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Climate Change Mitigation Through Organic Farming in Vegetable Production

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Abstract

Vegetable crops provide food and nutritional security to millions of people. They are short duration in nature and different development phases are significantly influenced by environmental vagaries. The rise in temperature, changes in precipitation patterns, excess UV radiation and extreme weather events like droughts and floods threatening the crop growth, yield and economic return. Again the farming practices as well as production of agricultural inputs such as nitrogen fertilizers, synthetic pesticides and fossil fuels emits at least one-third of GHG emissions of the world. Several reviews suggested that organic agricultural systems have an inherent potential to both reduce GHG emissions and to enhance carbon sequestration in the soil. Organic farming largely excludes the use of synthetic fertilizers, pesticides, and hormones with greater emphasis upon crop rotations, crop residues, animal manures, on-farm recycling, symbiotic nitrogen fixation and biological system of nutrient mobilization and plant protection that minimizes the environmental impact on crop production and preserves the long term sustainability of the production system.Several field studies have proved the positive effect of organic farming system on soil carbon pools, which have strong mitigation potential of climate extremes. Crop diversification and an increase of soil organic matter will enhance the nutrient buffer capacity and the microbial activity, both will strengthen soil fertility and will enhance resilience against extreme weather events. The scaling-up of organic agriculture would promote and support climate friendly farming practices hence more research and development of organic agriculture are needed to better unlock its potential and application on a large scale. The present work reviews the different aspects of organic practices that have direct role in mitigating the climate change effect in vegetable production system.

Keywords

Organic Farming, Climate Change, GHG Emissions, Carbon Sequestration, Mitigation Strategies

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1. Introduction

Vegetables are rich and cheaper source of carbohydrates, protein, minerals and vitamins and plays important role in overcoming micronutrient deficiencies as well as alleviating poverty to millions of people. The different development phases of vegetable crops are highly sensitive to environmental extremes. The unpredictable high temperature and erratic rainfall patterns disrupt the normal growth and development of the plant. Global climate change is emerging as one of the major constrains for world vegetable production. According to studies carried out by the Intergovernmental Panel on Climate Change (IPCC) the average global temperature has increased by 0.74ºC between 1906-2005 and a further increase of 0.2ºC to 0.4ºC in the next 20 years is expected. Atmospheric CO_2 will increase from the current concentration of 360 ppm to 400–750 ppm by 2100. Sea level will rise from 15 cm to 95 cm by 2100(IPCC, 2007).Therefore rise in temperature, changes in precipitation patterns, rise of sea levels, excess UV radiation and higher incidence of extreme weather events like droughts and floods and are already causing significant agricultural yield losses

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and will become even more prevalent in the coming decades due to the effects of global change (Battisti and Naylor, 2009; Lobell *et al.*, 2008). So, there is an urgent need to focus different effective adaptations and mitigation strategies to minimize the environmental impact on crop production and preserves the long term sustainability to make the production system more resilient to climate change. These challenges could be met through organic agriculture as it has the ability to continue functioning with unexpected events of climate change (Borron, 2006).Organic agriculture offers an alternative production system as it restricts or avoids the use of mineral fertilizers and in turn tends to increase the carbon sequestration in the soil. Organic farming practices preserve soil fertility and maintain or increase organic matter that can reduce the negative effects of climate extremes while increasing crop productivity (ITC and FiBL, 2007; Niggli *et al.,* 2008). The practices also promote and enhance agro-ecosystem health, including biodiversity, biological cycles and soil biological activity. The present study was aimed to review and analyze the currently available scientific information to identify different organic farming practices to mitigate climate change effect and to highlight the potential of organic farming as a climate change adaptation strategy for food and nutritional security of the world.

2. Adverse Effect of Chemical Farming on Eco System

Traditional crop production system releases a significant amount of carbon dioxide, methane and nitrous oxide into the atmosphere amounting to around 13.5% of global anthropogenic greenhouse gas emissions (Fig. 1) annually, mostly methane from livestock rising, biomass burning and wet cultivation practices, and nitrous oxides from the use of synthetic fertilizers. In addition to the indirect contributions through, land conversion to agriculture, fertilizers production and distribution and different farm operations. Hence the contribution of agriculture could be as high as 17-32% of global anthropogenic emissions (Bellarby *et al.,* 2008). Indiscriminate use of synthetic fertilizers have large scale deleterious effect on the global Nitrous oxide emission and the amount increased by 17% from 1990 to 2005 and are projected to increase by 35–60% up to 2030 (Smith *et al.*, 2007).Nitrogen fertilizer applications to soils result in nitrous oxide emissions, as this gas is a by-product of the transformation of nitrogen compounds added to the soil. Nitrous oxide fluxes from soil are mainly driven by microbial activity, through nitrification and denitrification processes (Firestone and Davidson, 1989).Besides soil emissions after fertilizer applications (direct emissions),fertilizer-related nitrous oxide production can also result from indirect emissions. However these emissions are very dependent on the methods used to obtain fertilizers as half of synthetic nitrogen fertilizer-related greenhouse gas emissions could occur in the production phase, whereas the other half occurs from the soil (Tirado *et al.*, 2010).

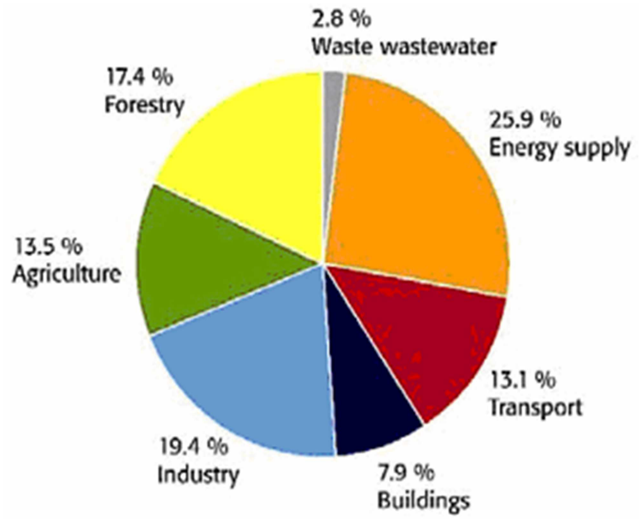

Fig 1. Green House Gas emissions (*Source* Khanal, 2009)

3. Organic Farming to Combat Climate Change Effect

There are a variety of organic farming practices that can reduce agriculture's contribution (Table 1) to climate change. These include replacement of chemical fertilizers through organic amendments, crop residue recycling, incorporation of legume in crop rotations, crop diversification, avoidance of burning of crop waste and residues as well as more use of organic mulches, bio-inoculants and organic growth promoting substances as vegetable production strategies. All these practices will help to build up soil organic matter and will offer sustainable carbon credits generation (Bellarby *et al*., 2008 and Niggli *et al*., 2008).

Table 1. Mitigation potential of organic agriculture.

Source of GHG	Share of total GHG emissions	Impacts of organic management	Remarks
Direct emissions from agriculture	10–12%		
N_2O from soils	4.2%	Reduction	Higher nitrogen use efficiency
CH_4 gas	3.5%	Opposed effects	-
Biomass burning	1.3%	Reduction	Burning prohibited
Paddy rice	1.2%	Opposed effects	Increased by organic practices

Source of GHG	Share of total GHG emissions	Impacts of organic management	Remarks
Manure handling	0.8%	Equal	Reduced methane emissions
Direct emissions from forest clearing	12%	Reduction	Clearing of primary ecosystems restricted
Indirect emissions			
Mineral fertilizers	1%	No use	Restricted use
Carbon sequestration			
Arable lands		Enhanced	Increased soil organic matter
Grasslands		Enhanced	Increased soil organic matter

Source: Scialabba and Muller-Lindenlauf (2010)

Table 2. Adaptation potential of organic agriculture

Objectives	Means	Impacts
Alternative to industrial production inputs (i.e., mineral fertilizers and agrochemicals) to decrease pollution	Improvement of natural resources processes and environmental services (e.g., soil formation, predation)	Reliance on local resources and independence from volatile prices of agricultural inputs (e.g., mineral fertilizers) that accompany fossil fuel hikes
In situ conservation and development of agrobiodiversity	Farm diversification (e.g., polycropping, agroforestry and integrated crop/livestock) and use of local varieties and breeds	Risk splitting (e.g., pests and diseases), enhanced use of nutrient and energy flows, resilience to climate variability and savings on capital-intensive seeds and breeds
Landscaping	Creation of micro-habitats (e.g., hedges),permanent vegetative cover and wildlife corridors	Enhanced ecosystem balance (e.g., pest prevention), protection of wild biodiversity and better resistance to wind and heat waves
Soil fertility	Nutrient management (e.g., rotations, coralling, cover crops and manuring)	Increased yields, enhanced soil water retention/drainage (better response to droughts and floods), decreased irrigation needs and avoided land degradation

Source: Scialabba and Muller-Lindenlauf (2010)

4. Organic Practices to Reduce GHG Emission

Research from North America and Europe shows that organic farming systems are around 30% more efficient in using fertilizer nitrogen than conventional farming systems, which leaves very little nitrogen of the farms as greenhouse gases or as nitrate that pollutes aquatic systems. Significantly because of this efficiency very little nitrogen leaves the farms as greenhouse gases or as nitrate that pollutes aquatic systems (Drinkwater *et al*., 1998, Mader *et al*., 2002). Studies show that best practice organic agriculture emits less greenhouse gases than conventional agriculture (Mader *et al.,* 2002; Pimentel, 2005; Reganold *et al*., 2001). Higher soil organic matter under organic farming system enhanced carbon sequestration ameliorate some of the main causes of climate change can result in a net reduction in greenhouse gases. Two long-term comparison trials (21 and 22 years) of conventional and organic systems have found that the organic systems use less fossil fuels and therefore emit significantly lower levels of (around 30% less) greenhouse gases (Mader *et al.,* 2002, Pimentel 2005). Higher soil organic matter under organic farming system enhanced carbon sequestration and subsequently results in a net reduction in greenhouse gases ameliorate some of the main causes of climate change.

5. Organic Practices to Enhance Carbon Sequestration

Organic farming practices have the potential to ameliorate some of the main causes of climate change. The highest mitigation potential of organic agriculture lies in carbon sequestration in soils (Diacono and Montemurro, 2010) and better carbon sequestration can counteract up to 40% of global greenhouse gas output (Rodale, 2008). However the actual amount of mitigation is difficult to quantify, because it is highly dependent on local environmental conditions and management practices. Niggli *et al.* (2008) estimated that a conversion to organic agriculture would considerably enhance the sequestration of carbon dioxide through the use of techniques that build up soil organic matter, as well as diminish nitrous oxide emissions by two-thirds due to no external mineral nitrogen input and more efficient nitrogen use. Organic systems have been found to sequester more carbon dioxide than conventional farms, while techniques that reduce soil erosion convert carbon losses into gains (Bellarby *et al*., 2008; ITC and FiBL, 2007; Niggli *et al.,* 2008). The potential for generating carbon credits is mainly seen in more use of compost, recycling of biomass waste for compost preparation and manure storage and handling. Organic agriculture is also self-sufficient in nitrogen due to recycling of manures from livestock and crop residues via composting, as well as planting of leguminous crops (ITC and FiBL, 2007).

6. Impact of Composts

Traditional practices of using undecomposed cow dung manure results in loss of several minerals through leaching or denitrification. Decay of raw cow dung manure or organic materials releases greenhouse gases such as carbon dioxide and methane. By converting the organic substrates into compost, much of the carbon get fixed into a more stable form and the carbon is effectively sequestered which can reduce current global carbon emissions by as much as 10%(Liang *et al*., 2008; Woolf *et al*., 2010). Again a shift from anaerobic to aerobic fermentation of manure through composting can reduce further methane emissions in the air. Proper storage and handling of manure also have significant effect on methane emission in the air.It was found that the aerobic storage of compost can further reduce methane emission in air over the manure storage under open field condition. The overall is to promote soil conservation, enhance productivity, and recycle crop and animal byproducts etc. Implementation of this strategy involves (Fernandes *et al*., 1997): (i) managing of soil environment via, (ii) managing soil fauna for enhancing activity and species diversity, and (iii) managing timing of farm operations especially with regards to application and placement of amendments. Also important are the management options with regards to the landscape position. Dr. Paul Hepperly, Research Director at The Rodale Institute and Fulbright Scholar, stated: "We've shown that organic practices can do better than anyone thought at sequestering carbon, and could counteract up to 40 percent of global greenhouse gas output" (Rodale 2008).

7. Impact of Crop Residue Recycling

Crop residues are abundantly generated in large quantities during normal crop cultivation. These residues are valuable sources of organic carbon as well as several essential nutrients. Through natural process these wastes convert most of the organic matter in due course of time and thereby restabilize the environment but the share size of the wastes in short time period can overwhelm the capacity of this natural processes and results environmental pollution. Tandon (1995) suggested that a sizeable proportion of nutrient needs of agriculture, horticulture, forest and aquaculture can be met through appropriate recycling of a number of wastes and byproduct. Gaur (1999) made a comparative study on nitrogen content and C:N ratio of vegetable crop residues and agricultural crop residues and found that tomato, cabbage, turnip residues contains 3.3, 3.6 and 2.3 percent nitrogen and have 12, 12, 19 C:N ratio respectively compared to 0.5%, 0.8%, 0.3% nitrogen and 80, 50 and 110 C:N ratio respectively of rice, maize and sugarcane. Crop residues contains high amount of carbon and have high energy value because of assimilated solar energy that can serve as potential carbon stock of the soil. Removal of crop residues from the crop field will lead to removal of essential mineral elements from the soil. Retention of crop residue will enrich the carbon stock of the soil and will help to recycle the essential plant nutrients in soil. It will also help to reduces soil, water and wind erosion of the soil. It is because of its high energy value that crop residues as biofuels are considered an alternative to fossil fuel (Somerville, 2006; Lal, 2008).

8. Impact of Organic Mulches

Organic mulches are those mulches which are made out of natural substances. Over the time, organic mulches will decompose and becomes part of the soil and adds organic matter to soil, helping the soil to better retain water and nutrients, results in improved plant canopy in terms of biomass, root growth, leaf area index as well as nutrient retention and nutrient uptake efficiency and finally higher yield and better quality produce. The organic mulches are temporary and will have to be replenished from time to time as it decomposes with time. Use of surface mulch can help to store more precipitation water in soil, increases infiltration and decreases evaporation. These favorable changes in micro-climate reduce soil radiation, vapor pressure deficit and soil temperature (Singh *et al*., 2011). Mulched cover also provides favorable microhabitats for beneficial insects. In the context of climate change proper use of different mulch materials will help to combat the adverse climatic changes and will benefit the crop through better yield and quality produce. Straw from rice, wheat, barley and other crops; bark mulches from the by-products of pine, hardwood logs or cypress; wood chips;Sawdust is by-product of wood processing; Pine straw; compost (two to three inches layer of compost); Shredded leaves; Lawn cuttings were the good examples for organic mulches.

9. Inclusion of Legume in Crop Rotation

The practice of alternating the species or families of annual and/or biennial crop grown on specific field in a planned pattern of sequence so as to break pest, disease and weed cycles and improve soil fertility and organic matter is called as crop rotation. Crop rotation with a non-host legume is ideal in terms of pest management and soil fertility (Prasad, 2008). Legumes based crop rotations have a number of non N-rotational effects like increased soil microbial biomass (Kucey *et al*., 1988; Wani *et al*., 1991), improved soil structure (Latif *et al.,* 1992) and increased water-holding capacity of the soil (Wani *et al*., 1994). Judicious crop rotation may be useful for increasing short term soil organic matter and for achieving healthy, fertile and productive soils. Requirements for other nutrients like phosphorus, sulphur and micronutrients are met with local, preferably renewable resources. Organic agriculture is therefore often termed as knowledge based rather than input based agriculture (Ramesh, 2008).

10. Impact of Bio-Inoculants

Bio inoculants as the name indicates are the fertilizers of biological origin, which help in biological nitrogen fixation, solublization of insoluble plant nutrients, stimulating plant growth or decomposition of plant residues. A number of biofertilizers can be broadly classified into 3 groups: Nitrogen fixing, Nitrogen fixing microorganisms on the basis of their Nitrogen fixing mechanisms may be of 2 types i.e. Symbiotic nitrogen fixer: eg. *Rhizobium* (for legumes) and Non- symbiotic nitrogen fixer or free living eg. *Azotobacter* and *Azospirillum* (for non-legumes). Phosphate mobilizers convert the insoluble P into soluble form such microorganisms referred to as Phosphate Solubilizing Biofertilizers (PSB). These include several hetrotrophic bacteria (*Bacillus*, *Pseudomonas*) and fungi (*Aspergillus, Fusarium* and *Pencilium*). Some fungi forms symbiotic association with plant, called Mycorrhiza, and helps in the absorption of P, Zn, Cu and Fe. Among these VAM fungi is are most important that colonize various crop plants. Under stress condition microbial inoculation with *Azotobacter, Azospirillum* and phosphate solubilizing bacteria produces indole acetic acid, gibberellins and other substances that promote the growth of root hairs and increase total root area of plant which in their turn facilitate nutrients uptake by plants and maintain normal growth (Klopper *et al.,* 2004). Corn, beans and clover inoculated with VAM fungi improved their osmoregulation and increased proline accumulation which incurs drought tolerance (Grover *et al*., 2010). *Achromo bacterpiechaudii* inoculation in tomato and pepper causes Synthesis of ACC-deaminase which enhances salinity tolerance (Grover *et al*., 2010). Inoculation with *Methylobacterium sp.* and *Burkholderia sp*. reduces nickel and cadmium stress in tomato by reducing their uptake and translocation (Marquez *et al*., 2007). Tomato and Pepper when inoculated with *Achromobacterpiechaudii* ARV8, ACC-deaminase synthesis enhances which incur drought tolerance (Grover *et al*., 2010).

11. Impact of Organic Growth Promoting Substances

PGPR (Plant Growth Promoting Rhizo-bacteria) this group of microorganisms that enhance the plant growth by way of secreting phytoharmones (Auxins, Cytokinine, Gibberellic acid, Indole Acetic Acid etc.) or suppressing deleterious microorganisms in rhizosphere. Endophytic relationships involve the PGPRs residing and growing within the host plant in the apoplastic space (Vessy, 2003). ABA synthesis is one of the fastest responses of plants to water stress, triggering ABA-inducible gene expression and causing stomatal closure, thereby reducing water loss via transpiration and eventually restricting cellular growth (Wilkinson and Davies, 2010; Yamaguchi-Shinozaki & Shinozaki, 2006).It has been suggested that in longer-term responses to stress, hormones such as ABA and CK may function to regulate the production, metabolism and distribution of metabolites essential for stress survival and recovery (Pospisilova and Dodd, 2005; Stoll *et al*., 2000).Plants produce a huge variety of secondary metabolites with roles in various biological processes, such as pollination, seed dispersal, and resistance to biotic and abiotic stresses (Wink, 1999).

12. Crop Diversification

More soil fauna diversity for enhanced soil biological activities. Crop diversification enhances farm resilience positive effects on pest prevention and better utilization of soil water and nutrients more efficient use of available nutrients. The diversification of cropping systems also make more efficient use of available nutrients, with improved productivity and economic performance, which is of high importance in times of limited nutrients and financial Constraints. Organic agriculture provides a diversity of crops, rotations, landscapes and farming activities (ITC, 2007; Bengtsson *et al*., 2005).Organic farmers prefer not to use uniform crops and breeds and opt for more robust traditional species, which they tend to conserve and develop. Additionally, growing different assemblages of crops in time and space seeks to enhance the agro-ecosystem resilience to external shocks such as extreme weather events or price variation, which are all risks most likely to increase as the climate changes.

13. Conservation and Maintenance of Farm Biodiversity

In organic farming system conservation of natural resources as well as flora and fauna biodiversity and their development is the key factor favoring more efficient use of water, nutrients and energy for crop production (Anonymous, 2007). This also renders organically managed systems more able to sustain production under adverse climatic conditions associated with climate change.Genetically, traditional and adapted varieties are chosen for their greater resilience to various biotic abiotic stresses. At the specific level, diversity of flora and fauna optimize nutrient and energy cycling for agricultural production. Ecologically, the maintenance of natural areas like pond, marshy land, bushes in and around organic fields thereby, non-use of chemical inputs creates habitats suitable for beneficial insects, birds and wildlife. The provision of structures providing food and shelter, and the lack of pesticide use, attract new or re-colonizing species to the organic area, including wild flora and fauna and organisms beneficial to the organic systems such as pollinators and pest predators.The species abundance and/ or richness, across a wide-range of taxa, tend to be higher on organic farms than on locally representative conventional farms (Hole *et al*., 2005). These biodiversity benefits are likely to derive from the specific management practices employed within organic systems, which are either absent or only rarely utilized in the majority of conventional systems (Gardner and Brown, 1998). However, the benefits to biodiversity of organic farming may vary according to factors such as location, climate, crop-type and species, and are likely to be strongly influenced by the specific management practices adopted. At present, the organic standards generally only encourage practices that specifically promote biodiversity (such as field margin management to enhance natural predator populations) rather than require them. The biodiversity benefits of organic management are likely to accrue through the provision of a greater quantity/quality of both crop and non-crop habitat than on conventional farms. Three broad management options, largely intrinsic to organic farming and that are likely to be particularly beneficial to farmland biodiversity (at least in lowland systems) can be identified: (1) prohibition/reduced use of chemical pesticides and inorganic fertilisers; (2) sympathetic management of non-crop habitats and field margins; and (3) preservation of mixed farming (Hole *et al.,* 2005).

14. Conclusion

Agricultural practices primarily depend on different climatic parameters. Changing environmental conditions severely affects agricultural productivity and increases vulnerability to the farming system. The present work has demonstrated that organic farming practices have the potential to ameliorate some of the main causes of climate change. By adopting organic farming the soil carbon levels can be enhanced through carbon sequestration. Again through recycling or organic residues, incorporating legumes in crop rotation, crop diversification, the recycling and utilization of nutrients can be increased and that will promote efficient utilization of resources and enhance sustainability in the farming system under diverse climatic condition to combat emerging climate changes of the world.

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