic matter becomes more resistant to erosion and tillage is done easier than before. By doing so, lesser energy use is observed and also less of green house gas emission. The moisture or water that is captured more helps the plants grown in such soils to utilize during dry periods. Research experiments have evidenced 30% higher yields in fields during drought where the soil organic matter was high than conventional systems. Meta-analysis of published articles concludes that the organic farming systems perform superior than conventional systems in capturing the CO_2 released from atmosphere. Reganold, et al. [6] proved that organic farming helped to stop erosion where carbon losses are converted to gains because of:

- Animal manure and green manure applications.
- Crop rotations and with intercropping and cover crops improved soil fertility.
- Recycling of crop residues through compost making.

Carbon Sequestration – An Important Phenomenon to Store Carbon in the Ecosystem

Intergovernmental Panel on Climate Change (IPCC) suggested that through anthropogenic carbon emissions are reduced in future, the already accumulated CO2 in the atmosphere have to be ensured for safe levels and needs to mitigate climate change. Carbon sequestration research focus on carbon capture and storage (CSS) and reforestation giving less importance to soil carbon sinks. Of late, melting of glaciers and ice sheets coupled with alarming heat warrants the severe exploration of all possible sequestration strategies. When proper management is done, soils sequester carbon from the atmosphere. As Lal [7,8] reported the usefulness of soils as one of the major carbon sink and how it is drawn becomes essential considering the global estimates. According to World Bank [9], one third of all arable land on a global scale is used for agriculture and these lands have to be used for increasing the soil carbon content which is going to be a major component as a sink for carbon sequestration. There are many agricultural practices employed to increase the soil organic matter content by using huge quantities of organic inputs and enhance the soil processes and prevent losses due to microbial turnover. World-over nations concentrate and focus on the agricultural soils that claim as a potential climate stability wedge and drawdown solution. The advantages of increasing soil carbon content that improves soil structure, fertility and water holding capacity of soils outweighs the potential costs.

Sequestration Through Agriculture

World - over, the debate on whether agricultural practices help in the ability of soils to absorb enough CO_2 to stabilize the current atmospheric CO_2 levels is going on among the scientists. On the other hand, most of the reviews on conventional farming showed that most of them are losing soil carbon and slows the rate of loss. Alternately, agricultural systems that include recycling of farm wastes, crop rotation, diversity, application of organic manures etc. are found to increase the soil organic matter. The Research Institute of Organic Farming, Switzerland, FAO published a preliminary report on 45 comparison trials of organic and conventional systems that included about 280 datasets. This research study comprised of arable lands grasslands and permanent crops in several continents. Analyzing the data from the above concluded that organic systems recorded higher soil carbon sequestration. A study conducted by Andreas Gattinger et al reported that the organic management accumulated about 37.4 tons of C ha^{-1} compared to conventional management system with 26.7 tons C ha^{-1} and the difference between these two systems was recorded to be 10.7 tons of carbon. The accepted formula for the calculation of CO_2 in terms of soil organic carbon (SOC) is SOC x 3.67 = CO_2. Calculating the formula for the above study reported more than 39.269 tons of CO_2 sequestration in the organic system in a duration of 16.7 years, which means an average of 2351 kg of CO_2 as sequestered per hectare per year in the organic systems in comparison to conventional system. In a peer reviewed data analysis a publication by PNAS, comparison was made for 41 research trials revealed that organic systems sequestered about 550kg of carbon per hectare per year which is equivalent to 2018.5 kg CO_2 per kg per year. This report led to widespread adoption of organic farming practices currently leading to the potential to sequester around 10Gt of CO_2 which marks which marks the range of emission gap in the year 2020 with 8 – 12 Gt CO_2/yr. These remain examples that are significantly higher or lower than the average.

Another study conducted by the Rodale Institute in Pennsylvania comparing organic and conventional cropping systems for more than 30 years confirmed that organic methods were effective in removing CO_2 from atmosphere and fixing it in the soil as organic matter. As Tim LaSelle and Paul Heperly reported the FST organic experiments sequestered carbon in the soil at 875 lbs/ac/year through crop rotation using raw manure and the carbon sequestered in a rotation using legume cover crops was at the rate of 500 lbs/ac/yr.

According to the compost utilization trial (CUT) from Rodale Institute which is a 10 year experiment conducted to study the use of composts, manures and synthetic fertilizers revealed that the use of composted manure along with crop rotation in an organic farming system with 2000 lbs/ac/yr of carbon sequestration. While fields applied with standard tillage practices that relies on chemical fertilizers lost about 300 lbs/ac/yr equivalent to a sequestration rate of 2055.2 kg of CO_2/ha/yr. Finally the study concluded that higher rates of sequestration observed in an organic farming system. The total carbon sequestered into the soil accounts to 2000 lbs/ac/yr which is equivalent to the sequestration rate of 8220.8 kg of CO_2/ha/yr. When this value is extrapolated global level would sequester 40Gt of CO_2.

How Organic Farming Helps in Carbon Sequestration?

Organic farming enhances the carbon sequestration to achieve sustainability without the use of synthetic fertilizers, pesticides etc. Role of organic mulches in carbon sequestration is the major concern. Organic mulching is carried out by covering the top soil with organic matter may be compost or farm yard manure followed by addition of dry organic matter over. Any compost material is rich in beneficial microorganisms, the dry organic matter has high amount of carbon and the green manure is rich in nitrogen, the three in combination are needed for the metabolic activity of microbes and also to enrich the soil fertility. Application of all these three upon decomposition gives a ratio of 10:1 carbon and nitrogen which is ideal for multiplication of the microbes in the soil. Farming done by this method improves the farmer's income which is reflected in their yield. Hence, organic farming not only improves soil fertility but also sequesters atmospheric carbon into the soil. Organic Centre, a nonprofit research organization of Washington DC in collaboration with University of Maryland published an article in the Journal Agriculture, Ecosystem and Environment stating that the amount of carbon captured in soil increased by 18% while the microbial biomass carbon storage went upto 30%. A metanalysis under the leadership pf Professor Kate Tully and Rob Crytal Ornelas of over 4000 scientific articles revealed the specific techniques for carbon building for implementation by the farmers. Upon examining the different practices followed they were able to list out them to be use of soil organic amendments, conservation tillage and cover crops, compost and manure for the biggest and fastest impact on C sequestration by 24%.

In this regard, the Round Table on Organic Agriculture and Climate Change (RTOACC) can serve as a platform to exchange ideas and promote the bilateral or multilateral research on C sequestration as influenced by organic farming systems. However in future SOC investigations, the above described data gaps and methodological uncertainties should be taken into account. The literatures pertaining to C sequestration as influenced by organic farming system was collected and reviewed about 40 scientific publications to convert into meaning full data matrix. Upon evaluation quantitatively the results revealed higher soil organic carbon in soils in organic farming system was in line with the findings of Leifeld and Fuhrer [10]. Their evaluation of 32 peer-reviewed papers and 68 data sets revealed that after conversion, SOC contents in organic systems increased annually by 2.2 percent on average, whereas in conventional systems, SOC did not change significantly. Also they found out that there is lack of SOC data in developing countries since no comparison of data has been done especially Africa and Latin America. With limited data on SOC, they found it difficult to draw conclusions and come to a consensus with regard to soil carbon storage.

An estimate of the maximum technical mitigation potential from soil C sequestration by switching to organic agriculture can be gained by applying the average difference in sequestration rates for net zero input systems (0.27 Mg C ha^{-1} y^{-1}) to the current global arable land area. This results in 0.37 Gt C sequestered per year globally (0.03 Gt C in Europe, 0.04 Gt C in the United States), thus offsetting 3% of current total GHG emissions (2.3% for Europe, 2.3% for the United States), or 25% of total current agricultural emissions (23% for Europe, 36% for the United States), and equaling approximately 25% of the annual technical agricultural mitigation potential, as identified elsewhere [11]. The cumulative mitigation till 2030 would contribute 13% to the cumulative reductions that would be necessary until 2030 to stay on the path to reach the two degree goal by 2100 [56 Gt C globally from 2010 till 2030] [12].

Conclusions

Carbon sequestration on agricultural lands is possible through a range of soil management strategies and could be substantial with widespread implementation. Sequestration of historic carbon emissions is now essential as mitigation alone is unlikely to stabilize our atmosphere. There are numerous management strategies for drawing carbon out of the atmosphere and holding it in the soil [13]. These strategies vary in effectiveness across different climates, soil types, and geographies. There are still debates about the durability of sequestration in soil and about the precise conditions that maximize drawdown of carbon emissions. This paper explores how soil carbon is sequestered, the state of soil carbon research, and the debate on the extent of its potential. It offers a set of recommendations for ongoing research and highlights the many co-benefits to increasing soil carbon. Organic farming is the only solution for climate change impacts by improving the carbon capture and storage systems [14]. Organic agriculture has considerable potential to reduce green house gas emissions. Organic agriculture aims at improving the soil fertility and nitrogen supply by leguminous crops, crop residues and cover crops. The enhanced soil fertility leads to stabilization of soil organic matter and in many cases to a sequestration of carbon dioxide into the soil. Impacts like soil erosion could be prevented and the fertility status may be maintained for sustainability. Organic systems are highly adaptive to climate change due to the application of traditional skills and farmers' knowledge, soil fertility- building techniques and a high degree of diversity.

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