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Review Article

A Review of Irrigation Practices for Improved Agricultural Operations in Nigeria

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ABSTRACT

Irrigation is a vital component of agricultural operations worldwide, particularly in regions with limited rainfall and erratic weather patterns. In Nigeria, where agriculture plays a major role in the economy, irrigation practices are crucial in ensuring stable and enhanced agricultural production. Moreover, the level of investment and abundant water resources ought to have expedited the goals of food self-sufficiency and socio-economic development in the country. This paper is aimed to review the current irrigation practices in Nigeria, discuss potential improvements to optimize agricultural operations and sensors in irrigation, sensor technology and their applications in different aspects of agriculture. The review showed that the major persistent issues that have been hindering the performance of irrigation practice to achieving the set goals were inconsistent government policies, non-implementation of wireless sensor networks and lack of technical know-how among the farmers on irrigation farming system, and untimely financial intervention. In addition, the communication gap between the government and the farmers was responsible for some cases of underutilization and abandonment of large-scale irrigation system. The study concluded that to achieve food security and socio-economic development through irrigation systems practice in Nigeria, there is need to provide proper policy framework, appropriate wireless technologies, and farmers' awareness and training in using those wireless technologies in order to achieve crop yield.

1. INTRODUCTION

The climate in Nigeria is characterized by relatively high temperature and variations in the amount of precipitation throughout the year with alternating two seasons (rainy and dry) (Ibe and Nymphas, 2010). The rainy season is generally from April to October and the dry season from November to March, with some

degrees of spatial and temporal variations in the amount and distribution of rainfall across the agro-ecological zones (Bibi *et al.,* 2014; Akande *et al.,* 2017). The southern part of the country has the highest average annual rainfall, ranging from 1524 to 2035 mm with duration of eight to nine months. The middle belt ranges from 508 to 1524 mm while it is less than 508 mm annually for a period of five to six months in the north and less than four months in the far north (Oriola and Alabi, 2014).

Furthermore, a short dry season is known as "August break" generally comes up in the month of August. The dry season persists from late October to early March. This period witnesses dusty north-east winds (Chineke *et al.,* 2010). However, the Northern Nigeria which experiences short wet season, the dry season is very long, from October to mid-May. Annually, the average temperature ranges from 21 °C to 32 °C in the south while the north has a temperature range of 13 °C to 41 °C. Nigeria, the most populous country in Africa, was estimated to have a population of over 140 million in 2006 and the United Nation estimate in 2015 was roughly 181 million (United Nations, 2017). However, the exponential projection growth in the population has not translated to food sufficiency but rather the agricultural production is on the decline. There is an uneven spatial population distribution with about 65% living in rural areas and the rest in urban areas (Aidi *et al.,* 2016). The major occupation of people in rural areas is agriculture but with a low level of productivity (Dayo *et al.,* 2009). The level of food insecurity in the rural areas of Nigeria is alarming with 84.3 % reported in some communities in the north and about 56% in the south west of the country (Akinyele, 2009). The country relies mostly on the importation of agricultural produce to feed its growing population in spite of her production potential in agriculture. The only way out to address the challenges of food insecurity and rural poverty is to find the solution to agricultural production in the country (Xie *et al.,* 2017).

In Nigeria, agriculture remains the bedrock of the economy as it provides a living for the majority of its populace. World Bank (World Bank, 2014) reported that the agricultural sector alone accounts for 33% of the total GDP of Nigeria and the sector employs around 23% of the total economically active population (FAO, 2014). Agriculture used to be the Nigerian major source of foreign exchange from independence in 1960 up to the mid-1970s when Nigeria was the world's largest producer of groundnuts, palm oil, and cocoa, and one of the major producers of millet, maize, yam, cassava, coconuts, citrus fruits and sugar cane (Ladan, 2014). However, the sector has been on the neglect and contributed less economically since the early 1970s when attention was shifted to oil revenues. Notwithstanding the reliance of the country's economy on proceeds from oil export, Nigeria remains agrarian with her endowed substantial natural resources including 68 million hectare of arable land, abundant freshwater resources covering about 12 million hectare, and an ecological diversity which enables the country to produce a wide variety of crops and livestock, forestry and fisheries products (Arokoyo, 2012). Moreover, the dry northern savannah is appropriate for sorghum, millet, maize, groundnuts, and cotton while cassava, yam, plantain, maize, and sorghum can successfully be grown in the Middle Belt. Cash crops like oil palm, cocoa and rubber can be grown in the South whereas low-lying and seasonal flooded areas can grow rice (FAO-Aquastat, 2016). The government has acknowledged the need to diversify the country's economy by giving adequate attention and promoting the development of the agricultural sector in order to shift from a mono-cultural economy of oil exports (Olajide *et al.,* 2012).

Farming system in Nigeria can still be regarded as subsistence-based and it is predominantly rained, which makes it overly dependent on weather fluctuations. The irrigated agriculture only accounts for one percent of the cultivated area (FAO-Aquastat, 2017). Many farmers are out of jobs during the dry season and local food prices are on the rise as a result of food scarcity during this period. However, the green revolution requires all-year- round farming. The role of irrigation cannot be ignored as it is the only way to achieve the mandate of "Green Alternative" of the present administration. There is a need to evaluate the irrigation practices in the country so as to know what has been done in the past, the present status, and how to improve for the future developments. The purpose of the review is to increase crop yield by monitoring and controlling the quantity of water based on the requirements of the crops and applying the water at a regular interval as required by that crop and ensuring security of farmers from intruders using

wireless sensor networks (WSN). The review proposes a type of remote control system of irrigation in that it does not require much human labour.

2. HISTORY OF IRRIGATION PRACTICES IN NIGERIA

The irrigation practice in Nigeria can be traced back to 700 AD (Olubode-Awosola and Idowu, 2004), however, became more pronounced after the drought of 1970-1975. Sojka *et al.* (2002) defined irrigation as the practice of applying additional water, beyond what is available from rainfall, to the soil to enable or enhance plant growth and yield, and, in some cases, the quantity of foliage or harvested plant parts. Furthermore, water could be sourced from groundwater through pumping to the surface or surface water diversion from one landscape position to another. The traditional application of water to land for dry season farming was first conceived in northern Nigeria in form of gravity, bucket/calabash and pump methods by farmers without any financial assistance from the government (Yahaya, 2002). Food and Agriculture Organization of the United Nations (FAO) classified irrigation scheme into three, based on land mass size such that large irrigation scheme has over 10,000 hactre, between 100 – 1000 hactre is classified as medium-scale scheme while the small-scale scheme has less than 100 ha (Moris and Thom, 1990). In Nigeria, irrigation schemes and projects consist of three categories; the public irrigation schemes, which are government-executed schemes, the farmer-owned irrigation scheme, and the floodplains called Fadama irrigation scheme. As the dire need for irrigated crop cultivation grew, a study was carried out in 1972 to examine the water resources and irrigation development potential in the country. Consequently, the study led to the institution of three models public irrigation schemes; namely the Bakolori scheme, the Chad Basin scheme, and Kano River irrigation scheme (NINCID, 2015). Subsequently, additional eleven more River Basin Development Authorities (RBDAs) were added across the country after the success of the pilot schemes in 1976. These RBDAs include the Niger Basin; Lower Benue Basin, Upper Benue Basin, Lake Chad Basin, Benin- Owena Basin, Sokoto Rima Basin, Hadejia Jamare Basin, Cross River Basin, Ogun- Osun Basin, Anambra- Imo Basin, and Niger Delta Basin. Their mandates among other things were to carry out developmental functions of irrigation infrastructures in their respective agro-ecological zones so as to promote irrigated agriculture in order to enhance food self-sufficiency.

Moreover, the rural water supply function was added to the functions of the established river basins and this brought about the change of name from the initial River Basin Development Authorities (RBDAs) to River Basin and Rural Development Authorities (RBRDAs) in 1995. Through the RBRDAs, about 162 dams with 11 billion m^3 reservoir capacity were constructed, with the intention to irrigate about 725,000 ha. However, the expected efficiency and sustainability of these large-scale public irrigation schemes to provide food sufficiency were not met as only about 32% of actually irrigated areas of equipped areas were covered. Most of these schemes have become obsolete due to high operating costs, poor maintenance culture by the beneficial of the schemes.

In order to arrest these situations, with the available abundant water resources, there was a policy shift to small-scale irrigation through state's Agricultural Development Projects (ADPs) funded by the World Bank. Boreholes and tube wells were constructed across Nigeria's northern states and motor pumps were distributed to lift the water for irrigation (Kimmage, 1991). Inland valley bottoms were explored and executed in phases, Fadama I, II and III, as National Fadama Development Program by providing financial support to farmers for the procurement of irrigation facilities including boreholes, irrigation pumps, and tube wells in such fadama areas (Takeshima and Yamauchi, 2012; Nkonya *et al.,*2012). Despite these efforts, with large and small-scale irrigation systems combined, the earlier performance of agricultural production in terms of food production and economic growth has not been matched.

Regardless of the combined outputs of the irrigations systems, the private small-scale schemes and improved Fadama development program have witnessed improved performances based on the Federal Ministry of water resources assessment as presented. Kolawole (1988) opined that the declining in the performance of the irrigation schemes is as a result of the combination of technical, economic, social, institutional, and

political factors. Moreover, Olowa and Omonona (2008) identified higher value in actually irrigated areas of Hadejia Jamaare in comparison to the equipped areas as a result of importance of irrigation in the region, where the rainfall is very low and there are incidences of drought, compare to the southern parts of the country where the rainfall is relatively high.

2.1. Current Conditions of Irrigation

Irrigation farming allows farmers to produce all year round thereby resulting in higher agricultural outputs and improved farmer's income. However, in Nigeria, the current state of irrigation development has not been fully explored. Currently, only 45% of the total irrigation potential of 2.0 million hectare, is under irrigation (FAO-Aquastat, 2017). The northern part of the country where the average rainfall is very low as 70% of the total irrigation potential and about 20% can be found in the humid south with the balance in the central and western plateau areas. The country has huge potentials for irrigation with dam projects spread all over the country. However, most of the dams, the ones that the government has invested in, are either under-utilized for irrigation or abandoned (Yahaya, 2002). Irrigation scheme like the Hadeja-Jamaare river project, the utilization of the project is just about 50% while the Zobe dam in Dutsin-Ma in Katsina, which was constructed 40 years ago, currently has very the little irrigation activities. Also, at the Bakolori irrigation dam in Zamfara State, under the Sokoto Rima Water Project, the area cultivated is not commensurate with the amount of water in the dam. According to the Federal Ministry of water resources (FMWR, 2017), in Nigeria, there are about 264 dams with a combined storage capacity of 33 billion m^3 of water for multipurpose use that includes water supply, irrigation, hydropower, fisheries and eco-tourism, of which 210 are owned by the Federal Government, 34 by the States and 20 by the private organizations. These dams have combined of about 350,000 ha of irrigable land around the vicinities ready for development. Moreover, there are 27 on-going small earth dams nationwide with a total potential irrigable land 2,700 ha. The government is currently making frantic efforts to revive the agricultural sector among which is a policy on placing a ban on the importation of some agricultural products like rice, cocoa, vegetable, among others, that can be abundantly produced in the country. This is to enable the farmers to have the confidence to produce more by exploring the available irrigation infrastructures. Tashikalma *et al.* (2014) investigated the profitability of rice, maize, tomato and pepper under both rainfed and irrigated agriculture for 2007 to 2009 seasons. Similarly, Kundell (2008) compared the yields of selected crops including onions, sugarcane, and wheat for the 1998/1999 season and observed that there is an appreciable increase in the yields of agricultural production in irrigated agriculture as compared to rained agriculture.

Apart from the provision of irrigation infrastructures, the Nigerian farmers have also recently benefitted financial supports of US$495.3 million under the Transformation Irrigation Management in Nigeria (TRIMING) project from the World Bank (World Bank, 2014). This is to enhance improvement of the existing irrigation on 27,000 hectare and benefit more than 140,000 farmers while mobilizing private sector investment. The project aims to expand food production and spawn economic growth in rural areas through large-scale public irrigation improvement. Currently, the total investment for Nigeria in irrigation projects from 2016 to 2017 is estimated at $443 million (World Bank, 2014). The investment expected to cover small-scale irrigation development, rehabilitation/modernization of irrigation schemes, and large-scale irrigation development. The source of funding for the project is dominated by public sources such as the Federal and State Government of Nigeria. The project is expected to bring about 34,881 ha under irrigation while the surface benefitting from the rehabilitation of irrigation schemes would be 57,198 ha (World Bank, 2014).

Nigeria agricultural sector has witnessed policies instability by the different administrations over the years. This has not only made the application of policy instruments unstable but also hinders the general developmental objectives of the agricultural sector in the country. A sizeable number of policy documents have been produced ever since Nigeria started dam construction and large-scale irrigation schemes in the 1970s (Ugalahi *et al.,* 2016). National water resources (NWR) policy, Draft of National Irrigation Policy, water resources infrastructure operation and maintenance policy and financial report of the water resources strategy are examples of policies and documents on irrigation between 1998 and 2007 (World Bank, 2014).

Among the recently set up policy frameworks is the project resettlement framework under the need for transforming irrigation management in Nigeria (Elufioye, 2017). The policy is designed to provide the procedures and guidelines that would be followed in taking care of any anticipated resettlements. The farmers are in dire need of this policy to restore the trust and build harmonize the relationship between them and the government. Similarly, a new policy on agricultural promotion (Agricultural Promotion Policy 2016-2020) was recently launched to institutionalize all the stakeholders involving in agricultural production to find a lasting solution to the perceived challenges and implementation plans of the policy framework (Ojong and Anam, 2018). Furthermore, in 2014, Nigeria government partnered with Food and Agriculture Organization to finalize the 2006 draft of the National Irrigation and Drainage Policy and Strategy (NIPD) which is expected to provide the essential framework that will guide the sustainable irrigation development, create an enabling environment, and stimulate private sector investment in irrigation development.

3. CHALLENGES OF THE IRRIGATION SYSTEM IN NIGERIA

The performance of agricultural use of irrigation water in sub-Sahara Africa, as compared to Asia, has been characterized by inefficiency and poor management (Nwa, 2003). However, Nigeria irrigation system has recently started receiving due attention and there is an observed facelift in its development. Nevertheless, there are still underline challenges that need to be adequately addressed in other to meet up with its developmental objectives such as contributing substantially to the national economy, and rural development.

Firstly, Nigeria irrigation development has been faced with inconsistent and unstable policies and inappropriate legal framework over the years. Water and agriculture are regarded as separate entities under different ministries (Ugalahi et al, 2016). These have made the two ministries to have different independent policies formulation. Federal Ministry of water resources (FMWR) is saddled with the policy formulation for irrigation development in Nigeria. However, the Federal Ministry of Agriculture and Rural Development (FMARD), State Irrigation Departments, and River Basin Development Authorities (RBDAs) have variant duties regarding the irrigation development in Nigeria. Rather than complementing one another to ensure sustainability of water resources for agriculture and consumption in Nigeria, the Ministries and the respective agencies have resulted to a competition among one another which resulted to a fragmented and conflicting approach to irrigation development in the country (Goldface-Irokalibe, 2008; World Bank, 2014). Notwithstanding the unstable policies witnessed in the past, the current government's agricultural transformation agenda and the finalization of the National irrigation and drainage policy and strategy are expected to set things right in the future especially in terms of appropriate framework and policy stability (FMARD, 2011).

Secondly, the farmers are not interested in the operation and maintenance of the large-scale irrigation facilities. Adekunle *et al.,* (2015) found out that poor knowledge of irrigation techniques among the farmers was one of the factors affecting their participation in large-scale irrigation scheme. Those that manage to participate are not equipped with the requisite knowledge for the operations and maintenance of the facilities. This problem is one of the current challenges being faced by the large-scale irrigation scheme in Nigeria. The participating farmers see the facilities as government properties which should be maintained by the government. These do not only make the equipment short-lived but have also resulted in the abandonment of irrigation scheme due to lack of irrigation equipment and infrastructure to make use of.

Thirdly, the current challenge of incessant flooding is a threat to large-scale irrigation farming system to ensuring food security and rural development. However, the farmers, which are the benefits of the irrigation facilities, are not involved in planning and construction of large- scale irrigation systems. Most of their views and concerns in terms of agricultural productivity, relocation, and settlement plans are left unaddressed (Yahaya, 2002). This made most of them abandon the facilities after the completion. The level of awareness of the farmers regarding the large scale-scale irrigation systems is very low in Nigeria.

4. IRRIGATION PRACTICES IN NIGERIA

4.1. Traditional Surface Irrigation

Traditional methods, such as furrow and basin irrigation, have been widely practiced by Nigerian farmers for decades. While they are simple and affordable, these methods often lead to inefficient water use due to uneven distribution and high evaporation losses, (Omofunmi et al., 2018). There's a need to improve the efficiency of traditional surface irrigation through training and better water management practices. Traditional surface irrigation methods have been used for centuries in Nigeria and continue to play a significant role in sustaining crop production in various regions (Gbenga, 2007).

4.2. Rainwater Harvesting

Rainwater harvesting systems, such as rooftop collection and storage tanks, can help farmers capture and store rainwater during the wet season for use during dry spells. This approach can be particularly valuable in rural areas with limited access to irrigation infrastructure. Government incentives and support can encourage the adoption of rainwater harvesting practices. Rainwater harvesting is an essential water management practice in Nigeria, given the country's variable rainfall patterns and limited access to clean and safe drinking water. Importance: Rainwater harvesting is crucial in Nigeria due to its potential to address water scarcity issues, especially in rural and semi-arid regions. It provides a decentralized and sustainable source of water for various purposes, including drinking, agriculture, and domestic use. Several rainwater harvesting methods are employed in Nigeria, including rooftop harvesting, surface water harvesting, and groundwater recharge. Rooftop harvesting, where rainwater is collected from building roofs and stored in tanks, is the most common method. It is important to note that rainwater harvesting in Nigeria has the potential to address water access challenges, improve agricultural productivity, and enhance climate resilience. However, addressing challenges related to infrastructure, maintenance, and water quality is crucial for its successful implementation and long-term sustainability. (Gobin et al., 1996; Ajayi and Ugwu, 2008; Ishaku, 2011; Lade and Oloke, 2015; Mohammed et al., 2018).

4.3. Solar-Powered Irrigation

Solar-powered irrigation pumps have the potential to revolutionize farming in Nigeria. They provide farmers with a sustainable and cost-effective way to access water for irrigation. By harnessing solar energy, farmers can reduce their reliance on fossil fuels and costly diesel generators. Government initiatives and financial support can promote the widespread adoption of solar-powered irrigation systems. Solar-powered irrigation in Nigeria represents a promising solution to address the challenges faced by the agricultural sector in the country. Nigeria, with its vast agricultural potential, can significantly benefit from this technology (Oyedokun et al, 2017). It is commonly agreed that solar-powered irrigation holds great promise for transforming Nigeria's agriculture sector, increasing food production, and improving rural livelihoods. However, addressing challenges and fostering an enabling environment through policies and support mechanisms are crucial for its widespread adoption and success (Kani, 2022; Durga et al., 2023).

4.4. Sprinkler Irrigation

Sprinkler irrigation is another effective method for water distribution. It is suitable for a wide range of crops, including grains and cash crops. Sprinkler systems are adaptable and can be used in both small-scale and large-scale farming. However, they require access to a reliable water source and proper maintenance to prevent clogging and ensure uniform water distribution (Biswas, 2015). Sprinkler irrigation is a modern and efficient irrigation system that has the potential to significantly improve agricultural operations in Nigeria. Sprinkler irrigation helps conserve water by delivering it directly to the crops' root zones, reducing evaporation and water wastage. In a country like Nigeria, where water resources are often scarce, efficient water use is crucial.

Compared to traditional manual irrigation methods, sprinkler systems require less labor and can cover larger areas, making farming more efficient and reducing the burden on farmers. While sprinkler systems require energy for pumping water, they are often more energy-efficient than flooding or furrow irrigation methods,

especially when coupled with renewable energy sources. Sprinkler irrigation in Nigeria faces challenges such as initial setup costs, power supply issues for pumping, and maintenance requirements. Additionally, water quality and availability can be limiting factors. While sprinkler irrigation offers several advantages for agricultural practices in Nigeria, its widespread adoption requires investment in infrastructure, technology, and education to empower farmers with the knowledge and resources needed to harness the benefits of this irrigation method effectively (Anyanwu et al., 2010; Shiva et al., 2018; Ngasoh et al., 2018; Akinfolarin, 2020; Agro, 2023). The layout of sprinkler irrigation system is shown in Figure 1.

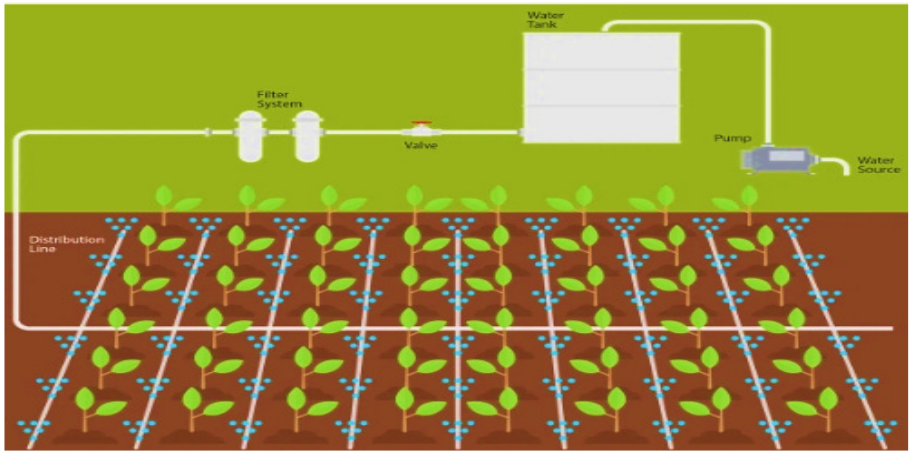

Figure 1: Layout of sprinkler irrigation system (Source: www.khatabook.com)

4.5. Drip Irrigation

Drip irrigation systems offer a more efficient way to deliver water directly to plant roots, minimizing water wastage. These systems are particularly suitable for high-value crops, such as vegetables and fruits. Drip irrigation can significantly increase crop yields while conserving water resources (Novo, 2020). Promoting the adoption of drip irrigation among Nigerian farmers, especially in peri-urban areas, can lead to improved agricultural operations. Drip irrigation is an efficient and modern agricultural technique that has shown significant promise in Nigeria, addressing various challenges faced by farmers in the country (Willis, 2020).

Nigeria experiences irregular rainfall patterns, making water scarcity a significant issue for agriculture. Drip irrigation delivers water directly to plant roots, minimizing wastage and ensuring optimal water utilization. This efficiency is particularly beneficial in arid and semi-arid regions. Drip irrigation also enhances crop yields by maintaining consistent moisture levels in the soil. It ensures that crops receive water and nutrients precisely when needed, promoting healthier growth and higher production.

Drip irrigation holds great potential for Nigeria's agriculture sector. However, to fully harness its benefits, there is a need for investment, education, and support to make this technology accessible to smallholder farmers and promote sustainable and efficient farming practices in the country (Akinfolarin, 2020, Tawheed et al., 2019, Taghvaeian, 2017, Willis, 2020, Novo, 2020). A typical layout of the drip irrigation system is shown in Figure 2.

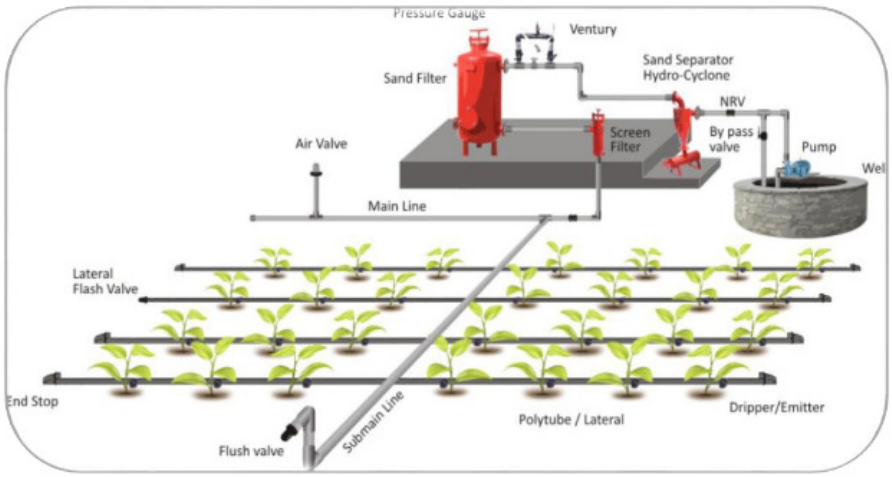

Figure 2: A typical layout of drip irrigation (Bal et al, 2015)

5. APPLICATION OF WIRELESS SENSOR NETWORKS (WSN) FOR FARM IRRIGATION

Most of the researchers found that the use of technology is most important part of agriculture because it reduces human efforts. As a result, some of the researches are developing technology which is more helpful for increasing the agricultural yield. Figure 3 depicts a typical wireless sensor network deployed on field for agricultural applications. The field consists of sensor nodes powered with application specific on-board sensors. The nodes in the on-field sensor network communicate among themselves using radio-frequency (RF) links of industrial, scientific and medical (ISM) radio bands (such as 902-928 MHz and 2.4-2.5 GHz).

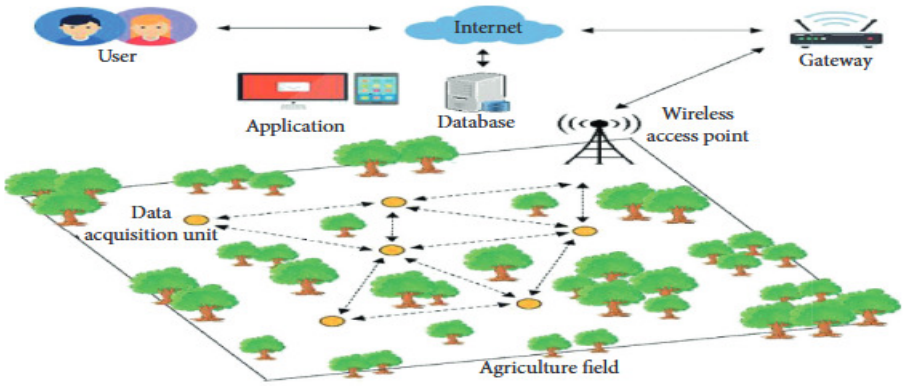

Figure 3: A typical wireless sensor network deployed for agricultural application (Li et al, 2020)

Dias et al., (2013) developed a new single probe heat pulse sensor (SPHP), which comprised of only one element, an n-p-n junction bipolar transistor, worked as both heating and temperature sensing elements. Xiao et al., (2013) developed a wireless, integrated, frequency- domain soil moisture sensor for paddy field (WFDSS) applications in china. This soil sensor was able to measure soil moisture content and water depth at the same time and transmitted the collected data wirelessly to a remote data management center. Shabadi et al., (2014) developed an Android application which helps the farmer to ON/OFF the motor without his physical presence in the field. Bartlett et al., (2015) have created an online evapotranspiration- based irrigation scheduling tool called Water Irrigation Scheduling for Efficient Application (WISE) that uses the soil water balance method and data queries from Colorado Agricultural Meteorological Network (CoAgMet) and Northern Colorado Water Conservation District (NCWCD) weather stations. To expedite and mobilize required user interaction with the software interface, a smartphone app has been developed that allows users

to quickly view their soil moisture deficit, weather measurements, and the ability to input applied irrigation amounts into WISE. Montoya et al., (2013) and Kuchekar et al., (2015) have proposed advanced water deployment system. In this system combined action of wireless sensor network and embedded system was used in the irrigation. The temperature, humidity and soil moisture were measured by wireless sensor network and GSM service was used to inform the user about the exact field condition. Chavan and Karande (2014) developed an application for observing various factors such as soil moisture, humidity and give remote monitoring using Zigbee which sent data wirelessly to a middle server which assemble data, accumulate it and permit it to be display as required and also be sent to the client mobile.

According to Hade and Sengupta (2014), the system for the automatic irrigation by remotely which was founded on embedded system to gather farmers' energy, money and time also used only when there will be need of water. In this approach, the soil test for water content, salinity and chemical constituents and fertilizer requirement of data, collected by wireless and processed for better drip irrigation plan. This was reconsidering various monitoring systems and proposed an automatic monitoring system model using Wireless Sensor Network (WSN) which helped the farmer to progress the yield. Prasad and Madkar (2013) designed a system that monitored multi parameter of agricultural using low power Zigbee wireless communication technology for system automation and monitoring. Real time data was collected by wireless sensor nodes and transmitted to base station using Zigbee. Data was received, saved and displayed at base station to achieve soil temperature, soil moisture and humidity monitoring. The data was continuously monitored at base station and if it exceeds the desired limit, a message was sent to farmer mobile through GSM network for controlling actions.

Mohamed et al (2011) provided real-time information about the lands and crops that will help farmers make right decisions. Using the basic principles of Internet and WSN technology, precision agriculture systems based on the internet of things (IOT) technology was explained in detail especially on the hardware architecture, network architecture and software process control of the precision irrigation system. The software monitors data from the sensors in a feedback loop which activates the control devices based on threshold value. Implementation of WSN in PA optimized the usage of water fertilizer and also maximized the yield of the crops. Aline (2014) presented the initial setup of the Lofar Agro project that concentrates on monitoring micro-climates in a crop field. In addition to the agronomic experiment, Lofar Agro aims at gathering statistics on the wireless sensor network itself. These statistics formed the basis for simulations of algorithms in wireless sensor networks and will be distributed. Rubala and Anitha (2017) designed and developed an agricultural monitoring system using wireless sensor network to increase the productivity and quality of farming without observing it for all the time manually. Temperature, humidity and water levels are the most important factors for the productivity, growth, and quality of plants in agriculture. The temperature, humidity and water level sensors were deployed to gather the temperature and humidity values. The sensor has to transmit the gathered information through the wireless communication network to the data server (cloud). IoT has important significance in promoting agricultural information. Depending upon the threshold value motor is controlled automatically. The monitored crop details are uploaded to the cloud via the IoT gateway. Hence the farmers can easily to access and control the agricultural production, whereas saving the input materials, improving efficiency, productivity and profitability in farming production system.

6. FUTURE IRRIGATION DEVELOPMENT PROSPECTS

The agricultural sector has been projected as an alternative to the future economic sustainability of the country (Omorogbe et *al.,* 2014). However, its developmental plan cannot be achieved without addressing the challenges being faced by the irrigation systems. Water resources development for irrigation plays a key role in agricultural and economic growth (Mugagga and Nabaasa, 2016). Since agriculture and irrigation are intertwined, especially in a country like Nigeria where there is a wide spatial-temporal variation of rainfall across the country (Bibi *et al.*, 2014; Akande *et al.,* 2017), every plan towards agricultural development must also be extended to irrigation system development. It is on this premise we reviewed the future prospects of irrigation development in Nigeria under the population growth, resources availability, and government policy. With the unabated population growth, the dire need to meet the growing

food demand and the nutritional requirement of the population require bringing more land under cultivation. Consequently, the opportunities for future irrigation water development as the rainfed agriculture cannot sustain the production of growing food demand (Cosmas et *al.,* 2010; Olayide et *al.,* 2016). According to Takeshima and Adesugba (2015), the average population growth in Nigeria between 1961 and 2013 was 2.6% with continuous growth in agricultural productivity. Nevertheless, the available resources for agricultural and irrigation development are still underutilized including land, water resources, and other agricultural inputs (Mallam *et al.,* 2014). The essential needs, however, are the sustainable irrigation development to meet the future demand for food production (NINCID, 2015). Currently, the total arable land in the country is estimated at about 34.6 million ha, however, only 40% is under cultivation out of which less than 5% is irrigated (Omorogbe *et al.,* 2014; Lowder *et al.,* 2016).

Notwithstanding the abundant land and water resources, the availability of land for crop production is under threat due to recently increased conflict of the resource among the farmers and the herders in some selected agro-ecological zones of the country (Dimelu et al., 2017). The productivity of the available land can be enhanced through irrigation systems and other agricultural inputs including fertilizers (Takeshima and Adesugba, 2015). Furthermore, Cosmas *et al.* (2010) and Xie *et al.* (2017) are of the opinion that more land can be cultivated by engaging in small-scale irrigation scheme. The potential of future expansion of small-scale irrigation system under baseline conditions was estimated at 1 and 0.65 million ha for dry and rainy seasons, respectively (Xie *et al.,* 2017). The development of small-scale irrigation system will not only improve the performance of the agriculture sector in terms of food production but also allow the participation of private sectors in the development of future irrigation systems. On this account, the recent government policy towards increased importation tariff and an outright ban on importation of some staple food like rice has started bringing development to the country's irrigation system as more stakeholders including private sectors and youths are now interested in irrigated agriculture (Ogundele, 2007; Arigor et al., 2015). One of the examples is Kampe- Omi dam project under the Lower Niger River Basin which has been underutilized after the construction. This is now targeted by the Kogi State Government in collaboration with private sectors for massive production of rice. More lands are now under cultivation for food and fiber production; however, optimum productions cannot be achieved through rainfed practice alone without additional water through irrigation systems. The irrigation development in Nigeria will continue to receive attention now, and in the future, as there will need to increase food production to feed the unabated growing population in the country.

7. CONCLUSION

In conclusion, irrigation practices play a pivotal role in shaping the landscape of agriculture in Nigeria. Traditional surface irrigation methods have been a longstanding foundation, offering accessibility and affordability to small-scale farmers. However, these methods require improvements in efficiency and water management to address challenges like water wastage and maintenance burdens. Rainwater harvesting emerges as a crucial practice, offering decentralized and sustainable water sources, particularly in regions with irregular rainfall patterns. Government support and community involvement are essential for its success. Solar-powered irrigation represents a game-changer, tapping into abundant solar energy to provide reliable water access for farming. With proper policies and support, it has the potential to revolutionize Nigeria's agriculture sector. Modern irrigation practices, such as drip and sprinkler systems, bring significant benefits by enhancing water efficiency, increasing crop yields, and reducing labor requirements. Their adoption in Nigeria can lead to improved agricultural operations, especially in the face of climate change challenges. In summary, a blend of traditional wisdom and modern innovation, coupled with government support and community engagement, holds the key to addressing Nigeria's agricultural challenges and ensuring food security for its growing population. Wireless monitoring in the agricultural field not only allows user to reduce the human power, but it also allows user to see accurate changes in the agricultural productivity. Use of precision agriculture is increasing day by day because of the development in WSN technology and IOT and its adaption in smart farming. These sensors technology found to be suitable for collecting real time data for different parameters pertaining to weather, crop and soil helps in developing solutions for majority of the

agricultural processes related to irrigation and other agricultural processes. The development of wireless sensor applications in agriculture makes it possible to increase efficiency, productivity and profitability of farming operations.

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9. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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