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*Review*

# Organic Horticulture as a Potential Tool to Mitigate Climate Change and for the Production of Healthier Fruit and Vegetables

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**Abstract:** Organic horticulture is a holistic management system which follows good production practices and should be considered as the cornerstone of mitigating climate change and to produce healthier fruits and vegetables. This agroecosystem practice not only benefits the green economy but promotes and enhances soil biological activity, biodiversity, and other biological cycles in the sphere. The last decade has observed a rise in the production and consumption of organically certified agricultural products due to their higher nutritional value, lowered risk of exposure to harmful chemicals and improved organoleptic properties. The aim of this review was to demonstrate the considerable impact of organic horticulture on mitigating climate change and simultaneously satisfy consumer needs. The outcome of this review demonstrates that there are still numerous research studies required to evaluate how different farming systems and pedoclimatic conditions can contribute to more efficient horticultural practices.

**Keywords:** organic horticulture; natural farming; climate change; sustainable farming systems; carbon footprint; greenhouse gas emissions

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## 1. Introduction

It is well-known that consumers are becoming more conscious of lifestyles which contribute to a low carbon footprint and prefer organic produce. The effect of global climate change is one the greatest concerns faced by mankind in the 21st century. Organic farming provides an opportunity to counteract the effects of current farming practices, such as utilizing synthetic fertilizers, pesticides, and genetically modified organisms by minimizing pollution of the air, soil, and water, and enhancing the health and productivity of interdependent communities of plants, animals, and humans [1]. Organic farming, furthermore, eliminates both chronic and acute exposure of farm laborers, consumers [2] and surrounding aquatic and terrestrial ecosystems, to toxic pesticides [3]. In addition, organic produce offers more nutritious products [4], which contain higher vitamin and mineral content [3]. Organic horticultural practices also have a downstream effect on the quality of the produce, which are perceived to have a better taste due to the higher sugar content and a longer shelf-life as a result of metabolic integrity and superior cellular structure [3].

Modern day horticulture provides many opportunities to incorporate more natural farming practices, without affecting yield with the ultimate aim of higher returns. Integrated and applied organic farming promotes healthy soils and soil microbiota [3], thereby enhancing the availability of nutrients to the cultivated plants [5], which offers a more sustainable approach. Organic farming prevents genetic mutations and immune development in insects, an adverse effect associated with pesticide use, thereby potentially reducing pest outbreaks [6]. Furthermore, organic farming practices are considered cheaper and more economically competitive as it reduces various input costs associated with conventional farming practices such as the use of pesticides, herbicides and synthetic fertilizers [3]. The evident reliance of closed organic farming systems on resources found in nature and within farming bodies, offers a more harmonious adjustment to nature and as such, represents a privileged ethical strategy for humanity [7].

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Climate is described by characteristic conditions such as temperature, precipitation, humidity, soil, snow and ice cover. The climate is constantly changing due to various natural factors, of which human activity is the most recent and concerning factor which has had an increasing impact on the Earth's climate over the past 200 years. Its impact is defined by the greenhouse effect [8], with temperature changes increasing due to high levels of manufacturing and economic activity, including increases in major greenhouse gas emissions such as carbon dioxide and methane [9]. Organic agriculture has further demonstrated its capacity to reduce greenhouse gas (GHG) emissions through carbon sequestration and employing fewer inputs. Consequently, in the area of climate change, the transition from conventional agriculture to organic practices is being acknowledged as a viable alternative farming system that holds promise for addressing both climate change mitigation and environmental protection objectives [10,11].

## 2. Organic farming

Organic farming is a production system that mitigates or largely eliminates the need to use synthetic fertilizers, pesticides, growth regulators and feed additives and relies essentially on aspects of crop rotation, crop residues, animal manure, legumes, cover crops, non-agricultural organic waste and biological pest control (cover crop and insects), which all contribute to maintaining optimal soil productivity, texture, and nutrients to the cultivated plants. [12]. This farming technique has evolved into an agricultural system that focuses on resource conservation and recycling, with the aim of building a more sustainable production system [13].

Organically farmed produce is one of the most popular commodities which modern consumers are most interested in purchasing. The organic food market has grown significantly during the past few years (2016-2017) with several countries in the market showing double-digit growth according to the International Federation of Organic Agriculture Movements (IFOAM) and Research Institute of Organic Agriculture FIBL's most recent study, which supports this assertion. The countries with the largest increases were France (18%), Spain (16%) and Denmark (15%) [14].

In South Africa, organic farming has a long history, the country is a founding member of the International Federation of Organic Movements (IFOAM) [15]. South Africa largely supports organic farming, with an estimated organic produce market of between R200-400 million in 2005 [16], however, there is currently no comprehensive database to capture the exact number of organic farmers across the country [15]. However, organic certification bodies may be contracted to release such up-to-date figures with a real-time breakdown of certified organic certification of fruit and vegetable production.

Organic foods are often perceived as being healthier and having better flavor than conventionally grown crops, as conventional farming practices are usually associated with unwanted residues from pesticides and herbicides. These may accumulate in the soil and in certain crops, such as potato tubers, and therefore, negatively impact organoleptic properties as well as human and animal health [17]. Higher concentrations of nitrates and lutein were found in conventionally farmed potato tubers when compared to organic potato tubers [14]. Despite lutein reportedly being a health benefit for eye health, it may become detrimental when consumed in high amounts, including the yellowing of human skin due to the nature of its pigments as a carotenoid. Furthermore, potatoes from organic production were, on average, richer in polyphenolic compounds such as phenolic acids and flavonoids.

Organic cultivation practices are rapidly being adopted and are already being practiced in more than 120 countries throughout the world [18]. From a global perspective, organic horticulture is still a niche practice, since less than 1% of worldwide farmland is cultivated naturally and since only a small percentage of the worldwide populace is consuming organic produce in noteworthy amounts. Since the generation yields from organic farming practices are moderately low, and the goals of organic farming according to standards and measures, are not being achieved on most farms, these practices need improvements which are based on scientific evidence and better implementation [19].

Organic farming practices are not without their disadvantages, fruits and vegetables are typically grown in heated greenhouses and require higher energy inputs, contributing to high emissions. In addition, air freight is a large producer of greenhouse gases contributing to a higher carbon footprint, which is of particular concern as most of these products are transported by air.

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Organically farmed produce is also highly fragile and more prone to spoilage resulting in large amounts of waste [20].

### 3. Economic benefits of organic cultivation

Whilst organic farming is a system that eliminates the use of chemicals on farms by improving agricultural practices which would conventionally utilize hormones, fertilizers, feed additives and pesticides, it relies heavily on natural methods such as animal manure, crop residues, crop rotation, off-farm organic waste, utilization of biological systems for crop protection and nutrient mobilization [21]. This suggests a more hands-on approach to farming and requires more attention to the land being farmed. According to Das et al. [21] organic farming yields more nutritious food that is safe for consumption, reduces input costs at large and due to the niche market, premium prices can be obtained for organic produce. Premium prices, however, exclude a majority of the global population which could potentially be corrected earlier on in the production costs. Organic farming assists farmers in running sustainable homes [22] and in turn contributes to the overall combating of global climate change. In 2017, it was reported that the number of organic products worldwide was increasing significantly (Figure 3.1) [21]. Between 2012 and 2020, the organic sector in the European Union (EU) experienced notable growth, with a 56% expansion in organic land area, a 40% rise in the number of organic producers, and a noteworthy 114% increase in the monetary value of retail sales [23]. In addition to the premium prices that can be charged for organic produce, organic certification can indirectly be linked to other economic benefits since certified farmer organizations (or buyers) in developing countries typically provide services such as price information, training, credit or value addition to assist farmers to meet certification criteria and produce the quality demanded in worldwide organic markets. As smallholder access to services is often limited, the additional services provided by certified organizations can assist with the improvement of the smallholder farms resulting in increased revenue [1,21]

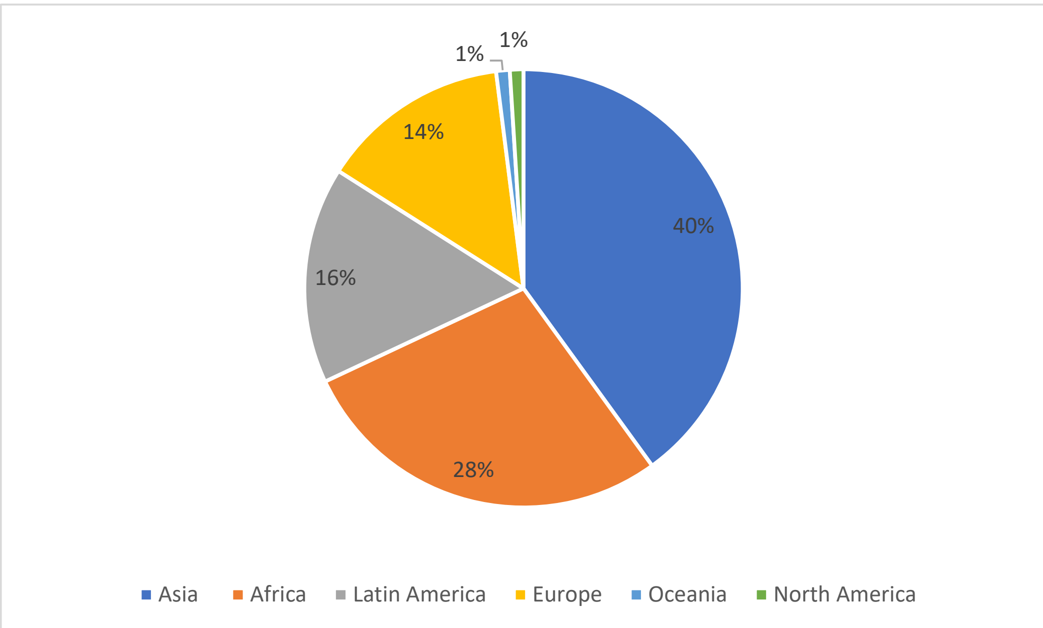


**Figure 1.** Percentage of organically farmed produce by each continent of the world in 2017 [21].

### 4. Conventional vs. organic horticulture

Organic farming and conventional farming are two common management practices in agriculture, which use different methods and practices [22]. Conventional agricultural processes use synthetic pesticides and chemical fertilizers to produce higher yields and profits [21], while organic farming in simple terms, means the cultivation of plants without the use of synthetic fertilizers or pesticides [22]. Organically produced plant-based foods are often thought to have better health-promoting properties than those produced in conventional or integrated production systems [24]. Organically grown foods, especially leafy greens, and tubers, have a high dry matter

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content compared to conventional cultivation methods [21]. Furthermore, conventionally produced plant-based foods and meats are becoming recognized risk factors for both their safety and quality [24].

Organic fortification with organic farming results in nitrogen gas ($N_2$) emissions on the same yield scale as non-organic farming systems. Strengthening organic farming will address climate change mitigation, as organic farming systems are reported to provide greater ecosystem services and social benefits in a larger context compared to non-organic systems. Additionally, organic farming promotes fair labour practices, supports local economies, and enhances social well-being. It also considers environmental, economic, and social equity aspects, promoting a holistic and resilient approach to food production. [25].

## 5. Potential health benefits of organically grown fruits and vegetables

Various health benefits are associated with organic farming such as reduced occupational health risks as both farmers and farm employees are less likely to be exposed to toxic pesticides and residues [1]. Organic produce appears to have higher levels of health-promoting phytonutrients, vitamins and minerals. Plant foods with higher concentrations of polyphenols have been shown to be produced through organic cultivation practices and to contain phytochemicals with anticarcinogenic, anti-inflammatory, antibacterial, antioxidant, antihypertensive, immunological regulating, cardioprotective, vasodilatory and analgesic properties, according to numerous scientific reports [26,27].

Several high-profile meta-analyses published in recent years have challenged the notion that organic foods are healthier, whilst others have found differences between organic and conventional produce that may translate to better health outcomes for consumers, such as higher levels of antioxidants like vitamin C and polyphenols, lower levels of cadmium (Cd) and pesticide contamination, a lower incidence of antibiotic-resistant bacteria and less water content (greater dry matter per unit fresh weight) in organic produce [28,29]. Studies have shown that vitamin C was significantly higher in organically versus conventionally produced plant foods [27,30]. Citrus, strawberries, bell peppers and potatoes are some of the crops that are reportedly high in naturally occurring vitamin C. It would however be beneficial for tuber crops like the potato to be actively considered for more natural and organic production since it's a global staple food.

A growing number of recent studies have demonstrated the beneficial effects of crop-based foods on human health. Consumption of fruits and vegetables, in particular, has been demonstrated to be useful in preventing cardiovascular disease [31] and more so due to the higher levels of flavonoid expression in organic cultivation. Cereals, legumes and berries have also been shown to aid in maintaining human health. Their impact can be attributed to a variety of factors, firstly, crop-based foods are often low in sugar and fat, especially in processed forms but they are also high in nutritionally beneficial components such as vitamins [3,32], antioxidants, and bioactive chemicals [33]. Fruit and berry extracts have been shown *in vitro* to decrease cancer cell proliferation. Thus, elements from fruits, particularly berries, have been shown to inhibit cellular processes associated with tumor growth. Furthermore, extracts from strawberries were found to reduce the rate of cancer cell growth, with organically grown strawberry extracts showing a higher inhibition of cancer cell growth compared to commercially produced strawberry extracts [33,34].

## 6. Greenhouse gas emissions (GHG)

The greenhouse effect is defined as the increase in the Earth's surface temperature (lower layers of the atmosphere) caused by the accumulation of greenhouse gases. As a result of this phenomenon, temperatures are higher than normal, causing irreversible effects such as climate change and global warming [9,35]. In order to simultaneously achieve increased crop yields and reduce greenhouse gas emissions in small-scale homestead crop cultivation, a variety of approaches are needed, as no single approach can adequately address the complexity of crop production and the challenge of greenhouse gas emissions, simultaneously. Adopting different approaches can result in positive synergistic effects that exceed the additive effects of each approach used separately. Nonetheless, due to the lack of scientific data in the field, further efforts are urgently needed, including research and field demonstrations to identify optimal combinations of different approaches [36].

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Greenhouse gases include water vapor, carbon dioxide ($CO_2$), methane ($CH_4$) and ozone ($O_3$). The former is the main contributor to the greenhouse effect (up to 72%) globally. The next most important component is $CO_2$ (9-26%), with $CH_4$ and $O_3$ contributing 4-9% and 3-7%, respectively [9]. Carbon dioxide and other greenhouse gases produced by natural processes were present in the atmosphere long before humans played a significant role. These gases have kept the Earth warmer (about 32°C) than it would have been in their absence, by partially blocking the infrared radiation emitted by the Earth [37].

The challenge of agricultural development today is not only to meet the demand for food but also to be more environmentally conscious. The global demand for food is expected to increase in the future as the population increases, however, increased food demand in the form of food crops, horticulture, plantations and animal husbandry has increased productivity, leading to increased GHG emissions specifically from the agricultural sector [38]. Combined emissions from the agriculture sector accounts for an estimated one-fifth of the annual increase in GHG emissions. Agricultural production and biomass burning also contributes to $CO_2$ emissions, as do land-use changes such as deforestation. Agriculture is also considered a major source of $CH_4$ and nitrous oxide ($N_2O$) emissions, estimated to account for about 50% and 70% of total anthropogenic emissions, respectively [39].

The food system contributes up to 30% of GHG emissions, with agriculture accounting for the largest share of this percentage. In agriculture, livestock is the largest source of GHG emissions, while outdoor horticulture can also have a significant impact. The method in which food is transported, packaged, prepared and stored can also result in high GHG emissions [20]. Urban food production, such as urban agriculture, community gardens, allotment gardens and home gardens, is an important part of urban ecosystems since they not only contribute to improving the physical, mental and social health of people but also to the health of the environment. The local food movement has seen growing interest in urban gardens as an alternative to mainstream food systems. Urban food production has the potential to produce food with reduced transport, energy, and packaging intensity and with greater carbon sequestration compared to conventional food systems, thus reducing net GHG emissions [40].

Fertilizer discharge and leaching into the environment also leads to environmental problems such as eutrophication [41]. Several studies have focused on slow-release fertilizers as a solution to reducing groundwater pollution, reducing greenhouse gas emissions and mitigating the impacts of climate change [42]. Organic inputs in particular slow release nutrient pellets and liquid guano have become imminent in all farming practices due to its no risk to GHG emissions.

**7. Mitigating and adapting to climate change**

Some studies report that if crop yields decline due to climate change, the effects on the well-being of subsistence farming households will be severe, particularly if the subsistence component of production declines [43].

Organic agriculture can help with adaptation by increasing water infiltration, which allows soils to absorb most of the rainwater even during heavy rainfall events by improving water-holding capacity, which promotes plant survival during drought periods. At the same time, organic agriculture can lower fossil fuel emissions by up to 60% compared to conventional agriculture and limit the long-term use of fertilizer and agrochemicals by 20%. However, the greatest contribution that organic agriculture has to offer to climate change mitigation, is from carbon sequestration. On average 79%, that is, 0.1-0.5 tons of organic carbon can be captured per hectare of land in humid temperate conditions. The most important aspect of the relationships between climate change and organic farming is the realization that many small farmers cope with and even prepare for climate change by increasing the use of drought-tolerant local varieties, water harvesting, mixed cropping, agroforestry and soil organic practices [43].

Organic systems, on average, include more soil organic carbon than conventional systems, notwithstanding the wide range of organic farming practices and underlying concepts. Soil organic carbon benefits from organic farming may be realized only if this management system is combined with larger carbon inputs than in conventional treatments [44]. Organic systems may significantly lower GHG emissions and hence contribute to mitigating global warming by increasing diversity at the farm level and being included into high diversity landscapes. Organic farmers who do not utilize agrochemical inputs and instead, diversify their traditional farms and rural landscapes, could significantly cut GHG emissions from pesticide and fertilizer production [43].

## 8. Conclusions

The need for growth in the organic horticulture production systems worldwide is evident. It is not only a requirement for the mitigation of climate change but produces food that is more acceptable for consumers. Organic horticulture can have a remarkable impact on mitigating climate change, due to the reduction in carbon sequestration by not using chemical fertilizers that release large quantities of GHG into the atmosphere. This is notably advantageous to the environment due to no leaching of nutrients and chemicals that contaminate water bodies in the soil. In addition, it is the only farming system that is safe for both the farm workers and the environment since it is chemical free. Many researchers have found that organic horticulture produces healthier fruits and vegetables compared to conventional cultivation. While acknowledging this nutritional superiority, it is essential to recognize the trade-off in yield quantity, with organic farming generally yielding lower quantities than conventional methods. Organic farmers receive compensation in the form of premium prices for their products, which is a reflection of their dedication to sustainable and health-conscious farming methods. Because of its many advantages, organic horticulture is seen as an essential and long-term solution to the problems that face the environment and modern agriculture.

Suggestions are therefore made to add a curriculum that includes organic agriculture for primary and secondary schools. Additionally, support should be given to specialized institutes that teach organic agriculture. Higher education in organic agriculture systems should be developed, so that organic agriculture can be understood more and get the attention and required resources to be at the same level as conventional agriculture in terms of research knowledge and information. Consumer education and awareness about the drawbacks of conventional agriculture should be actively promoted. By developing a deeper understanding of conventional agriculture, consumers can make informed choices, contributing towards a more sustainable and responsible food production system. In addition, specifically African governments must acknowledge the variety of interests represented in the organic sector, making sure that each is fairly taken into account, and give underprivileged groups more consideration. On all levels, governments need to take a proactive role in promoting organic agriculture and data on organic agriculture needs to be recorded yearly in each country throughout the African continent so that the growth and level of it can be known to identify the gaps and opportunities for further actions. There are other developing countries around the world which are succeeding in organic agriculture such as Turkey. It's extensive agricultural system and minimal use of agrochemicals make it easy to transition to organic farming, reducing chemical pollution and promoting sustainable practices. Its experiences in organic agriculture can be used for defining and improving policy programmes, market development, exports, extension services and research activities in other similar countries.

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