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# Embracing drip irrigation technology to stimulate smart farming: a study in Dokolo District, mid-north Uganda

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***Abstract:*** **This study was intended to investigate the potential of embracing drip irrigation technology as a strategy to stimulating smart farming in Dokolo district. We adopted a descriptive design on one of the farms that has employed the technology benefiting approximately 80 community members. Data were collected using in-depth interviews and observations and it was analysed using a thematic analysis based on the key aspects that emerged in the study. The outcomes suggest that the merger of key beneficiaries, the irrigation system, architecture and the solar power station have the potential of translating farming communities in Dokolo district into smart farmers even if the initial cost as well as cost of maintenance are very high thus the need for government to subsidise farmers during importation of such machinery. These outcomes may be used as contributions for the mid-north farming communities to benchmark and seek means of adopting group-based irrigation schemes for continuity and higher crop yields. This paper contributes to available knowledge by emphasising the centrality of irrigation in the era of longer periods of drought that continue to disappoint farmers country-wide.**

***Keywords:*** **Irrigation, smart farming, architecture, solar power.**

## 1. INTRODUCTION

Water and food are the most basic commodities in the world, which makes agriculture a source of livelihood to mankind. This is because; water is used to empower agriculture through irrigation system to facilitate food production across the globe (Adenugba, 2019). Due to Climate change and a rapid increase in population, there is intends pressure on the world water resource for agriculture which has become fundamental for sustainable development. The sustainability of global agricultural production is contingent upon the irrigation system due to climate change which has affected the distribution of rainfall. Unfortunately, the efficiencies of irrigation technology are surprisingly low across the world (Jeremey et al, 2015). The irrigation sector accounts for 70% of the global water use and the large share may be partly explained through the use of inappropriate irrigation systems (Caldera & Breyer, 2019). The very low efficiency is attributed to the wide spread use of surface irrigation systems where a large percentage of the water is lost via conveyance, soil evaporation and runoff.

These problems can only be reduced by transition from extensive surface irrigation systems to pressurized irrigation systems such as sprinkler and drip technology with higher irrigation efficiency and increased water savings (Fyles & Madramootoo, 2016). The efficiency of surface irrigation systems can lie between 30 and 60% while that of sprinkler and drip irrigation is between 50% to 70% and 70% to 90% respectively. Unfortunately, only 11% of the world's irrigated area is equipped with sprinkler technology and 3% with drip irrigation systems. The irrigation has played a fundamental role in the development and economy of the United States. It was extremely important in the settlement of several western states such as Arizona, California, Idaho, Nevada, and New Mexico and two eastern states of Arkansas and Florida (Maupin et al, 2014). While irrigation has ancient roots, technological advancement such as pumps, plastics, computers, and sensors has transformed modern irrigated agriculture. The Modern irrigation methods arose in the United States in the mid-19th century with the settlement of the Utah Great Salt Lake Basin and this resulted to the passing of the Reclamation Act which ultimately calumniated to the construction of over 100 water projects in 17 western states, making extensive settlement and large scale irrigation projects on western lands a reality.

Israel is one of the most densely populated countries in the world and characterized by desert and semi desert climatic conditions. The major problem of the country extend to frequent droughts, desertification of agricultural land, rapid urbanization, technological uncertainty, degradation of water quality and increased water scarcity (Megersa & Abdulahi, 2015). Among these constrains, water scarcity is the primary limiting factor in Israel agriculture. However, recycled use of water for irrigation is the recent new innovation used to solve problem of water scarcity in Israel. Consequently, the sustainability of the country is dependent upon irrigation system especially pressure drip irrigation system to improve crop productivity and enhance food security to feed the ever increasing population. Similar technology innovated by Israel to alleviate problem of scarce irrigation water resources in the arid and semi-arid of the world is adopted by Iran to increase food production (Naftchali & Ritzema, 2018). Pressurized irrigation systems such as sprinkler and drip irrigation systems are being utilized where water is distributed under low pressure through a piped network in a predetermined pattern, and applied as a small discharge to each plant or adjacent to it. Generally, the ultimate goal is to supply the entire field uniformly with water so that each plant has the right amount of water it needs at the right time.

The Pakistan agricultural sector heavily relies on irrigation system due to the unreliability of the climatic conditions. Although canal water is the major supplier of irrigation water, irrigated agriculture is also dependent on groundwater resources in the country (Watto & Mugera, 2019). Groundwater is fundamental to overall irrigation water supplies and it has increased over the last few decades. For instance, between 1960 and 2010, groundwater contribution to irrigation water supplies has increased from 8% to more than 50% as a result of free expansion of tube wells privately installed by thousands of farmers. The adoption of tube-well technology was encouraged by the government policies, such as rural electrification, subsidization of electricity, diesel and drilling services, free pump sets, and the provision of long term loans on soft conditions.

In Africa, the use of Wastewater in agriculture production is premised on the concept of sustainable development. In the cities of Kumasi in Ghana, the use of wastewater for irrigation is linked to rapid urbanization (Amoah et al, 2016). The practice improves the livelihoods of farmers, contributes to the urban food basket and improves the urban environment by diverting wastewater to agricultural fields. The wastewater is released into drainage and nearby water bodies which is then used by farmers for irrigation. Wastewater irrigation in the cities of Ghana is mainly for the production of vegetables, such as cabbage, lettuce, spring onion and carrots. In Egypt, the Kafr Sheikh and Noubariya communities are involved in irrigation farming in the two regions of the country, the Old and the new lands respectively. The New Lands are desert lands that have been reclaimed and cultivated since the Revolution of 1952 (Najjara, Baruah & El Garhi, 2019). The Noubariya settlement in the New Lands was contingent upon the Mubarak Resettlement Scheme (MRS) of 1990 which was implemented by the Ministry of Agriculture and Land Reclamation (Molle et al, 2015). The irrigation in the New Lands is based primarily on drip and sprinkler systems, and the Old Lands were irrigated by the natural overflow of the Nile River before it was supported by High Aswan Dam. These have therefore, reduced water losses and ensured more equal distribution of water to farmers.

In Kenya, irrigated agriculture occupies 4% of the total land area (2.9 million ha). It accounts for 3 percent of the Kenya's gross domestic product (GDP) and 18 percent of the total value of all agricultural produce. The main irrigated crops in Kenya are rice, wheat, maize, vegetables, coffee, fruits, sugarcane, cotton and horticulture. Rice is the third main cereal crop grown in Kenya after maize and wheat (Muema, Home & Raude, 2018). These crops are mainly grown in government established irrigation schemes managed by National Irrigation Board (NIB). These irrigation schemes includes, Ahero, Bunyala, West Kano irrigation located in Western Kenya and Mwea irrigation scheme in Central Kenya. The other NIB managed irrigation schemes are Hola, Perkerra, Bura and, more, recently the Galana-Kulalu Food Security Project.

Agriculture is a vital sector in the economy of Uganda and source of employment for 70 percent of the population. The sector also contributes 24 percent to the country's Gross Domestic Product (GDP) and 40 percent to export earnings and is essential for ensuring sustainable food security (Mwesigye et al, 2017). Accordingly, the sector remains the most critical for Uganda to attain inclusive wealth creation and employment, and to achieve the vision 2040 of Transforming Ugandan Society from a Peasant to a Modern and Prosperous Country within 30 years. Unfortunately, water shortage especially for crop production is limiting the Uganda's economic development. Less than 3% of arable land is irrigated

(Ministry of Water and Environment, 2011). The variation in climate especially in Uganda continues to influence the precipitation patterns and distribution, which have severe negative impacts to smallholder farmers. The increase in drought contributes to moisture deficit in the soil leading to crop failure, drying of seasonal rivers and reduction of water levels in lakes and rivers which affects agricultural activities in the country.

To counter the water shortage for agriculture, The Ugandan government is currently promoting pressurized drip irrigation farming and rehabilitation of the irrigation schemes as the suitable approach to dry season agriculture, reduce intermittent drought conditions, and minimize water wastage (Bwire, Watanabe & Suzuki, 2017). Consequently, Crops such as Tomato, onion, cabbages, and green pepper are targeted by the government and the smallholder farmers for food and source of income in the innovation. It is necessary to adopt effective water use and water saving agricultural measures such as low pressure drip irrigation system to maximize water usage efficiency and to realize high crop production during uneven rainfall and dry conditions. Irrigation is generally defined as the artificial application of water to plants to sustain or enhance plant growth (Stubbs, 2016). In crop production, it is mostly used in waterless areas and in periods of rainfall shortage to protect plants against heat and drought. There are three primary sources of water for on farm irrigation, for instance, groundwater from wells, water delivered to farms, and on farm surface water which can be used in the agricultural production to increase productivity.

The irrigation development is considered as a strategy for poor smallholder farmers to get out of poverty by shifting towards market oriented agriculture (Mango et al, 2018). Consequently, higher value crops are grown mainly under irrigation system. This is done as a response to climate variability, and Crops uses residual moisture in addition to irrigation to ensure adequate water supply during the growing period. The implementation of irrigation best management practices (BMPs) can further increase irrigation performance by creating greater precision for water use. This can reduce the cost of production and ensure that all areas of the field are more evenly irrigated. Averagely, irrigated yields are roughly double that of non-irrigated crops. As a result, irrigation can also allow farmers to grow higher value crops and extend growing seasons (Jorge et al., 2015). The controlled environment of an irrigation system can also be used for the application of other production related inputs, such as nutrients and pesticides. Depending on the system, some irrigation BMPs allow synthetic nutrients and pesticides to be mixed with irrigation water and distributed concurrently and this can reduce costs and provide more precise application. There are many types of irrigation systems practiced globally and key among these are the Sprinkler irrigation system which is one of the most common methods of irrigation facilitated by the high level of irrigation mechanization. In this irrigation system, the supply of irrigation water on the farm imitates natural rain which is uniformly distributed in the farm (Kruzhilin et al, 2018). The sprinklers irrigation system compensates lack of soil moisture and increases the humidity in the surface layer, as well as decrease in soil temperature. However, it destroys soil structure and soil compaction and result in the formation of puddles and runoff, and hence irrigation erosion.

The Irrigation practices in Europe fundamentally consisted of gravity-fed surface irrigation systems. Subsequently, the water is conveyed from surface sources such as rivers or reservoirs, both natural and artificial and is distributed to individual fields through a network of canals of different sizes, relying on gravity as the driving force (Masseroni et al, 2017). The main cultivated crops are cereals, particularly maize and rice, which require approximately two to three times the amount of water compared with other extensive crops. However, these systems often use very high amounts of water to satisfy the irrigation requirements of the crops and are thought to be expensive. In a localized irrigation system, trenches are dag in the hill side of farm which leads off the seasonal streams that descend the valley sides to the farm land. At the source of the streams, small mud and brush dams raise the water level and allow gravity to channel the water into the farm (Davies, 2008). The trenches are then contoured out of the stream gulley often following incredibly ingenious routes, cascading down faces and winding under and around the crops. This increases soil moisture which supports the crops during dry season and hence high crop productivity.

Drip or trickle irrigation is a type of modern irrigation system that slowly applies less amount of water to parts of plant root zone. Water is supplied regularly to preserve constructive soil moisture situation and avoid moisture stress in the plant with proper use of water resources (Fule & Awachat, 2014). There is a higher degree of water control and Plants can be supplied with more specific amounts of water and as a result, disease and insect damage is reduced because plant undergrowth stays dry. However, drip irrigation pulls salts from the underlying horizons into the upper fertile soil layer and the inability to regulate air humidity in the plant environment (Tokarev et al, 2020). Similarly, it is impossible to use drip irrigation for anti-frost irrigation and it cannot be used to cool the soil at high air temperatures and intense solar insulation.

Agriculture is a critical sector and an engine of growth and employment in Uganda and offers over 70% of the population with job opportunities especially in rural area. But the viability of the sector is being affected by climate change especially in northern Uganda where crops are normally affected by dry weather leading to low productivity and food insecurity. Therefore, this research is aimed at assessing the efficacy of the smart farming technology especially the pressurized drip irrigation system introduced by government at Odeye village in Dokolo district to improve agricultural production. The pressurized drip irrigation system being implemented by the government of Uganda through the Ministry of Water and Environment and the Ministry of Agriculture Animal Industry and Fisheries across the country is a new technological innovation for farming which has drawn the attention of every citizen in the country.

It was important for the researchers to learn the operations of the new innovation to acquire an informed knowledge about the technology and offer policy advice to the government to increase the benefits of the project to beneficiaries. Water for crop production is becoming scarce, both in quantity and quality, not only in traditionally prone arid and semi-arid zones but also in regions where rainfall is abundant. Northern Uganda especially Lango sub region is not exceptional, There is a long dry spell affecting agriculture productivity leading to food insecurity. However, the high yield crops during the dry spell at Odeye cell in Dokolo district are observable along the great North road attracting the attention of every road users. This influenced the researcher to take a kin interest to study and find out the type of innovation being used to achieve this sustainable agricultural system. In Uganda, very few empirical research have been conducted to find out the contribution of pressurized drip irrigation system in improving agricultural productivity to increase food security especially in Northern Uganda. In addition, very few of these studies have focused into Odeye irrigation system as a case study. Therefore, there is knowledge gap that research seeks to narrow.

The key issues covered in this study are; the key beneficiaries, the irrigation system, architecture and the solar power station. In this research, two data collection methods were used by the researcher to gather the information regarding the irrigation farming at Odeye Small Scale irrigation system. In depth interview was used by the researcher to collect the data for this research. The researcher engaged the Agronomist Opio Richard from the ministry of Agriculture in face to face interviews so as to generate the required data suitable for providing answers to the research project. The Agronomist is deployed in the farm by the government of Uganda to train and guide the farmers on how to use the irrigation system and provide information about crop management. This method of data collection was used because it provides the opportunity to explore the in depth information related to the study. Observation method was also adapted to systematically gather a wide variety of information regarding irrigation farming especially drip irrigation system at Odeye small scale irrigation system as a case study. The researcher observed the state of the art of the innovation, the system and its operations, the yields of crops to draw conclusion on the viability of the project and answer the research study.

## 2. OUTCOMES OF THE STUDY

The innovation delivers water at or near the root zone of plants, drop by drop and it is the most water efficient method of irrigation since evaporation and runoff are minimized. The irrigation system is combined with mulching of the farms which has further reduced water evaporation. This has improved the yields of the crops and the productivity which has resulted into food security and enhanced income to the farmer groups. The use of renewable energy in the production system has enhanced clean environment from any gaseous pollution which can contamination the outputs. The solar energy generates power from sunshine and stores it in the battery packs which are then used to pump water from the valley dam to the tanks for irrigation of crops in the farm. The materials used for mulching acts as soil manure which improves soil nutrients after decomposing in the farm. This improves crop yields resulting into high crop productivity of the farmer groups and enhances their income which elevates their standard of living and also reduces food insecurity. In addition, the risk of fruits and vegetable contamination is reduced since the movement of fertilizers and other chemical compounds by deep percolation is reduced. Unlike in sprinkler or overhead irrigation system in which water is distributed by overhead high-pressure sprinklers or guns and washes the fertilizers and other chemical compounds through percolation into the fruits and vegetable.

**Key characteristics of drip irrigation beneficiaries**

The Odeye small scale drip irrigation system is located at Odeye cell, Amuda ward, and Agwata town council in Dokolo district. The district is located in Lango sub region in the northern part of Uganda. This irrigation project was initiated by the government of Uganda in year 2020 and handed over to the community to boost agricultural productivity and to enhance income to farmers. The participation of farmers in irrigation system management as a community based design of development programs has grown into a key operational strategy in this irrigation project. Farmers are trained by the agronomists from the Ministry of agriculture on crops management and utilization of the new innovation in agricultural production. In this irrigation project, there are 80 community members who have formed 18 farmer groups and they are involved in onion, Water melon, tomato, green pepper, eggplant and garlic production. However, it is imperative to note that, pressurized drip irrigation system is being used in the crop production. The farm is seated in 12 acres piece of land and each acre constitutes a plot. In each plot, crops are planted in lines and drip irrigation pipes are fitted in between the lines of the crops for water distribution during irrigation, where each plot has water control irrigation taps which supply and stop water supply where necessary.

**State of the art of the irrigation system**

The automation of the irrigation system is the central focus in the innovation. The need for optimization of water usage is recognized by the state of the art in the irrigation system. The automated machines are employed to evaluate and predict water needs for irrigation to ensure efficient use of water. Water is pumped from the valley dam to the tank using solar power which is remotely controlled and then supplied to the gardens using drip irrigation system.

**Architecture**

The smart irrigation system has four major components which includes, the valley tank dam, solar power station, the networking infrastructure and water management control station, which includes water storage tanks with capacity of 10,000 litres, drip irrigation pipes, water pump, Sensors and micro control unit (MCU) fitted into the system.

**The solar power station**

The irrigation system is powered solely using the cells of the solar panels. The power generated is stored in a battery pack and is used to power the pump connected to the valley dam to pump water into the water management and control station. The solar power station is independent of the other subsystems; the other subsystems depend on input from the solar power plant. The integration of the solar power system, the networking architecture and water management make up the complete functional system.

**The water management and control station**

The water management and control station consist of water pumps, Sensors, drip irrigation pipes, water storage tanks and micro control unit (MCU). The MCU controls the operation of the station where the valley dam is connected to the power station using the water pump and water is generated and then stored in the tanks such that, in case of a power shortage, the reservoir ensures that the irrigation can be carried out when needed. The purpose of the sensor and the micro control unit is to allow the automatic shutdown of the system in case the required amount of water is pumped into the stored tanks and it has the automated security alarms system which alerts the Ministry of Water and Environment, the regional office in Lira City and the Agronomist at the farm of any security issues on the solar system.

Environmental protection is very critical in any project implementation in the contemporary world. Whenever people gather in a central place, they tend to destroy the environment through poor garbage management. Therefore, farm management came up with a slogan of keep Odeye clean and they established garbage collection centres in every part of the farm and the garbage are categorized according to their level of destruction to the soil. Accordingly, there is hazardous container, non-biodegradable and biodegradable. The garbage is then put in a central pit and mixed with chemicals to decompose and later used as manure in the farm to improve soil nutrients. The use of greenhouse to raise seedlings within the farm has reduced the cost of production and pests and diseases. Farmers are equipped with the skills of seedlings management in order to generate quality seedlings for planting. At the entrance of the green house, there is a pool of disinfectant mixed with water and all the farmers wear gumboots and walk through the chemical at the entrance to avoid carrying pests and germs from the environment into the green house to destroy the seedlings. The involvement of the local farmers in the management of the project has already created a rapport amongst themselves and the Agronomist and this has acted as a motivator in the sustainability of the project. The group formation in the project has changed the mind-set of the participating farmer from non-productive activities such as alcoholism to a more profitable business venture and has enhanced their household income through the sale of agricultural outputs.

**The main challenges facing irrigation technologies**

There is high crop productivity such as tomato, onions, green pepper, water melon, and garlic cultivated in the farm due to sufficient supply of water using drip irrigation and the use of fertilizer to boost soil nutrients. This increased productivity has helped to reduce food insecurity and boosted sustainable agriculture, because crops are planted all year round without any fear of drought. However, the innovation is also facing a technical challenge. There is unequal distribution of water in the plots located on the hilly side of the farm during the irrigation. This is because of the low pressure from the system to take water to the hills. The failure has exposed the crops to the direct sun heat resulting to poor yields and sometimes the crops drying out. The land in which the project has occupied is limited and there is no space for expansion in terms of plots and membership. The farm is seated on a 12 acres piece of land with 80 members. Since there is no area for expansion, it means that even the membership will not grow. This will make the irrigation project to have a very limited impact in the community.

The project lacks the principles of inclusiveness and limits participation. This is because there are only 80 community members involved in the project at the expense of the whole community. As a result, the benefits of the project are limited to the few households and this will in the long run affect the sustainability and ownership of the project. There is lack of value addition of the outputs and this is reflected in the sale of raw crops to the consumers within the surrounding environment and the district at large. This is because government did not plan for the outputs coming out from the farm. This has resulted to wastage of the bulk harvest as seen with the rotten tomatoes in the store at the farm. Finally, there is also lack of market linkages for the outputs as promised by the government. These outputs require immediate markets because they are perishable agricultural products. Therefore, the inadequacy of the market as resulted to low prices of the outputs and has negatively affected the farmers' household income and the standard of living. We therefore, recommend that government should back track the issues of value addition in the value chain and provision of the markets for the agriculture products in order to make the project viable.

## 3. CONCLUSION

The agricultural sector is the engine of growth in any economy across the globe. This is because agriculture is a source of employment in both developed and developing countries which require huge investment for the sustenance of the ever increasing population. This is the reason why many conventions such sustainable development goal and Maputo declaration emphasized increased investment in agricultural sector to increase food production to ensure zero hunger and improved nutrition globally. Therefore, the introduction of smart farming technology such as pressurized irrigation system in Uganda is a response to these global conventions to improve agricultural sector and enhance food security for the increasing population and to transform the country from a peasantry society to a more modern and prosperous economy.

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