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Review Article

Appraising the current state of irrigation schemes in northern Nigeria using sustainability pillars

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ABSTRACT

Irrigation has been identified as a key to achieving food demand in the face of rapid increase in population and climate change impact. In northern Nigeria for example, irrigation practice has been adopted as an alternative to achieving in food production to meet the demand of the population. Nevertheless, the existing irrigation schemes encountered several challenges coming from the 5 basic sustainability pillars including social, environmental, economic, institutional and technological. This paper attempts to appraise the current state of irrigation schemes through revealing the underlined challenges confronting these schemes that cut across sustainability pillars. The findings discovered that irrigation schemes contributed immensely toward achieving food security and socio-economic development. However, the huge investment in irrigation sector have resulted in massive economic fatalities. This could be attributed to poor management, under-utilization, and abandonment even though few are performing remarkably well. Thus, there is a need to adopt new water sharing methods that can improve water-use efficiency, users-managers joint approach, building competent institutions with an improved monitoring, evaluation and surveillance systems. Others include frequent policy review, development of water conservation-base law enforcement agency as well as well-timed sensitization and awareness campaigns.

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INTRODUCTION

The irrigation sector has undoubtedly contributed immensly toward economic development, poverty alleviation and food security in many countries including Nigeria [1]. The problem of food insecurity represents the biggest crisis of the 21st century worldwide. This is exacerbated due to additional changes posed by the ongoing challenges posed by the Corona Virus (COVID-19). The main point that require attention is that the harmfull effect of food insecurity is spreading from the developing to the developed countries of the world. According to the FAO report of 2018, about 821 million people do not have enough food, 2 billion people suffer from malnutrition and the numbers are rising at a high rate in both Africa and Asia [2]. Nigeria is not exceptional as its population is increasing at an alarming rate and this has glaringly highlighted the need for more food pro-

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duction to meet up and sustain the population demand. For example, the level of food insecurity in the rural areas of Nigeria is reportedly disturbing as it affected about 84% and 56% of the communities in northern and southern parts of the country respectively [3].

Nigeria relies mostly on the importation of agricultural products as about 31 and 23% of the total food demands were imported in 2011 and 2012 respectively [4]. For example, about 8 million metric tons of rice and 5.6 million tons of wheat were imported in 2019 to feed its growing population despite its production potential in agriculture [5]. Nigeria imported more than 10 million metric tons of rice between 2010 and 2014 [6]. It has been suggested that the only way out of food insecurity and poverty is to remarkably attain a sustainable crop production in the country [7]. To improve agricultural productivity in the country, irrigation farming along with the use of improved seeds, fertilizers, mechanized and smart farming as well as other relevant and modern farming technologies is the best alternative option. This will help in reducing the level of hunger, poverty and malnutrition [8]. Therefore, irrigation can be regarded as a powerful factor in increasing crop productivity, more stable incomes and providing employment and increasing prospects for multiple cropping and crop diversification [9]. In the specific context of agriculture, sustainable irrigation strategies need to allow for increased and sustainable crop production to meet the ever-increasing food demands, while preserving natural resources [10, 11]. Moreover, irrigation farming allows farmers to produce all year round thereby resulting in higher agricultural outputs and improved farmer's income. According to [12], the objective of irrigation practice is to achieve the economical use of available water and ensure equity for distribution over time and space. In addition, the success of any irrigation project depends on the proper functionality of water conveyance and distribution systems. Unfortunately, many irrigation schemes in northern Nigeria are performing far below their potentials due to poor management by both relevant governmental agencies and farmers [13]. Northern Nigeria was choosen as the case study because a larger proportion of irrigation is practiced in the northern part of the country. In addition, the northern part of Nigeria is characterized by low and erratic rainfall as well as a short rainy season. Mortherover, southern Nigeria depends largely on the northern for food production due to arable land in the northen part of Nigeria.

It was observed that improvement of the performance of the existing irrigation schemes is one of the possible approaches to water conservation, particularly in dryland areas like northern Nigeria [14]. The term sustainability in irrigation is often characterized through indicators that express the performance of an irrigation scheme not only in terms of its ability to deliver the required irrigation water but also on economic viability, social well-being, environmental health,

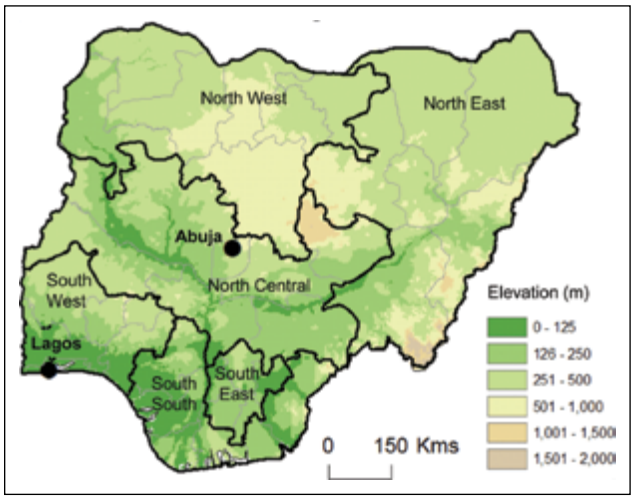

Figure 1. Map of Nigeria showing 3 northern and southern regions.

institution arrangement and technological advances. Thus, sustainable irrigated agriculture is said to be attained if irrigation practices do not lead to the depletion of either natural or human resources [11]. To meet the Nigerian population demands of food and fibre, there is a need to employ the concept of sustainability to further improve irrigated agriculture, thereby achieving sustainable food production, processing and value addition [15]. This can be achieved if all the causes and effects of many problems that have been lingering are diagnosed, propose solutions and the suggested solutions are implemented and put into practice. This review was therefore aimed to disclose the current status of the available irrigation schemes in northern Nigeria for their sustainability and functionality. The study will provide inside into what has been going on with regard to maintenance, utilization and level of crop productions in the irrigation schemes from sustainability point of view.

THE CURRENT STATE OF IRRIGATION SCHEMES IN NORTHERN NIGERIA

This section presents the review on the state of irrigation schemes in northern Nigeria and sustainability pillars were used to guide this review. The aim was to get more insight into the global irrigation scheme operations and maintenance practices with the main focus on northern Nigeria. This review yielded a schematic overview of irrigation scheme management using sustainability pillars. This is to evaluate the present state of functionality and the level of impact on the lives of people. Figure 1 shows the map of Nigeria showing the northern part, which constituted three regions (North West, North East and North Central), and southern part, which constituted three regions (South West, South East and South South). The irrigation scheme management sustainability-based review was conducted

and restricted to the northern part of the country. The history of irrigation practices in the northern Nigeria begun since when it was realized that the region is characterized with low rainfall and high rate of evaporation which make it either arid or semi-arid regions in addition to abandon arable lands. These made the previous governments of the regions to construct several water storage infrastructures (dams and canals) for irrigation practices. These resulted to several major irrigation schemes available in northern Nigeria most of which are intended to stimulate and facilitate the sustainable food production in the country.

Economic Aspect of Sustainable Irrigation Schemes

The economic productivity of several human endeavours depends largely on access to water resources [16]. Although about 24% of the global land area suffering from severe water scarcity [17] and 35% of the global population living in areas affected by water shortages [18], the economic development often occurs at the cost of overexploitation of water resources [19]. Agriculture is a major performer in the human appropriation of the limited water resources as about 70% of the global freshwater is consumed by this sector. After abandonment for about four decades due to abundant petroleum resources, the agricultural sector in Nigeria is gradually occupying a dominant position in the development of the national and rural economy. The sector provides not only food but also serves as the major source of employment to the teeming population of Nigeria. The agricultural sector provides jobs to about three-quarters of the Nigerian working population [20]. Farmers are usually less busy on the farm during the dry season, putting into account the rainy (May to October) and the dry (November to April) seasons of Nigeria. Hence, the provision of irrigation facilities that offer the opportunity for all-year-round farming can serve as an alternative source of employment and an additional gain to the Nigerian economy [21].

Recently, drastic agricultural reforms (closure of land borders and banning of importation of major agricultural food products among others) have been made in Nigeria resulting in a sharp increase in crop production which significantly reduce food importation and jobs were created [22, 23]. Agriculture is one of the main economic sectors in Nigeria employing about 60% of the population of the country [23]. This scenario is in line with other developing countries that agriculture provides the leading source of employment. Thus, increasing agricultural productivity is critical to economic growth, development, and the nation's Gross Domestic Products (GDP). One important way to increase agricultural productivity is through the introduction of improved agricultural technologies and management systems.

In Nigeria, post-project evaluations of the majority of the irrigation schemes revealed that their economic performances are low compared to pre-project predictions [15]. Such undesirable outcomes are a result of the fact that social and environmental concerns of these schemes were not incorporated in the analysis. The participation issue presents the usefulness of water users' involvement in the maintenance and sustainability of the irrigation schemes which further improve economic benefit [24]. One of the possible causes of the decline in food production is an inefficient allocation of resources in the agricultural production potentials [25]. For example, land, labour, capital and water resources are inefficiently allocated thereby leading to a decrease in their productivity. To further improve the economic status of the rural dwellers as well as to attain food security and national growth, irrigation schemes need to be revitalized to increase food and cash crops production [26].

The economic welfare of a country and its ecosystem health is directly linked to water stress and the rate of water depletion [24]. Evidently, the Kano River Irrigation Project (KRIP) has played an important role in discouraging migration from rural to urban centers and alleviating the employment problems of its immediate community [20]. Similarly, there has been a sharp difference from the dry season farmers' income in Bauchi State when compared with rain-fed farmers for the same kind of farm produce. The dry season (irrigation) farmers get more profit than rain-fed farmers counterparts. This is not unconnected with the high demand for fresh irrigated crops during the dry season [27]. Moreover, a study on the Socio-economic impact of an irrigation project in Taraba State reported similar findings among the farmers in respect of economic gain. Project on the beneficiary of the Fadama II project in Kaduna State indicates an increase in the net farm income of the beneficiary farmers [28]. Hence, creating a more efficient irrigation water management approach has the potential to substantially increase agricultural production, farmers' incomes, and create employment opportunities.

Social Aspect of Sustainable Irrigation Schemes

Inherently, human beings are aiming to achive their need and these needs describe in-born requirements for an individual to be satisfied [29]. The management of open-access resources such as irrigation water involved numerous stakeholders with diverse interests which posed a unique challenge to the managers. These interests are the factors that affect individuals' ethical practices including propensity to compliant or unlawful activities. Ethical awareness is the ability of an individual to identify his deliberate action and understand what consequences that action might cause to others. Thus, for an individual to make an ethically accepted action depends on a person's moral awareness, motives and the benefits that individual is expected to gain. This depends largely on value-related factors such as culture, knowledge, and social well-being [30]. One of the problems that devastate irrigation water users' well-being is water scarcity which leads to poor crop production. Water scarcity represents a multidimensional state of human so-

cial deprivation characterized by a lack of access to affordable and safe water to satisfy societal needs or a condition in which these needs are met at the expense of the environment [10]. The mission for sustainable natural resource utilization is an essential part of the ongoing 2030 agenda for sustainable development goals (SDGs). It is one of the 169 agreed targets being aimed at monitoring and assessing the level of sustainability with which resources, such as irrigation water are being managed and utilized [31].

This creates a challenge of ensuring societal well-being through the supply of human basic needs including food security, income to the rural dwellers and national GDP of which water (through irrigation) plays an essential role [32, 33]. Thus, irrigation contributed immensely to the provision of a wide range of socio-economic benefits on which the well-being of society is based [34]. However, irrigation water is subjected to several challenges including climate change, poor management, chemical, wastage, overexploitation and other human-related influences [35–38].

The social setting can be a social group, a community, town, region or a nation, thus, any change that occur either as ideas, norms, values, roles and social habits can be referred to as social change. When alteration occurs in the rural social system, it is termed as rural social change, and such a change could be in all attributes of a societal unit such as number, quality and importance. Different changes come to the notice of the rural population of the developing countries, including Nigeria. For example, the introduction of large scale irrigation projects, use of the machine in farming practices, application of agrochemicals to control weeds, pests, diseases and increase and sustain the fertility of the soil lead to the transformation of sustainable agriculture and hence, the well-being of that society [20]. The attainment of a sustainable agricultural production system is becoming a major concern of agricultural researchers and policymakers all over the world [39]. Implementation of sustainable development, therefore, requires integrated policy, planning and social learning process. Irrigation practices provide employment and stabilization to the rural population and undoubtedly provide major social benefits. A typical example is how the Kano River Irrigation Project (KRIP) played an important role in limiting rural-urban migration by creating jobs for the rural dwellers [20].

Environmental Aspect of Sustainable Irrigation Schemes

Environmental impact refers to any change in the environment or in its components that may affect human health, flora, fauna, natural and cultural heritage as well as other physical structures, social, economic or cultural conditions [40]. For example, the challenges facing the irrigation sector in Nigeria is not only to attain food security and eradicate poverty among rural dwellers but also to ensure a healthy environment. Inappropriate management of irrigation schemes might lead to environmental problems such as high-water tables, poor drainage, salinization and pollution [13]. The majority of irrigation schemes in northern Nigeria are characterized by environmental degradation such as salinity, waterlogging and declining groundwater resources which could adversely affect future demand for water [41]. Both quantity and quality aspects of water are important as these jointly affect the success of irrigation schemes and environmental sustainability [42]. Thus, in the process to establish any socio-economic projects such as irrigation schemes, there is a need to ensure long-term maintenance of valued environmental resources in an evolving human influence [43]. Studies revealed that the majority of the economic development of the developing countries often occur at the expense of overexploitation of water resources which ultimately leads to ecosystem degradation [19].

Even though the extent is different, several environmental-related problems including soil erosion, aquatic weeds infestation, sedimentation, infrastructural deterioration and overgrazing are observed in many irrigation schemes in Nigeria [43]. For example, despite the functioning of the Kano River Irrigation Project (KRIP), there was a serious decline in hectares of land due to environmental-related issues such as waterlogging, salt accumulation (salinity, sodicity, saline-sodic) and reduced fertility [20]. There is a gradually building up of salinity problems in KRIP, even though the threat from salinity is not alarming yet. This problem of salinity has been reportedly alleged to continue to increase as long as irrigation is practiced unless preventive and corrective measures are put in place [44]. Generally, irrigation schemes design, operation and management should seek to maximize not only crop productivity and economic and social gains but also to ensure environmental stability and health as shown on Figure 2 [45]. Thus, irrigation scheme designs should consider using new technologies that ensure water allocation and application efficiencies such as micro irrigation methods (sprinklers and drip). In addition, in situ soil and water conservation methods such as mulch practices and deficit irrigation can significantly improve the overall ecosystem health.

The quality of surface and ground water in Nigeria was generally poor due to oil and gas exploration, agricultural production, landfill leachate, and poor sewage disposal. In addition to discharging untreated and/or poorly treated wastewater by the manufacturing industries which is reportedly linked to the corrupt socio-political circumstances of the country [46]. Another major issue of concern that has to do with the groundwater quality is the hydro-geological interactions of the groundwater with the base-rock. Such hydro-geological interactions commonly led to the Lead and Barium in groundwater in many locations across the country. Rainwater in Nigeria was observed to be fairly clean however, low pH is the only major issue affecting rainwater. Bottled and sachet water are currently the best and safer source of drinking water for the country's popu-

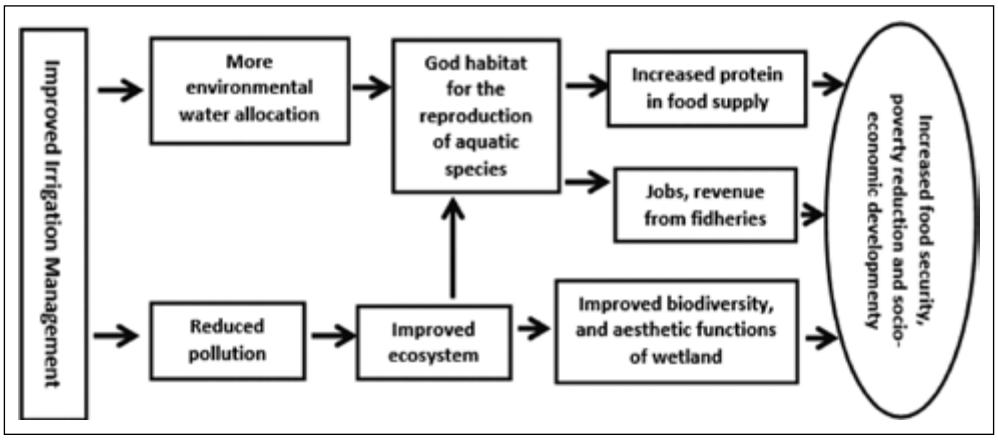

Figure 2. Framework for sustainable irrigation scheme design, operation and management [45].

lace. Generally, there are few wastewater treatment plants in the country, thus, there is a need to strengthen the water quality monitoring, and evaluation agencies.

Technological Aspect of Sustainable Irrigation Schemes

The development and improvement achieved so far in irrigation technologies are key to addressing the challenges of low agricultural productivity [47]. Availability and access to irrigation water and smart agricultural technologies were considered essential for crop production [48]. For instance, the success of the green revolution in Asia was achieved through the rapid expansion of irrigation areas with availability and access to new technologies including the development of high yielding varieties, fertilizers, micro irrigation techniques, tube-wells and water extraction mechanisms [49]. For example, technological advance provides irrigation sector with methods of optimizing water usage using variety of solutions based on sensor networks, microcontrollers and machine learning or fuzzy logic [50]. These methods have been in use to evaluate and predict optimum water required for irrigation. Such a smart irrigation is a systems made up of solar power station, networking infrastructure and water management and control stations (water storage, sprinkle or drip lines, water pumps, soil moisture sensors and micro-controller unit). In smart irrigation systems, the system components are commonly coupled using the Internet of Everything (IoE) approach as schematically summarized and shown in Figure 3. The use of such irrigation technology exerted a positive and significant impact on sustainable crop production and food security in Nigeria specifically [48].

Agricultural activities in Jibia Irrigation Project (JIP), Katsina State, depends mainly on power supply from diesel generators and electricity from the national grid to supply water to the farmlands. This has slowed down the pace of irrigation development in the area. The full exploitation of the agricultural potential of JIP and that of Nigeria in general, requires the exploitation of our vast renewable energy sources to provide the needed power [51]. Also, an alternative way to the high power demand of the operation of JIP and the likes is water conservation practices using different types of mulch. KRIP being one of the major irrigated agriculture in the northern Nigeria reported that, the majority of the farmers lack the technical know-how on water conservation and it is based on this that the researchers recommended the need to create awareness to the farmers where major irrigation is taking place. This will assist in achieving water conservation and management strategies in order to effectively and efficiently utilize the limited available water resources.

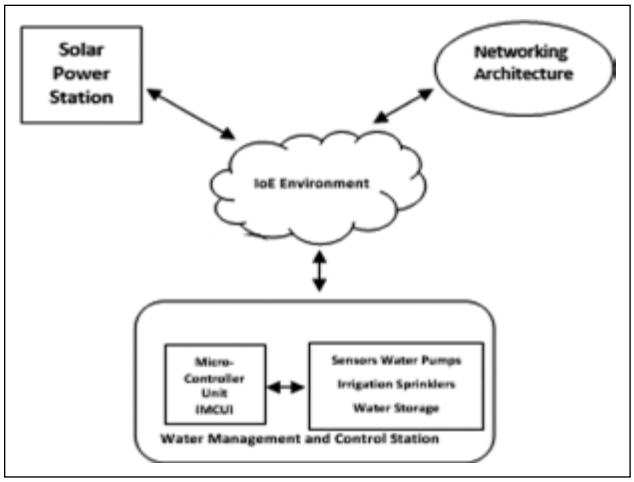

Figure 3. Technological advances for coupling smart irrigation components using IoE [50].

Irrigation schemes in Nigeria such as Watari Irrigation Project (WIP), Barwa-Minjibir Irrigation Scheme (BMIS), Tomas Irrigation Project (TIP) and Kpong Irrigation Project (KIP) in Niger Delta Basin Development Authority (NDBDA), had to abandon farming activities due to poor water-sharing techniques [51]. Thus, farmers should be fully conversant with irrigation technologies through agricultural machinery and credit facilities. Moreover, farm inputs such as fertilizer, seed, chemical and other materials

needed by farmers should be made available to the farmers. Infrastructural decay is also another problem that has been affecting the success of irrigated agriculture in northern Nigeria. About 30% of water structures at WIP were found to be damaged and malfunctioning [52]. Similarly, the conveyance structures were silted and infested by weeds which significantly reduced the carrying capacity of the canal. Also, about 8% of the irrigable area downstream was abandoned due to inadequate supply of water. There is an increased occurrence in soil salinity and sodicity issues within the WIP due to a poor drainage system [53].

In this regard, the majority of the irrigation schemes in northern Nigeria such as Sokoto Rima, Watari, Jibiya and Tomas are operated far below their design capacity due to lack of adoption of improved equipment and poor maintenance [54]. In addition, a larger proportion of the currently used irrigation equipment was purchased during the inception of the projects (the 1970s to 1980s) without replacement. Thus, there is a need to conduct empirical studies in Nigerian irrigation schemes to assess the following;

a. How farmers demand irrigation technologies.
b. How their zeal and willingness to adopt improved irrigation technologies are affected by specific agro-ecological and socio-economic characteristics.
c. How their adoption of such improved irrigation technologies may be hampered by poorly functioning markets.

Institutional Aspect of Sustainable Irrigation Schemes

Institutions are the political, social or business organisations (public or private) that are involved in policy-making and implementation. While institutional sustainability is the continuation of the benefit flows to the users/clients/owners/employees or the general public with or without the programmes or organisations that stimulated them in the first place [54]. Institutional performance is considered as one of the yardsticks with which the performance of developmental institutions such as irrigation schemes can be evaluated. At the end of the 20th century, the increasing role and relevance of social and institutional structures in connection with the whole field of contemporary environmental management are gaining prominence. Currently, institutional mandates constituted social well-being, economic gain as well as environmental health. Such a sustainability-based management strategy has gained more attention all over the world as this form an important developmental strategy as enclosed in the ongoing sustainable development goals (SDGs). The main aim of such a strategy was to effectively and sustainably manage and utilize the limited available natural resources [55]. For example, in the irrigation management sector, this approach has in recent years been employed to shift irrigation management toward a community-based by sharing power with multiple sets of other institutions stakeholders [56]. This requires every stakeholder involved in all levels of irrigation management to collectively take responsibility for managing the affairs of the schemes.

The small-scale private irrigation schemes (SPRI) sector in Nigeria is supported by a range of private agents, including irrigation technology service providers, NGOs, water user associations (WUAs) as well as public institutions such as the National Fadama Development Project (NFDP), the Agricultural Development Project (ADP), the State Irrigation Department (SID), river basin development authorities and state and federal government ministries [56]. A study carried in 1972 led to the institution of three models of public irrigation schemes; namely the Bakolori Scheme, the Chad Basin scheme, and Kano River Irrigation Project, subsequently additional eleven more River Basin Development Authorities (RBDAs) were added across the country after the success of the pilot schemes in 1976 [57].

The Nigerian government does not only own, operate and maintain irrigation schemes, but provides agro-support services such as land preparation, seeds, fertilizers, chemicals, and assists in marketing the produce. The reforms in water institutions such as Participatory Irrigation Management (PIM) systems were formulated and implemented to achieve effective operation of the schemes, equitable distribution of irrigation water among farmers, high crop productivity and food security among others [58].

In the Hadeja-Jama'are river irrigation project, the utilization of the project is just 50% while the Zobe dam in Dutsin-Ma, Katsina which was constructed 40 years ago, currently has few irrigation activities as the scheme is not formally developed. 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 [59]. For instance, at the end of the 1999/2000 irrigation season, out of the 100,300 ha developed only 35,000 ha were irrigated giving a pathetic 35% capacity utilization. Most of the irrigation schemes that the government has invested in are either under-utilized for irrigation or abandoned irrigation schemes like the Hadeja-Jama'are river project, the utilization is 50% while the Zobe dam in Dutsin-Ma in Katsina, which was constructed 40 years ago, currently has little irrigation activities [52]. Cases in points that highlighted the danger of poor irrigation management institutional performance are the findings by [53]. More than 29% of the farmers of Tomas Irrigation Project (TIP) expressed unhappiness with the water allocation method currently used and about 55% of water users hold the opinion that irrigation scheme management, operation and maintenance is an exclusive responsibility of the government. In addition to poor water management, infrastructural decay and stakeholders' conflict as the major problems affecting the scheme.

CONCLUSION

This chapter presented a review of the operation and management of irrigation schemes in the northern part of Nigeria. The main aim of this study was to identify and relate key values operating in the northern Nigerian irrigation sector from a sustainability point. This includes identifying the causes and effects of impending problems and hence, suggesting ways forward to achieve sustainable food security at the face of the ever-increasing population in the country. The major motivation factor for this review was the fact that studies on assessing the performance of systems such as irrigation schemes using the concept of sustainability are gradually gaining popularity and growing at a high rate in recent years. The appraisal revealed that several impediments have been hindering the performance of irrigation practice in Nigeria which includes inconsistent government policies, low awareness and lack of technical know-how among the farmers on irrigation farming system, and untimely financial intervention.

Another insight of interest gained from the work was that the huge investment in both large- and medium-scale irrigation schemes in the northern part of Nigeria have been resulted in irrecoverable losses due to quite several issues. Some of these problems comprise of under-utilization of water resources, poor management, infrastructural decay and abandonment. Generally, studies revealed that irrigation schemes in northern Nigeria performed far below expectations with approximately 65% capacity utilization. About half (50%) of the farmers express unhappiness, dismay and loss confidence with the way irrigation schemes are operated. Water managers blame farmers to lack enthusiasm toward abiding by the set rule and regulations governing irrigation schemes. In addition, study by [54] revealed that about 45% of the farmers do not participate in the maintenance of the irrigation schemes which further exacerbate the problems. However, some irrigation projects are performing relatively very well. The income and the standard of living of the farmers around well-performing irrigation projects were observed to improve significantly compared to poor performing ones.

Thus, there is a need to holistically improve the general operational performance of the existing irrigation schemes in northern Nigeria through the following.

Some of the suggestions that should be done in Nigeria to improve the current situation including encouraging participatory irrigation management, ensuring effective and competent institutions with a strong monitoring and evaluation mechanisms, frequent policy review and alterations to suit the situation, and timely sensitization and awareness campaigns. Functions of water regulatory institutions should be streamlined with each institution given specific and defined roles to enhance efficiency in irrigation water resource management and this should be organised using the sustainability pillars. A research effort using a sustainability-based approach is also required to further identify the causes and effects of problems that have been hampering the performance of irrigation schemes in northern Nigeria. There is also a need to adopt new water allocation and application methods that can improve water use efficiency.

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DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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