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Optimization of Water Policy, Regulation and Technology for Sustainable Food Production in Nigeria: A Review

Okore Okay Okorafor*, Akachukwu Favour Nwaobi, Vincent Nnamdi Ugwah

Department of Agricultural and Bioresources Engineering, Federal University of Technology, Owerri, Imo State, Nigeria
Email: *okore.okorafor@futo.edu.ng, akachukwu.nwaobi@futo.edu.ng, vincent.ugwah@futo.edu.ng

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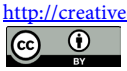

Abstract

Globally, over 70% of global water extraction are channeled to agriculture, while in Africa only 7% of agricultural practices use reliable water sources. In Nigeria just 0.8% of arable land is under irrigation, thus promulgating the necessity of water resources optimization despite its relative abundance (estimated at about 224 billion cubic metres) across the nation. This study presents a review on Nigeria's existing water policies, regulations and technologies, their limitations while also proffering tailored technology-based and policy-based solutions to ensure robust food production. Inaccurate data/information and inadequate framework for water policy implementation remains the major undoing of Nigeria's water sector which has grossly affected food production thereby making Nigeria a net importer of food. With food demand proposed to double by 2050, proven technology and policy-based solutions were highlighted for robust yield in food and livestock production. Ensuring water quality, use of irrigation/micro-irrigation techniques, ICT in water management, effective soil/water conservation practices and enforcement of water regulations/policies were considered as ways to optimize water resources for improved food production capacity for the actualization of sustainable development goals (SDGs) in the nation.

Subject Areas

Agricultural Science

Keywords

Water Policy, Optimization, Food Production, Sustainable Agriculture, Technology

1. Introduction

Food production is largely dependent on the availability of water. It is estimated that more than two-thirds of all freshwater abstraction world-wide (and up to 90% in some countries) goes towards food production. With this abstraction rate, it is estimated that 35% of the world's population will live in countries affected by water stress or scarcity by 2025 [1]. Nigeria has a total landmass of 923,768 km^2, which is nearly 15% of the area of West Africa, and its population density of 197 persons per km^2 is fivefold the 39 persons per km^2 average for Africa. In 2018, Nigeria's estimated population of 203,452,505 people, about half (50.3%) living in urban areas, makes it the largest nation in Africa and the seventh in the globe. By 2050, its population is anticipated to increase to around 398.5 million to become the world's third-largest nation after India and China [2]. However, it is evident that despite Nigeria's teeming population, food (crop) production increases have not kept pace with population rise thus posing a threat to food security: A pronounced challenge of sustainable livelihood confronting citizens of most developing nations [3]. Food security is a situation in which 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 healthy life [4]. The challenge of sustainable food production has stifled the performance of the agricultural sector as well as led to an increase in imports and a huge decline in national food sufficiency [3]. Juxtaposing the exponential surge in the Nigerian population to the need for food security makes the subject of water availability an all-important topic. More so, water required for food production must meet specific quality requirements if food production must be optimized. If the SDG goals of zero hunger, clean water and sanitation as well as other sister goals must be effectually actualized by 2030, then there is a need to ensure water availability for food production. Although there are myriads of work with facts about the challenges of water regulations and policies, very little is done to bring tailored solutions to Nigeria's peculiar challenges as it relates to harnessing water optimally for sustainable food production. This paper is geared towards reviewing existing water policies, regulations and technologies while also proffering targeted policy-based and technology-based solutions to increase sustainable food production in Nigeria.

2. The Nigeria Water Resources

Nigeria is blessed with abundant water resources with an estimated 224 billion cubic meters of water available, annually, from run-off of rivers in the eight hydrological zones of the country and is mainly used for domestic purposes (drinking, washing and bath), fishing, farming and irrigation, and livestock raising [5]. The nation is drained mainly by the River Niger, the River Benue and other various minor tributaries. Other major water bodies include the Lake Chad, Gongola, Hadejia-Jama'are, Kaduna, Cross River, Sokoto, Ogun, Osun, and Imo [6]. According to the national water resource masterplan of 1995, the

annual rainfall varies from over 4000 mm in the South-East to below 250 mm in the extreme North-East and is subject to significant temporal variation. The surface water resources potential of the country is estimated at 267.3 billion cubic metres while the groundwater potential is 51.9 billion cubic metres. Thus, the total surface area of water bodies in Nigeria, excluding deltas, estuaries and miscellaneous wetlands suitable for rice cultivation-but not necessarily suitable for fish cultivation, is estimated to be about 14,991,900 ha or 149,919 km^2 and constitutes about 15.9% of the total area of Nigeria [7]. In the Niger Delta region of Nigeria, several surface water resources abound which are distributed as freshwater, estuarine/brackish (fresh and salt water interphase) and marine ecosystem [8]. Despite possessing large reserves of surface and groundwater, a lack of water management and distribution capacity, coupled with highly variable rainfall patterns, has led to sustained water shortages across the country [34].

2.1. Food Production in Nigeria

Nigeria's high population invariably translates to a high demand for farm produce. It is no longer news that one of the major problems of sustainable livelihood confronting citizens of most developing societies is that of food security. Food security does not simply imply increased food production, it is a framework defined by four fundamental dimensions, namely: availability, accessibility, stability, and utility [9]. It also connotes affordability of food by the final consumer(s) [10]. These various indices, variables and factors influencing food production and its availability on a sustainable scale has no doubt generated lots of questions and concerns among students, scholars, stakeholders and policy makers [1] [7] [11] [12]. It is, however, evident that Nigeria's food production capacity is far from normal. For example, Nigeria is the continent's leading consumer of rice, one of the largest producers of rice in Africa and simultaneously one of the largest rice importers in the world. In 2008 alone, Nigeria produced approximately 2 million metric tons of milled rice while importing roughly 3 million metric tons, including the estimated 800,000 metric tons that are suspected to enter the country illegally on an annual basis [3]. Similarly, crop production in Nigeria is dominated by smallholder farmers using traditional methods that are full of drudgery These methods are reported to be time-consuming, labour-intensive, and expensive per hectare and offer little hope for increase in sustainable food production [13]. [14] identifies four major techniques for facilitating local food production namely: expansion of arable land; achieving higher levels of cropping intensity; increasing yields; and implementing agricultural policy reforms. It was also observed that some major challenges that could impede the actualization of the food yield improvement includes: imminent soil degradation due to climate change; desertification in the northern part on the continent which put a large number of the population at risk; massive migration into the cities with the concomitant transfers of potentially available force in the cities which can weaken local production capacities. Other adjoining impediments to optimum food yield include: excessive use or diversion of arable land

for biofuels, livestock and animal feed production as well as inadequate financial resources and investments. More so, it is worthy of note that inappropriate and indiscriminate transfer and application of science and technological innovations from the western developed countries to the developing countries of Africa could also pose a huge challenge [4]. Sustainability in food production is a major problem of Africa. There are a number of reasons for this problem which have been explored in this study, alongside suggested solutions. One of these solutions is the systematic application of appropriate science and technology innovations to agriculture in Africa [4]. It is also worthy of note that despite advances in Technology and biotechnology to boost food production (genetically engineered food, weed-resistant crops), these processes have their inherent effects thus making it less sustainable [15].

2.2. Water-Food Production Nexus

On average, agriculture accounts for 70% of global freshwater withdrawals. Also, the last 30 years have witnessed an increased food production rate by more than 100%. Food demand in Least Developing Countries (LDC) is expected to double as the population in the developing world reaches 7.5 billion by 2050 - including 2.2 billion in south Asia and 5 billion in Sub-Saharan Africa [14]. Consequently, FAO estimates that about 60% more food will be needed by 2050 to meet the food requirements of a growing global population [3]. These projections are largely dependent on water: an abundant but scarce natural resource. Water scarcity is one of the most pressing issues facing humanity today. More than 1.4 billion people live in water-stressed river basins and by 2025, this number is expected to reach 3.5 billion [14]. Consequent to water scarcity and unavailability, only about 7 % of African agricultural practices are using reliable water supply. In most African countries, cereal production like other crops is carried out without adequate irrigation. It is also on record that only 0.8 % of arable land in Nigeria is under irrigation compared to the 28 % in Thailand [16]. These daunting statistics go a long way to show that over the estimated timeframe, the availability of water for agriculture is gradually decreasing because the actions/processes required for replenishment are also limited. In the Niger Delta region of Nigeria, [11] underpinned challenges facing sustainable water supply management in the Niger delta wetland including lack of effective compliance to policies, fragmented responsibility, poor state of infrastructure, corruption, and low rate of costs recovery. In order to ameliorate these challenges, the researcher recommends the need to comply with water management policies that aim at economic efficiency, encourage stakeholder participation, and enforce existing laws and regulatory responsibilities.

3. Water Policies and Regulations in Nigeria

Food production and processing require large amounts of water of varying quality. Research projections connote that water needs will likely increase in the fu-

ture [1]. For this reason, it is necessary to ensure effective water-use policy to ensure all-year-round food production in Nigeria. Several laws, regulations and policies have evolved in Nigeria post-independence with the aim of addressing issues related to soil and water resource ownership, exploitation, protection and management. Some of these regulations and policies were targeted towards major soil- and water-resource-related regulations. The National Water Resources Policy was primarily instituted to provide a framework for addressing the challenge of clear and coherent regulation, providing clear definitions of the functions and relationship of sector institutions, finding solution to the problem of dwindling funds, providing reliable and adequate data for planning and projections as well as ensuring decentralization in order to boost efficiency, performance and sustainability [6]. More so, it was also aimed to ensure the autonomy of water supply agencies, accountability and human resource development. The formulation of these policies were guided by the Millennium Development Goals(MDGs), the NEPAD objectives, the UN Conference on the Human Environment [17], the Ramsar Convention [33], the World Conference on Water and the Environment [18], UN convention on the law of the non-navigational uses of international watercourses of 1998 among several others. The guiding principles upon which the national water policy was formed encompassed the tenets of state ownership of water and its resources, the use of water for common good of the nation, time based right to water use and no ownership right, equitable access between riparian communities and an integrated water resource management [19].

3.1. Irrigation and Drainage Policy

Understanding the potency of water to contribute to the national economy, The National water policy developed irrigation schemes to facilitate agricultural production thereby reducing the problem of water shortage caused by the unpredictability of rainfall. Its major objectives were to reduce poverty through effective irrigation schemes and also to optimize the use of water and land resources to enhance food crop production. To achieve these objectives, the Nigerian government proposed strategies such as encouraging indigenous tested and proven technologies and establishing communication systems for the adoption of best practices in irrigation development and management. They also went ahead to establish rules and regulations to guarantee billing and collation of service charges by irrigation agencies, encouraging private sector participation, supporting irrigation research and the use of irrigation research findings [6]. Likewise, drainage policies were implemented to avoid problems such as water logging, over exploitation of aquifers, disease vector breeding in waterlogged area as well as reduced crop yield [20].

3.2. Fisheries and Livestock Policies

According to [19], developing countries' share of consumption of global fish

output rose from 61% in 1990 to 78% in 2017. With an estimated annual per caput fish consumption of 13.3 kg in 2013, fish represents an important dietary element and one of the few sources of animal protein available to many Nigerians [3]. With total fish imports amounting to about USD 1.2 billion and exports valued at USD 284,390 million in 2013, Nigeria is a net importer of fishery products. Since fish production can only thrive in water of optimum quality and quantity, the national water policy enacted some policies to ensure that Nigeria's water bodies meet international requirements for fish production [6]. Likewise, water is a vital but poorly studied component of livestock production. It is estimated that livestock industries consume 8% of the global water supply, with most of that water being used for intensive, feed-based production [21]. To keep up with the ever-growing demand for this proteinous food source, the national water policy drafted some strategies to sustain livestock and fish production. These include ensuring that enough water is released through our dams to satisfy the downstream requirements for livestock production, and ensuring that water resources management respects the requirements of self-sufficiency in fish production through an effective liaison with the Federal Ministry of Agriculture and Natural Resources. Finally, by ensuring that newly planted dams guarantee the respect of the requirements of self-sufficiency in fish production [6].

3.3. Nigerian Water Regulatory Bodies

These policies are enacted by various acts as wells as implemented by various government agencies. Since the use of water cuts across various sectors and serves various purposes, effective water policy implementation often employs the integrated water resources management approach. [22] highlighted that several acts of parliament, agencies and institutions exist with the aim and responsibility of managing soil and water resources in Nigeria. These include the River Basin Development act, Water Resources Act of 2004, Federal Ministry of Water Resources, Nigerian Integrated Water Resources Management Commission, The National Water Resource Institute and the Hydrological Services Agency (NIHSA). While FMWR was charged with the responsibility of policy formulation and advising, the NWRI was set up to embark on research and manpower training. The RBDAs, on the other hand, were saddled with the responsibility of providing water to communities for the purposes of agricultural, domestic, and industrial consumption [23]. NWRI and twelve RBDAs spread across the entire country are subsidiaries of the FMWR. The RBDAs are backed up by the RBDA act of 1986.

3.4. Causes of Inefficiency in Nigeria's Water Authorities

The lack of collaborative efforts across basin authorities makes surface and groundwater management both at small and catchment scales practically ineffective. It is also observed that most environmental policies are cosmetic in conception with no objective structure for implementation to achieve the desired

goals [24]. More so, the governmental attitude to environmental and water issues in Nigeria can best be described as reactive rather than proactive. This assertion was evident by the creation of the National Water Resources Institute (NWRI), the River Basin Development Authorities (RBDA) in 1976 and Federal ministry of water resources (FMWR) in 1977. These bodies were in direct response to the threat of famine brought about by the drought of the early 1970s [5]. Furthermore, [22] also noted that the authorities lacked an essential scientific database in all hydrological and basin stations across the nation. This database serves to ensure adequate record keeping while also giving a panoramic view of the trends of rainfalls, flooding, water supply and other hydrologic data which are pertinent in fostering food security. There should be laid down implementation strategies that must be followed religiously for effectiveness in our water polices. This would help to define the deployment and implementation of policies for effective food production, food security and economic growth as regard agriculture.

4. Agricultural Innovative Policies and Technology for Optimized Food Production

Agricultural growth may promote the economy of a nation while simultaneously reducing reliance on imported food items especially in countries dependent on natural resources with high poverty rates and large farm populations, such as Nigeria. However, achieving this feat requires substantial structural policy reforms and large public investments [25]. Improving agricultural productivity, while conserving and enhancing natural resources, such as water, is an essential requirement for farmers to increase global food supplies on a sustainable basis [26]. However, the role of small holder farmers and their families in increasing agricultural productivity growth sustainably is no doubt crucial. Farmers are at the epicenter of any process of change involving natural resources and need to be encouraged and guided, through appropriate incentives and governance practices, to conserve natural ecosystems and their biodiversity, and minimize the negative impact agriculture can have on the environment [3]. Water optimization models for sustainable food production in Nigeria can be classified into policy-based optimization and technology-based optimization.

4.1. Technology-Based Water Optimization Strategies

There are various technological advances to ameliorate food insecurity in Nigeria as depicted by [10] and [27]. However, some technological approaches that are required to enhance or optimize food production while ensuring conservation of water resources include:

- **Irrigation optimization:** Flooding or undirected irrigation patterns are often inefficient and not an optimal way for utilizing reduce water use in Nigeria. Freshwater use for irrigation can be optimized by introducing new techniques such as drip irrigation, and efficient sprinkler systems, by timing wa-

ter application to match plant requirements, and by developing new water-efficient crop varieties. This can increase irrigation efficiency and crop yields as well as reduce water pollution by limiting the amount of runoff and controlling the process of salinization. For instance, Indian farmers were able to increase the crop yield per unit of water applied from 46% for potatoes to as much as 243% for sweet potatoes when drip irrigation was applied [1].

- **Harnessing optimal seasonal humidity:** Another way to optimize water use for sustainable food production is by growing more crops during the cool season when there is less evaporation. In a study carried out by [1], a project in Malaysia showed that 25% less water was required to grow rice by using a 'dry seeding' approach compared to the traditional method that required pre-transplant flooding of the rice paddle.
- **Use of improved irrigation schedule:** [28] carried out a review where the use of improved irrigation schedule was carried out for dry season tomato cultivation in Ghana. It resulted in water-saving (130 - 1325 mm) compared to traditional irrigation practices, and an increase in tomato yield (4% - 14%). More so, maize required 107 - 126 mm of water in periods of low rainfall and frequent dry spells, and 88 - 105 mm in periods of high rainfall and rare dry spells. These water management techniques could make year-round irrigated crop production feasible, using water saved during dry season tomato cultivation for supplemental irrigation of maize in the rainy season.
- **Implementing tailored water quality:** Water use can also be optimized by adapting to the water quality of different crops. [1] cites an example where salty drainage water from one crop is used to irrigate cotton, which is salt-tolerant. The highly salty drainage water from the cotton can be used to irrigate halophytes (extremely salt-tolerant plants).
- **Adequate water storage (surface and subsurface storage of water):** Water storage is often associated with dams, reservoirs and tanks. While surface storage includes natural wetlands and reservoirs, subsurface storage consists of groundwater aquifers and soil water storage that can be accessed by plant roots, tanks, and ponds. Storage makes more water available by capturing water when it is plentiful and making it available for use when there are shortages. This approach can be adapted majorly in the northern part of the country with relatively low rainfall.
- **Use of micro-irrigation technologies:** Modern irrigation technologies, such as sprinklers and micro-irrigation are often seen as one of the keys to increasing food production on smallholder farms which make up a large proportion of the land farmed in Least Developed Countries.

Successful models of micro-irrigation in India and Nepal have increased crop yields and reduced water consumption in addition to increasing income and household food security [14]. Applying this approach to most plantation farms across the North and Southern borders will no doubt boost food production.

- **Use of ICT in water management:** Technologies such as the Geographic Information System GIS can be used to map out a watershed and gather basic

geographic and hydrologic data required for effective water supply or adoption of agricultural techniques for optimized production. Also, ICT ensures a more detailed and precise approach to the proper management of water resources to meet plant requirements without losses.

- **Efficient wastewater treatment:** Deployment of enhanced wastewater treatment in various regions of water scarcity is pivotal to improving all year-round crop production as wells as optimizing water use. In Mexico, for instance, approximately 25% of municipal wastewater is reused to irrigate 300,000 hectares of land. Deploying tailored wastewater techniques (biological, physical and chemical) to ameliorate specific water pollution trends of different Nigerian locations will go a long way to the ensure optimization of our water resources. In secluded settlements, the installation of off-grid, onsite wastewater treatment which incorporates can incorporate biological filtration, membrane filtration and chemical disinfection to produce effluent which can be deployed for irrigation, will massively improve water availability for food production. This approach is currently studied and implemented in Israel [29].
- **Soil and water conservation practices:** This is another great strategy to manage the sudden excesses of water and frequent dry spells is the soil and water conservation measures. This can help to make better use of rainfall by increasing water infiltration and water storage in the soil. Soil and water conservation practices include terracing, contour bunds, infiltration pits, tillage, integration of tree crops, and green manuring. These techniques are however not capital-intensive investment and only require minimal land reshaping and modification.

4.2. Policy-Based Water Optimization

Some policy-based water optimization strategies for food sustainability in Nigeria include;

- **Provision of adequate and reliable data:** Government agencies tasked with the responsibility of providing reliable data are expected to provide dependable data upon which agriculturists can rely upon to design /develop water management framework or resources that will ensure optimization of water for food security. Such data include climatological, hydrological, meteorological, and even anthropological data which affects climate change and other environmental issues [5].
- **Enforcement of water regulations/policies:** Government should also be as committed to the enforcement of the water regulations and laws as they should be to making them. Before now, several government policies have only existed on paper without proper implementation. Incentives should be given to strict adherers while charges should be meted out to defaulters.
- **Functional interaction of government agencies and communities:** Government agencies must ensure functional collaboration between riparian communities' stakeholders so as to ensure that water abstraction and pollu-

tion is within the permissible standards that can favor an all-year-round agricultural production to foster food security/availability.

- **Proper allocation of water resources**: There should be optimal allocation of water resources in basins facing water scarcity (especially in the northern region with minimal rainfall) due to the increasing demands caused by population growth, urbanization, industrialization and agricultural intensification, and poor water resources management [28].

5. Conclusion

From the review, it is evident that various factors can affect crop yield and food production. These are not limited to Climatic factors [30], water stress [31], unavailable soil nutrient [32] among others. More so, it is quite evident that the Nigerian border encompasses enough water resources required for sustainable food production. Taking into account the issues discussed, it has been observed that the major causes of poor yield in agricultural produce and low level of food production in Nigeria include;

- Poor and unimplemented policies that will ensure water resources availability.
- Inadequate, unreliable and unavailable data and information about water availability.
- Absence of viable technology to harness and manage water resources.
- Corrupt personnel that do not ensure the proper regulation and management of water policies and water resource frameworks.

To remedy this situation, government agencies should make/facilitate policies alongside strategies for effective implementation. Nevertheless, harnessing smart irrigation technologies, hydrological data for optimized water resource allocation, soil and water conservation techniques as well as proper education/sensitization of all agricultural stakeholders (farmers, extension workers, policy makers among others) in Nigeria will go a long way to ensuring food security and the achievement of all the sustainable development goals dependent on water.

Conflicts of Interest

The authors declare no conflicts of interest.

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