Climate Resilient and Sustainable Horticultural Practices in Sub-Saharan Nigeria

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Abstract
This paper review climate resilient and sustainable horticultural practices by looking at how climate change affects horticultural production in sub-Saharan region of Nigeria. It is evident that horticultural crops are more susceptible and exposed to climate change. The study undoubtedly open the door for effective climate-resilient, sustainable, and environmentally friendly horticultural practices, which are essential for maintaining ecological balance and long-term agricultural productivity while lessening the negative environmental effects of traditional horticultural techniques that helps contribute to climate change. Food security and rural/urban livelihoods are seriously threatened by the unpredictable weather patterns as a result of climate change in sub-Saharan Africa. Nigerian horticultural practices that are considered traditional or conventional include the overuse of pesticides, inorganic fertilizers, inadequate irrigation and drainage systems, results in the loss of beneficial insects and plants, pollution, soil nutrients, water quality, and soil depletion or degradation. In contrast, horticultural practices that are climate resilient and sustainable prioritize the protection of natural resources, ecosystem development, and mitigation of adverse environmental impacts in order to guarantee higher productivity. Numerous important horticultural issues that are more environmentally friendly are reviewed and analyzed in the study. These issues have the potential to immediately lower production costs and improve overall ecosystems and biodiversity.

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1. Introduction

Low yields in horticultural production are thought to be caused by the industry's sensitivity to harsh weather (Bhardwaj, 2012) [5]. As stated by William *et al.* (2018) [31, 32, 33] and Datta (2013) [11], two key climate change parameters that have a significant impact on horticulture in particular and agriculture in general are unpredictable rainfall patterns and exceptionally high temperatures. Vegetable yield and quality have been found to be impacted by even a small increase in average daylight and/or night time temperatures (Mattos *et al.*, 2014) [19]. The typical development and growth of plants can be changed by the impact of rising temperatures and rainfall uncertainties on the various stages of horticultural crops' development, from vegetative growth to fruiting. In the end, this impacts farmers' financial returns and crop productivity. Extremely high temperatures have also been shown in other studies to impact the flavour, firmness, and physical and physiological issues that arise during the growth of vegetable fruits (Spaldon *et al.*, 2015) [27]; (Deuter, 2014) [12]. Furthermore, climate change is making food insecurity worse in Nigeria by altering yield and area growth, raising food prices, decreasing the availability of calories, and increasing childhood malnutrition (Ringler *et al.*, 2010) [23]. Baptista Salgado *et al.* (2022) [24] predicted that rising temperatures and rainfall volatility brought on by climate change would cause a 5¼ (17%) drop in crop yield by 2050, particularly in important staple crops in the area. One of the biggest threats to Nigeria's agricultural sector's productivity and long-term growth is climate change. Research has indicated that agricultural productivity is being adversely impacted by climate change. In sub-Saharan Nigeria, climate variability and change have become a significant issue for agricultural transformation, with severe temperatures and unpredictable and erratic rainfall posing a threat to food security and rural livelihoods (Williams *et al*., 2017) [32]; (Ching *et al*., 2011) [9]. The severity of these environmental factors in preserving and improving horticultural productivity is influenced by climate change. Approximately 70% of Nigerians work in agriculture, and since the production systems are highly weather-sensitive, they are susceptible to climatic fluctuations and changes (Apata, 2011) [2].

Due to their high water demand and stringent temperature requirements, horticultural crops which are highly diverse are especially vulnerable to climate change. The suitability of regions for horticultural crop cultivation may be impacted by climate change in the form of increased or decreased rainfall, elevated temperatures and drought, scarcity of water for irrigation, and susceptibility to pests and diseases. A significant risk to the agricultural sector from climate change is the dependence on rain-fed agriculture, which is predicted to have an impact on food security and improved poverty levels (Kabubo-Mariara & Kabara, 2018) [15]. However, the secret to the horticultural sector's continued growth and support has to do with comprehending how climate change affect a particular crop under a particular circumstance (Singh, 2013) [25]. Therefore, in order to maintain ecological balance and long-term agricultural yield while minimizing the environmental effects of conventional horticultural techniques, climate resilient and sustainable horticultural practices are essential. As the need for sustainable development and environmental stewardship is acknowledged globally, horticulture is seeing a rise in implementing eco-friendly practices.

2. Climate Smart Agriculture (CSA): Approaches and Strategies to Sustainable Horticulture

A capable solution to the problems that climate change is posing to sub-Saharan Nigerian agriculture is climate smart agriculture (CSA). It comprises, combining contemporary farming methods with conventional farming methods. Traditional agriculture provides important insights into adjusting agricultural systems to a changing climate because it is based on indigenous knowledge, cultural beliefs, and sustainable practices (Tsado, 2019) [30]. In most rural communities, the CSA approach is acknowledged for its capacity to improve farm productivity and incomes, as well as adaptation and resilience to climate change (Abegunde & Obi, 2022) [1]. With an emphasis on boosting agricultural productivity, adjusting to and strengthening resilience to climate change, and creating opportunities to lower greenhouse gas emissions from agriculture, CSA provides a comprehensive approach to address the interrelated issues smallholder farmers in African nations, especially Sub-Saharan Africa, face (Obaji *et al*., 2022) [20]. Furthermore, the FAO highlighted that CSA is a strategy that aids in directing efforts to shift agri-food systems toward environmentally friendly and climate-resilient practices, to tackle issues associated with agriculture and climate change (FAO, 2023) [13]. CSA is not a one-size-fits-all strategy, though, and must be customized to address the unique climate risks that various farming communities, geographical areas, and ecosystems face. Even though CSA provides a solution for many of the secondary and tertiary issues brought on by climate shocks; last-mile communities are still unfamiliar with this approach to climate adaptation and mitigation. Understanding "how it works" is only one aspect of effectively utilizing CSA at the grassroots level; so also another one has to do with understanding the complex network of cultural, economic, ecological, and technological elements that affect these adaptation strategies.

Sub-Saharan African rural communities are using a range of tactics and methods to modify their traditional agricultural methods in response to climate change. To deal with extreme weather and environmental changes brought on by climate change, indigenous peoples and local communities are using improved crop varieties and traditional knowledge (Swiderska, 2011) [28]. Building resilience and adjusting to the effects of climate change are two benefits of using traditional agricultural methods that have been developed over centuries (Singh & Singh, 2017) [26]. To preserve yields and soil fertility, changes are made to planting dates, crop varieties, drainage systems, advanced technology, and land management practices (Arbuckle *et al*., 2015) [3], are essential practical tactics employed by nearby farmers to mitigate the negative consequences of climate change. Traditional methods include inter-cropping and agroforestry, crop rotation, cover cropping, traditional organic composting/manure, and integrated mixed farming, have demonstrated the potential to improve productivity and mitigate climate change impacts (Tripathi *et al*., 2016) [29]; (Mashi *et al*., 2022) [18]. These practices provide valuable adaptation strategies in the face of climate uncertainties. Therefore, there is an urgent need to rediscover and re-implement traditional agricultural practices with modern approaches to enhance the ecological integrity of the ecosystems and biodiversity (Shittu *et al*., 2021).

3. Climate Resilient and Sustainable Horticultural Practices

The following sustainable horticultural techniques have been created and are advised for farmers to implement in order to increase resilience and lessen the effects of climate change in Nigeria's sub-Saharan region:

3.1. Use of organic matter/humus

For the soil to continue to be productive, organic matter and humus are essential. Soil structure is enhanced by organic matter and humus, which aid in binding soil particles into aggregates. This enhances drainage and aeration because well-structured soils facilitate easier air and water passage. The soil's ability to retain moisture is further enhanced by organic matter and humus (Kumar *et al*., 2023) [17]. Nutrients can also be released gradually by organic matter, but more significantly, humus can draw in and retain a lot of nutrients in the soil. The overall impact of climate change on horticultural production is lessened by these methods.

3.2. Crop rotation

Another well-known strategy for maintaining soil health is crop rotation, which involves planting different crop varieties in a specific order. Crop rotation improves soil structure, breaks the cycles of pests and diseases, and lessens nutrient imbalances. By diversifying crop species, horticultural systems can effectively control pests, enhance soil biodiversity, and optimize nutrient uptake (Borrelli *et al*., 2019) [7].

3.3. Organic farming

This method uses natural materials and techniques, making it an environmentally friendly horticultural style. By avoiding synthetic pesticides, inorganic fertilizers, and genetically modified organisms (GMO), this approach promotes environmentally and health-conscious sustainable agricultural systems. Preserving biodiversity, maintaining soil health, and minimizing adverse environmental effects are the top priorities of organic farming. Instead of using artificial pesticides, organic farmers employed a range of techniques, including crop rotation, composting, green manuring, and the use of beneficial insects for pest control. These techniques increase soil fertility, decrease soil erosion, increase microbial activity, and enhance water and nutrient retention (Reganold *et al*., 2001) [22]. One of the key benefits of organic farming in horticulture is the reduction of soil and water contamination and the preservation of ecosystems through the use of fewer synthetic pesticides and fertilizers. Based on previous studies (Zaller *et al*., 2019), stated that using organic farming methods can significantly lower the amount of pesticide residues in crops and the environment. It has been found that organic horticultural crops contain higher concentrations of several important nutrients and antioxidants than conventionally farmed produce (Baranski *et al*., 2014) [4]. Organic farming provides habitat for beneficial organisms such as pollinators and natural enemies of pests.

3.4. Integrated pest management (IPM)

An essential technique for effectively controlling pests while lowering the use of chemical pesticides and their detrimental effects on the environment is integrated pest management, or IPM. In order to maintain ecological balance, reduce risks to human health, and keep pest populations below dangerous levels, integrated pest management (IPM) practices combine biological, cultural, physical, and chemical management techniques. One of the key principles of integrated pest management (IPM) in horticulture is biological control, which involves using natural enemies such as viruses, parasitoids, and predators to control pest populations. IPM promotes the existence and activity of beneficial organisms, which enhances natural pest control methods. By releasing or maintaining biological control agents through habitat modification, selective planting, and the provision of alternate food sources, a more self-regulating and sustainable pest management system can be created (Gontijo *et al*., 2018) [14]. Cultural practices contribute significantly to IPM by creating unfavourable conditions for pests and increasing plant resistance and health. Cultural practices that disrupt pest life cycles and reduce pest load include crop rotation, the use of resistant varieties, proper hygiene, and planting timing. The objective of physical control methods in IPM is to physically exclude or remove pests from the crop environment. Barriers, traps, and netting are a few examples, of pest-removal equipment.

3.5. Water conservation technique

Water conservation is an essential part of sustainable gardening practices as water scarcity and efficient water resource management become more important. One of the best ways to save water in horticulture is through drip irrigation. By supplying water straight to the plants root zone, it reduces evaporation and runoff compared to traditional irrigation methods (Chaves *et al*., 2019) [8]. Drip irrigation systems can preserve optimal plant hydration while saving up to 50% of water. Accurate water application control not only lessens weed growth but also prevents fungal infections that are linked to excessive moisture on plant foliage. Another method of conserving water is precision irrigation, which employs state-of-the-art technology to supply water based on each plant's unique needs. Soil moisture sensors, computerized control systems, and weather data are used to better schedule irrigation and prevent over watering. By supplying water only where and when needed, precision irrigation reduces water waste and maximizes water use efficiency (Chaves *et al*., 2019) [8]. Because it preserves freshwater resources and lowers the nutrient load in waste water, recycling water is a valuable resource for plant nutrition. However, careful monitoring and appropriate treatment particularly by covering the soil's surface are necessary to ensure the safety and purity of recycled water for horticultural applications.

3.6. Management of soil health

Since maintaining long-term production, promoting plant development, and supporting ecosystem function all depend on managing soil health. Therefore, it is considered as a crucial part of sustainable horticultural practices. Cover crops are commonly used in horticulture to enhance soil health. Cover crops, such as legumes or grasses, are grown alongside primary crops or during fallow seasons to protect and enrich the soil. As stated by Borrelli *et al*. (2019) [7], cover crops boost soil organic matter content, promote nutrient cycling, reduce soil erosion, and enhance soil structure and water-holding capacity. Adding cover crops to horticulture systems may result in higher crop yields, reduced nutrient leaching, and enhanced soil biodiversity. Composting and vermin-composting are efficient methods for recycling organic waste and boosting soil fertility in horticulture. The breakdown of organic materials, such as plant remains or food scraps, into a nutrient-rich soil supplement is known as composting. In vermin-composting, earthworms are utilized to speed up the decomposition of organic materials and produce the best possible vermin-compost. As stated by Borrelli *et al*. (2017) and Choudhury *et al*. (2019) [10], both methods enhance soil structure, boost nutrient availability, and promote microbial activity in the soil.

3.7. Biodiversity enhancement

Increasing biodiversity is another essential element of sustainable horticultural practices. This is because it promotes ecological resilience, enhances ecosystem services, and increases the general well-being and productivity of horticultural systems. Planting a range of plant varieties is the first step towards increasing biodiversity in horticulture. By mixing crops, flowers, and native plants in horticultural landscapes, farmers can create habitat and food sources for a variety of animals, such as pollinators, beneficial insects, birds, and other wildlife. Many plant species contribute to a more stable and resilient environment, which reduces the risk of pest outbreaks and promotes natural pest control (Bommarco *et al*., 2013) [6]. Horticulture must protect native plants and ecosystems in order to increase biodiversity (Kremen *et al*., 2007) [16]. Another strategy for increasing biodiversity in horticulture is habitat manipulation. It is feasible to attract predators, pollinators, and beneficial insects by integrating different ecosystems into and around horticultural systems, such as hedgerows, wildflower strips, or insectary plants. Reducing the use of pesticides and utilizing integrated pest management (IPM) strategies are two more ways to improve biodiversity in horticulture.

3.8. Irrigation water

A productive agricultural sector and a healthy environment depend on a healthy river system. The hydrological features of the catchment are significantly altered by excessive irrigation and inadequate drainage water management, which can also have a negative impact on the environment and other producers. Significant amounts of formerly productive land are being lost due to rising water tables and the resulting soil salinization (Kumar *et al*., 2023) [17]. Thus, a well-designed and maintained irrigation and drainage system should produce a robust, healthy crop with minimal runoff above the natural level, minimal water table losses, and little release of organic matter, fertilizer, salt, and pesticides into the river system. At the design stage, every facet of water management must be taken into account, including drainage management, fertigation options, water quality, irrigation scheduling, and system design. By learning more about the relationship between crops and the soils they grow in, as well as the fate of water applied, horticulturists can get more efficient use out of their water resources. With a much smaller environmental impact, irrigation can be more precisely scheduled and applied once crop demands and soil water-holding capacity are established. In its most basic form, irrigation scheduling forecasts the amount of water that a crop is likely to require by using crop factors and evaporation data from weather stations.

3.9. Soil management

Preserving and improving soil health is one of the main objectives of sustainable horticulture. Without adequate soil fertility, structure, water-holding capacity, drainage capacity, and depth, no farming system can be maintained. In terms of the human life cycle, topsoil is irreplaceable and forms very slowly (Kumar *et al*., 2023) [17]. Raising awareness of the causes, signs, and effects of soil degradation is crucial. In order to better manage tillage and fertilizer practices, growers should safeguard their land from soil loss brought on by wind or water erosion and keep a closer eye on the physical and chemical state of the soil.

3.10. Erosion control

The first step in controlling erosion is farm planning. Some places are just too prone to erosion to support horticulture. By including windbreaks in farm plans, wind speed will be slowed and soil erosion from wind will be lessened. The mature size and shape of the windbreak must be taken into account when planting it. It might be necessary to combine species that grow tall and low. Numerous sources provide information on species that are appropriate for various locations and requirements, and consulting local experience is a reliable indicator (Kumar *et al*., 2023) [17]. By reducing the amount and rate of water flowing through the crop, well-planned and maintained farm irrigation and drainage systems will lessen soil loss from runoff. Because they can redirect runoff into appropriate locations and slow the flow of water during rainfall, well-designed drainage systems are especially crucial. To stop erosion on these drainage systems, cover crops must be maintained. Among other advantages, inter-row cover crops, which are grown between trees in the majority of perennial horticulture industries, shield soils from wind and water erosion (Kumar *et al*., 2023) [17]. Using green manure crops and strip cropping in vegetable production systems also helps shield soil from erosion caused by water and wind. Cover crops not only help protect the soil but also help control weeds and improve soil biodiversity.

4. Conclusion

Reducing the effects of climate change on the horticultural industry requires climate resilient and sustainable horticultural practices. By using eco-friendly methods that complement the natural world, horticultural systems can be strengthened to become more resilient and sustainable. Better soil health, reduced use of chemical inputs, improved water efficiency, biodiversity preservation, enhanced ecosystem services, and reduced environmental contamination are just a few benefits of these eco-friendly practices. Additionally, it facilitates the supply of healthier food for our everyday needs and supports farmers' sustainable means of subsistence. In order to support environmental sustainability and ensure that the horticultural industry has a more resilient and profitable future, it is necessary to accelerate farmers' adoption of climate resilient and sustainable horticultural practices in order to overcome the challenges posed by climate change in sub-Saharan Nigeria. This can be achieved by enhancing farmers understanding of these crucial areas and implementing their practical implications.

Competing Interest

The authors of this review declare that no conflict of interest exist among them.

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