HYDROPONIC FARMING: A PANACEA FOR CLIMATE CHANGE IMPACTS ON FOOD SECURITY IN NIGERIA

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Abstract

Climate change is a threat multiplier for hungry and undernourished people. Projections indicate that warming in Africa will be greater than global annual mean, with an average increase of 3–4 °C over the next century. With extreme weather-related disasters on the increase in Nigeria, yield of major crops grown by rain-fed dependent farmers reduces while, Higher levels of CO_2 emissions from human activities reduces their nutritional values. Combined with conflict as it is in most agrarian northern Nigeria, it destroys livelihoods, thrives displacement and undermines the Millennium Development Goals (MDG's) attainment and achievement of food security by year 2030 owing to it impacts on all food systems ranging from the production, quality, availability, access to utilization and the stability. As part of Nigeria government's effort in achieving the United Nations MDG's of eradicating hunger and extreme poverty by the year 2030, there exist the need to modernize agricultural practices by applying innovative technologies like hydroponics to meet current necessities and to achieve a sustainable food security through the agricultural sector economic growth. In Nigeria, the focus must be shifted towards hydroponic based innovations in mechanizing agricultural practices if food security must be achieved. Without, Nigeria's agricultural sector will not meet expected demands that mitigates climate change impact. The purpose of this study is to suggest the adoption of hydroponic system as a farming technique that can mitigates the impacts of climate change against food security in Nigerian.

Keywords: Agricultural, Mechanization, Climate Change, Food Security.

Introduction

Agriculture is the economic mainstay of most African countries including Nigeria. Despite the enormous benefits Nigeria derives from agriculture, its agricultural productivity still remains on a slow pace within the sub-Saharan region. Amponsah et al. (2012).

According to FAO (2010) report, some African countries agricultural sector generates up to 50% of their Gross Domestic Product (GDP), contributes over 80% of trade in value and more than 50% of raw materials to industries. Yields of maize and other staple cereals have typically remained at about 1,000 kg/ha, which is about a third of the average achieved in Asia and Latin America. Furthermore, 30% to 40% of agricultural produce is lost owing to poor post-harvest handling, storage and processing methods.

However, this sector provides employment opportunities for the majority of rural dwellers. According to National Bureau of Statistics (NBS) report for the first quarter of 2020, agriculture contributed 21.96% to the national GDP growth. NBS (2020)

Nigeria's natural environmental conditions for agriculture are favourable. However, the country remains highly dependent on food imports. In 2018, the Federal Ministry of Agriculture and Rural Development (FMARD), reported that Nigeria's agricultural production currently meets only half of its domestic cereal and meat needs and 60% of domestic fish consumption. Food self-sufficiency was only achieved in starchy staples such as cassava, yam and plantain, while rice and maize production falls far below demand.

FAO and UNIDO (2008) cited the low level of engineering technology inputs in agriculture as one of the main constraints hindering the modernization of agriculture and food production systems in Africa. Studies by Clarke and Bishop (2002) reported that humans are the most significant power source in Sub-Saharan African (SSA) countries where 65% of the land is cultivated by human power.

Sustainable agricultural development enjoyed by most developing economies of Asia and Latin America over the past three decades has been made possible through the adoption of highly extensive agricultural

mechanization. Investment in agricultural mechanization has enabled farmers in such countries to intensify production and improve their quality of life as well as contributing to national and local prosperity. Despite the importance of agriculture to most African economies, and despite low productivity, investment in agriculture with respect to mechanization in Africa is still low. Food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life. In recent years it has become clear that climate change is an inevitable process that will have negative impact, not only as a result of projected warming and rainfall deficits, but also because of the vulnerability of the population. Zewdie A (2014)

Soil cultivation is practiced since centuries as it contains nutrients formed during natural decay of organic matter and also has sufficient porosity needed for oxygen supply to the roots.

It is estimated that the livelihoods of 70 % of Africans are dependent on rain-fed agriculture, an activity that is characterized by small-scale, subsistence farms that are vulnerable to a variety of stresses, including those associated with climate change. Due to its largely adverse effects on African agriculture and livelihoods, climate change is expected to have a negative impact on food security Liette and Barry (2015).

Recently, a new technique called soil-less culture commonly referred to as "hydroponics"; a term derived from the Greek words' "hydro" means water and "ponos" means labour has been developed as an agricultural greenhouse farming technology to mitigate the impact of climate change on food security and to further improve crop productivity in lesser space and time by controlling the supply of water and nutrient Harmanpreet K. (2016).

It is in these views this study suggests to the Nigerian farmers, the adoption of hydroponic system as a farming technique that can mitigates the impacts of climate change against food security in Nigerian.

Methodology

A narrative literature review was conducted from peer reviewed literatures, working papers, conference papers and reports from known organizations related to climate change, food security and agricultural mechanization technologies. Manual searching and Google scholar search strategies were performed in this literature review from different databases. To include only up-to-date information, a maximum time frame of 10 years was placed on the age of the works included in the review.

Results and Discussions

Climate Change and Food Security: Climate change is an emerging stressor that is experienced over longer time frames through changes in climatic norms and over shorter periods through changes in the frequency and severity of extreme weather events. The evolution of rapid urbanization and industrialization by humans is having an obvious effect on global warming with its consequent impact on the melting of icebergs, and the further decreasing of arable land under cultivation. It is commonly recognized to have major implications on food security and livelihoods. It is the aftermath of higher temperatures which negatively impact on soil, water and crop productivity leading to decrease in crop growth and yields.

Also, with time, the fertility of soil will attain a saturation level, and productivity will not increase further with increased level of fertilizer application. Besides, poor soil fertility in some of the cultivable areas, there are less chances of natural soil fertility buildup by microbes due to continuous cultivation, frequent drought conditions and unpredictability of climate and weather patterns; leading to a rise in temperature and decline in ground water level that will threaten food production under the conventional soil-based agriculture.

Heather et. al., (2010) in a review on Climate Change and Food Security in Sub-Saharan Africa deduced that, the most direct impact of climate change on food security is through its availability due to changes in crop productivity. Sub-Saharan Africa is characterized by the reliance of a heavy segment of the population upon local resources for food. Many communities rely largely or solely upon their own subsistence farming for their food needs, with marginal groups especially dependent upon climate-sensitive resources.

Projected decreases in crop yields are always related to impacts of climate change on both soil and water. While climatic warming and normal rainfall deficits are expected to produce drought, a more frequent and high intensity of rainfall events will always contribute to soil degradation and flooding which creates problems regarding the availability and viability of land for agriculture. This is because, nutrient depletion by flooding limits the ability of many crops to prosper. More so, lack of viable soil not only reduces yield potential, but also limits the future potential of the land, as increasingly greater quantities and types of inputs are required to make the soil productive.

According to Heather et. al., (2010), soil degradation is furthermore a problem based on the limitations created in terms of what types of crops may be grown. Some crops may be seen as more resilient in poor conditions, but the result is less diversification of crops, and thus a narrower field of food sources, with resulting health implications. Soil degradation has implications for the water absorptive capacity of soil and water availability for agricultural production. At increasing levels of soil degradation, soil capacity to absorb water declines, increasing runoff and further exacerbating soil degradation. Not only does this result in the inability to utilize the most significant input to agriculture, but subsequent water run-off additionally takes topsoil with it, further draining the soil of essential nutrients.

Water always presents issues in terms of how it is utilized. Rain-fed farming systems are the dominant form of agriculture among subsistence farmers in Nigeria. This technique is considered more affordable than irrigation because of the low technology requirement, but it also increases vulnerability based on heavy reliance upon rainfall for water resources. Subsistence agricultural systems are always sensitive to increased volatility of rainfall and the resulting impacts on food crop yields.

FMARD (2018) stated that, the UN Millennium Project has recognized water as a key issue in relation to food security and identified increased irrigation of crops as a viable adaptive response. While increased stress on water resources is undoubtedly a significant concern in Nigeria, it has been argued by some that irrigation will further exacerbate poverty due to the costs to farmers already under stress. Furthermore, as water becomes scarcer, increased competition for water resources may constrain access by vulnerable subsistence populations and smallholder farmers. More so, potential diversion of water for industrial and domestic use will limit agricultural access. Climate change is thus projected to restrict the availability of irrigation in some region of Nigeria, with the cost of building and maintaining the technology in many cases greater than potential benefits.

Zewdie A. (2014) classify the effect of climate change on food security in four ways. First, changes in temperatures and precipitation have a potential to alter the distribution of agro-ecological zones which affects irrigation availability and demand. Second CO_2 effects are expected to have a positive impact due to greater water use efficiency and higher rate of photosynthesis. Third water availability which is highly sensitive to climate change can affect the food availability. Fourth agricultural loses can result from climate variability and the increased frequency of extreme events such as droughts and floods or changes in precipitation and temperature.

An assessment of the impact of climate change on food production duration in year 2020 according to NIMET (2020) prediction on the span of growing season, a near normal and above normal rainfall between 110-160 days in the Sahelian region of the north, 160-200 days for the central states are expected with an early cessation date of September. This is an indication of decrease in rainfall duration with a prospective reduction in expected yields estimated up to 30 percent in some Sahelian region states where 96% of the cultivated land depends on rain feed agriculture.

According to the National Development Planning Commission (2010), modernizing agriculture through mechanization technologies is an issue of concern in Nigeria where Science, Technology and Innovation (STI) is the foundation of every national development. Sadly, agriculture which falls directly under STI is still dependent on rudimentary equipment such as hoes and cutlasses. However, it is still unclear as to what options are already available and what should be followed to achieve this goal.

A study by Zewdie A. (2014) also revealed that, there exist a debate on the impacts of climate change on food security based on evidences from sub Saharan Africa. Climate change has a potential to shift land suitability which leads to increases in suitable cropland in higher latitudes and declines of potential cropland in lower latitudes. Also, moderate increase in temperature (1°C-3°C mean temperature) is expected to have a negative impact in the tropical and seasonally dry regions particularly for cereal crops. The study also revealed that, the impact of climate change on food production for year 2020 indicated about two thirds of arable land in the Sahel region of Nigeria is expected to be lost by 2025 due to decreased rainfall and reduce yields with an estimation of up to 50 percent in where 96% of the cultivated land depends on rain feed agriculture.

Prospects of Hydroponic System (Soilless Culture): In order to achieve all year-round production of crop, mechanization technologies that uses series of plant growth facilities through artificial regulation of indoor environment, such as lighting, temperature, CO_2, nutrient solution, must be adopted. A technique called soil-less culture commonly referred to as "hydroponics" has been developed to further improve crop productivity in lesser space and time by controlling the supply of water and nutrient and to mitigate the impact of climate change on food security. Li and Cheng (2014).

According to a review on hydroponic system by Vikash et. al., (2019), soil has usually been the most available growing medium for plants. It provides anchorage, nutrients, air, water, etc. for successful plant growth. However, soils do pose serious limitations for plant growth too, at times. Presence of disease-causing organisms and nematodes, unsuitable soil reaction, unfavorable soil compaction, poor drainage, degradation due to erosion etc. are some of them.

In addition, conventional crop growing in soil is somewhat difficult as it involves large space, lot of labour and large volume of water. Moreover, some places like metropolitan areas, soil is not available for crop growing at all, or in some areas, we find scarcity of fertile cultivable arable lands due to their unfavorable geographical or topographical conditions. As human population increases, arable lands are declining, people have to adopt new farming technologies like hydroponics to create additional sufficient channels of crop production.

Lately, another serious problem experienced was the difficulty to hire labour for conventional open field agriculture. Under such circumstances, hydroponic system (soil-less culture) can be introduced successfully. This system helps to face the challenges of climate change and also helps in production system management for efficient utilization of natural resources and mitigating malnutrition. Hydroponic products are also generally less tied to seasonal variability, since they can be located close to large population centers, thereby reducing travel time and the CO_2 emissions implications. Consumers tends to get the most nutritional value from these products as a result of the decreased amount of travel time of products from farm setup. It was in these views and many more that hydroponics farming is becoming the fastest growing technique in agriculture farming that could dominate food production in the future.

According to Harmanpreet K. (2016) research study on development of hydroponic systems for green house tomato, it is a greenhouse mechanization farming technique that protect the plants from extreme weather conditions during rainy and dry seasons which incorporates various technologies like drip irrigation system, automatic temperature control using evaporative cooling and light controlling systems to form a complete artificial farming area which is isolated from outside climate. He further stated that, almost all terrestrial plant can be grown with hydroponic technique which has added advantages being a simplified farming technology that reduces the land requirement for crops by 75% or more, also water usage reduction by 90% through it recycling processes; while there is no residual release of chemicals such as salt to the environment, plant nutrients are recycled within the system.

Basic Nutrient Solution Requirements: - According to Barman et. al., (2016), a better quality and high yield achievement is always possible through hydroponics due to accurate management of nutrition and all the growing conditions. Nutrient solution is one of the most vital factors which influences crop quality and yield. A hydroponics system contains mainly aqueous solution of essential elements of organic or inorganic compounds. There are seventeen essential elements which are considered for proper plants growth such as carbon, oxygen, hydrogen, phosphorus, nitrogen, potassium, calcium sulphur, magnesium, iron, zinc, copper, manganese, boron, chlorine, nickel and molybdenum. The most vital elements used in nutrient solution are nitrogen, phosphorus, potassium, calcium, magnesium and sulphur; and they are supplemented with micronutrients. All of these essential elements have physiological role and affect directly on plant growth and yield and can influence any characters of plant if one is absent in the growth medium.

Growing Media: - One of the most important factors for hydroponics technique according to Mugundhan et al., (2011), is to choose the right medium or substrate that should be used for better yields. Different media can be used for different growing techniques. The medium or substrate which can be used for hydroponics farming is an inert material does not provide any nutrients to the plant. It only acts as base to grow the better plant roots and holds moisture.

Mattice and Brown, (2010) in a related study stated that, the media should be solid sufficiently to support the plant growth and water infiltration through a longer period of time. Because soft substrates might be broken down quickly and decrease the structure and particle size. This leads to poor root aeration. Hence, coarse aggregates with sharp edges should also be avoided and the medium should not hold any poisonous materials.

Berndsen and Gardener, (2014) also suggested growth media to be used alone or in combination with others. The most common materials may be used as growing media are coarse sand, gravel, perlite, vermiculite. There have also other specialized materials which are used for hydroponics gardening such as shredded coconut fibers, expanded clay pellets and rockwools.

Advantages of Hydroponic System: - Vikash et. al., (2019) outlined the many advantages of growing plants under hydroponic (soil-less culture) over soil-based culture. Hydroponic system produces the healthiest crops with high yields and are consistently reliable; gardening is clean and extremely easy, requiring very little effort.

Here nutrients are fed directly to the roots, as a result plants grow faster with smaller roots, plants may be grown closer, and only 1/5th of overall space and 1/20th of total water is needed to grow plants under soil-less culture in comparison to soil-based culture, there is no chance of soil-borne insect, pest, disease attack or weed infestation too.

In overall, hydroponic provides nutrient regulation, higher density planting, and leading to increased yield per acre along with better quality of the produce. It is also effective for the regions of the World having scarcity of arable of fertile land for agriculture.

In hydroponics, weeds elimination as well as relief from soil borne diseases helps in the reduction of production costs as compared to soil-based cultivation which serves as host to number of insect pests and plant parasites. Other advantages this technology offer is low labour requirement, highly productive, conserve land, protects the environment and a complete control over nutrient balance.

According to Barman et. al., (2016) in a related study stated that, the major merit of hydroponics is that it potentially produces much higher yields and can be used in those places where land is not suitable or ground agriculture and gardening is not possible. It is practically feasible to grow any kinds of vegetables, fruits, herb or crops using this technique. Fruits and vegetables consumption highly decrease the rate of risk of many types of chronic disease in human. Now it is possible to improve the quality of fruits and vegetables by using green technique such as hydroponics.

Limitations of Hydroponic Culture: - The only disadvantage of this system is higher initial setup costs, but this can be offset by the high returns from the crops grown. Hussain et al., (2014).

Although soil-less cultivation is an advantageous technique but some limitations are significant. Technical knowledge and higher initial cost are required for commercial scale cultivation and controlled environment. Ensuring the proper condition for plant growth is sometimes difficult and expert management skills are necessary. It requires constant supervision and there have a chance directly or indirectly to introduce water or soil borne microorganism. If any problem arises in the culture, it might be fully loss of plant yield. Finally, it needs to supply light and energy to run the system Barman et. al., (2016).

Conclusion

The future of agriculture and its food security is hydroponics. This is because, it produces the healthiest crops with high yields in short period and low operational costs when compared with soil-based cultivation in open field with irrigation and the application of high amount of fertilizers, pesticides, and herbicides to grow the crops.

References

Amponsah, S. K., P. Oteng-Darko, and F. Kumi. Potential and constraints of agricultural mechanization in Ghana–a review. *International Agricultural Engineering Journal, 2012; 21(2): 38 ─43.*

Beibel, J P 1960. Hydroponics -The Science of Growing Crops Without Soil. Florida Department of Agric. Bull. Pp180.

Berndsen, C. and M. Gardener. 2014. Backyard Hydroponics. University of California Cooperative Extension, San Diego County.

Brown ME, Hintermann B, Higgins N 2009. Markets, climate change, and food security in West Africa. *Environ Sci Technol 43(21):8016–8020.*

Clarke, L. J., and C. Bishop. 2002. Farm Power - Present and Future Availability in Developing Countries. *ASAE Annual International Meeting/CIGR World Congress, Chicago, 30 July 2002.*

FAO and UNIDO. 2008. Agricultural mechanization in Africa; Time for action: Planning Investment for Enhanced Agricultural Productivity. Report of an expert group meeting jointly held by FAO and UNIDO in Vienna on 29–30 Nov. 2007.

FAO. (2010). Agricultural Mechanization in Mali and Nigeria: Strategies, Experiences and Lessons for Sustained Impacts. Agricultural and Food Engineering Working Document Series 8, 10-37.

FMARD (2018) Food and Agriculture Sector Development Policy (FASDEP II). Abuja, Nigeria.

Harmanpreet Kaur 2016. A thesis on: Development of hydroponic system for greenhouse tomato; Department of Soil and Water Engineering, Punjab Agricultural University.

Heather E. Thompson, Lea Berrang-Ford and James D. Ford (2010). Climate Change and Food Security in Sub-Saharan Africa: A Systematic Literature Review; Sustainability 10(2), 2719-2733; www.mdpi.com/journal/sustainability.

Hussain, A., K, Iqbal., S. Aziem., P. Mahato., A.K. Negi. 2014. A Review on the Science of Growing Crops without Soil (Soilless Culture) – A Novel Alternative for Growing Crops. Intl. J. Agri. Crop Sci. 7(11): 833-842.

Li H and Cheng Z 2014. Hoagland nutrient solution promotes the growth of cucumber seedlings under light-emitting diode light. Acta Agri Scandina 65:74-82.

Liette Connolly-Boutin and Barry Smit (2015). Climate change, food security, and livelihoods in sub-Saharan

Mattice, L. and C. Brown. 2010. Hydroponics Production, an Educational DVD for High School Agricultural Education. California Polytechnic State University, San Luis Obispo.p.12.

Mugundhan, R.M., M. Soundaria., V. Maheswari, P. Santhakumari and V. Gopal. 2011. "Hydroponics"- A Novel Alternative for Geoponic Cultivation of Medicinal Plants and Food Crops. International Journal of Pharma and Bio Sciences 2(2):286-296.

N.C. Barman, M.M. Hasan, M.R. Islam and N.A. Banu (2016). A review on present status and future prospective of hydroponics technique, Plant Environment Development 5(2):1-7, http://www.botanyru.org/journal.

National Development Planning Commission 2010. First National Implementation Plan (NIP). http://www.nationalplanning.gov.ng.

NBS 2020. Nigerian Gross Domestic Report, Q1 2020-www.nigeriastat.gov.ng.

NIMET 2020. Prediction: Overview of the 2020 Seasonal Rainfall Prediction.

Vikash Kumar Jha; Ankita Jain; and Nidhi Kumari 2019. A review on hydroponic system: hope and hype; https://www.researchgate.net/publication/330245272.

Zewdie A 2014. Impacts of Climate Change on Food Security: A Literature Review in Sub Saharan Africa. J Earth Sci Clim Change 5:225. doi:10.4172/2157-7617.1000225.