

The Internet of Things in Agriculture for Sustainable Rural Development

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Abstract— There are many difficulties that rural communities in Zambia and South Africa have in common, including those related to agriculture, connection, water, transportation, health, and education. As a result, there may be some similarities in the solutions used to address these concerns. In keeping with the needs highlighted in these communities and with a focus on agriculture, this research aims to examine the possible contributions of Internet of Things technologies (IoT) toward poverty reduction in these rural regions. Examples of IoTs used to lessen these communities' agricultural demands in the areas of crop farming, weather forecasting, wildlife management, forestry, animal farming, market identification, and rural financing are included in the study.

Keywords— agriculture, ruraldevelopment, internetofthings

Introduction

Agricultural informatics, also known as e-agriculture, is a field that leverages technological advancements in agriculture, agricultural development, and entrepreneurship to provide enhanced technology in rural services, information delivery, and dissemination via ICTs and the internet [9]. The primary goal of e-agriculture is to strengthen agricultural and rural development through improved information and communication procedures. More specifically, e-agriculture involves the creativity, planning, creation, assessment, and implementation of innovative ICT applications in rural areas with a focus on agriculture [11]. The potential of Internet of Things technology to help reduce poverty and improve

the quality of life for those living in rural regions is gaining increasing attention. This research contributes to this field by examining the possible benefits of IoTs in agriculture for South Africa and Zambia rural areas. On the other hand, the Internet of Things (IoT) refers to connecting physical objects to the Internet so that distant sensor data can be accessed and physical objects may be controlled remotely. The Internet of Things aims to bridge the gap between real-world items and their digital representations by offering an ICT infrastructure that makes it easier for 'things' to be exchanged in a safe and trustworthy way.

Due to advancements in price, accessibility, and flexibility, ICTs are now used in rural homesteads that depend on agriculture. Several factors, including one drive ICT for agriculture) ubiquitous and low-cost connection; 2) flexible and cheaper instruments; 3) advancements in data interchange and storage; 4) creative business models and alliances; and 5) the need for agricultural information services [26]. Enhancing agricultural productivity, marketing, and post-harvest activities can have a substantial direct and indirect influence on reducing poverty. This is true for any ICT solution that helps impoverished rural farmers make a better living [18].

Broadband ICTs must address the following barriers for all rural areas: 1) distance barriers, i.e., access to government and administrative services and structures; 2) economic barriers, i.e., access to larger business and labor markets; 3) social barriers to rural residents' access to health, social services, education, and training; and 4) traceability of production, products, and services throughout the value chain, including logistics [27].

I. PROBLEM STATEMENT

Similar but locally relevant solutions must be focused on resolving issues related to these similarities because rural areas in Zambia and South Africa share many challenges in the areas of agriculture, tourism, environmental management, finance, communications infrastructure, connectivity, water resources management, sanitation, roads and transport, access to markets, health, and education. This study suggests

using information and communication technologies (ICTs), specifically the Internet of Things (IoT), to provide services to rural communities in Zambia and South Africa. This will help address these communities' needs, reduce poverty, and close the digital divide between urban and rural areas. This research intends to identify needs and recommend IoTs in response to these needs that will contribute to lessening the impact of poverty in the rural areas of South Africa and Zambia, emphasizing the agricultural sector.

The question saskedare:

- What are the agricultural needs of the rural communities that, when addressed, will lead to the upliftment of their lives and poverty alleviation
- What IoT technologies are in existence, and what IoT scan in the future bed esigned and developed to meet these needs

There search objectives, therefore, will be:

- Review existing literature on the agricultural challenges in Zambia and South Africa
- Identify the IoT technologies that can address these needs through use cases

An interpretative technique is employed to solve the research challenge [7] successfully. The interpretative approach relies on qualitative techniques for data collection and analysis. It is essential for improving the researcher's comprehension of how people behave and act abouttheir study topic. It is predicated on the idea that social construction, including shared meanings, documents, and other elements, is the most effective way to gain information about reality. [5]. A literature review was done on rural communities' demands and difficulties in agriculture and IoT technologies that may be used to address those needs and problems. The result is a set of suggestions for IoT technologies mainly aimed at addressing the demands identified in the agricultural sector.

THE STAE OF A GRICULTURE IN SOUTH AFRICA AND ZAMBIA

15.9 million South Africans are estimated by Global Insight to be living in poverty in 2009. Of them, 11 million—or 69% of the country’s impoverished population—live in rural regions. Subsistence farming, social handouts, and remittances from family members employed in mines or cities are the primary sources of income for impoverished households in rural areas [22]. However, 90% of rural Zambians are classified as “smallholder households” and depend primarily on agriculture for their income [15]. IoTs would enable farmers to manage their rural transportation, identify and access markets for their produce, communicate with extension agencies to get knowledge on best practices, and receive weather forecasts to reduce agricultural hazards.

In comparison to the 2008/2009 season, Zambia’s agricultural production climbed by 118% in sunflower, 50% in soybeans, 9% in rice, 38% in maize, 7% in tobacco, and 5% in wheat during the 2009/2010 growing season [17]. Crop farming, horticulture, animal husbandry, poultry production, forestry, dairy farming, fish farming, game farming, and agro-processing are all part of South Africa’s diversified agricultural industry. Cousins (2009) states that 4.75 million South Africans are employed in agriculture, and 4 million of them work in the sector for “own consumption” [6]. The Internet of Things (IoT) may be used to manage agriculture, including monitoring livestock in shared grazing areas, operating agro-processing facilities, managing irrigation systems, and managing transportation logistics.

Due to its primarily rural environment, Zambia’s fishing industry continues to provide a substantial contribution to rural development in terms of creating jobs, generating revenue, and lowering poverty [17]. Huge prospects arise for refrigerated vehicles for transporting and cold storing fresh fish and IoT-based logistics in adjacent fields. Approximately 700 of the approximately 4700 storage dams in South Africa are owned and managed by the government. Consequently, South Africa promotes rural aquaculture in public dams to provide food security [19]. Aquaculture venture management can benefit from the use of IoT.

II. POTENTIAL IoT SYSTEMS IN AGRICULTURE

The following sections give a few examples of potential applications of IoT in agriculture. Automated drip irrigation can be used for agricultural purposes and in areas where the onset of climate change causes unexpected rainfall patterns. Drip irrigation is the method of watering crops that hydrates just the soil next to the plant's roots. By connecting information gathered from many sensors about temperature, radiation, humidity, and soil water content, one may regulate the location and the amount of water released. Since there is little to no connectivity to the electrical grid and renewable energy sources are available in rural regions, solar and wind power may be used to power water pumps, which then use that energy to pump subsurface water into tanks. Crops are watered using this water.

Weather forecasting may be accomplished by analyzing meteorological data over extended periods to lower agricultural risk. We call this analysis of extensive data. Temperature, winds, precipitation, crop type, soil fertility, leaf wetness, humidity, and soil moisture are all gathered locally by sensors and used in weather predictions for pest control. Because pest maturation depends on environmental circumstances, researchers can more reliably anticipate pest outbreaks by monitoring the life cycle of pests in conjunction with climatic data.

Animals are equipped with radio-frequency identifiers (RFIDs) that allow tracking to deter stock theft. Data remitted wirelessly can visualize the animal's position on a map in a control center. Animals frequently go lost in rural regions with shared grazing. Radio-frequency identifier (RFID) chips are affixed to livestock, and RFID readers are positioned at different monitoring locations to relay data to an agricultural extension services center. One might inquire about the animal's situation.

Moreover, IoT can make branchless financial services possible. Rural areas that lack access to banks can benefit from farmers being able to deposit, withdraw, and transfer money and pay bills through a network of agents that includes

retail establishments. Using modest information centers with an internet connection, a regional pricing information system may gather data from the major national markets and filter it down to the local level. Two-way or rural radio can disseminate market pricing to larger audiences in more remote regions.

Large bodies of water may have their water contamination detected by satellite light radiation. It determines the kind of pollution by measuring the wavelength of the contaminants. Aquaculture would benefit from this technique. River basin flooding is a concern. A river basin may be shown in real time on a website. In agricultural areas, the capacity to monitor the whole river basin and respond quickly to shifting weather and hydraulic patterns may save countless lives. The website receives information wirelessly from sensors that keep an eye on the surroundings in the river basin.

In remote places, wildfires are another concern. Heat intensity sensors and wirelessly transferred photographs to the appropriate stations can be utilized by satellite technology to identify fires. Plastic barcodes may be hammered into trees to stop unlawful harvesting of the highly sought-after hardwoods. The tag is scanned as soon as the tree is chopped, and the data is uploaded by satellite to a safe database. The database generates reports and keeps track of tree inventories. Trees can be traced from the forest to the consumer and every supply chain step.

Technologies like sensors are used in organic greenhouses to track and manage temperature, humidity, light, soil aeration, soil moisture and drainage, fertility levels, and soil aeration. When these technologies are connected to control systems, intelligent systems that enable farmers to cultivate various crops and efficiently use their resources may be created. Electrical energy is also needed for these organic greenhouses to function as intended. The energy source will be wind and solar power; thus, a system that connects wind turbines and solar panels to sensors will be needed.

Precision agriculture aims to optimize return on investment in agriculture, and the Internet of Things (IoT) can help with

this. Sensors for soil, water, and irrigation can assist farmers in safeguarding their crops by wirelessly communicating information to water reserve locations on when to irrigate. Farmers can also use automated drip irrigation in regions with limited water. This may be accomplished by integrating data from many sensors, which regulate the amount and location of water discharged.

Improved in-field monitoring is necessary to reduce crop loss from plant-eating bugs, animals, and wildfires, among other sources. One way to do this is to construct sensors that monitor the fields. These will be able to alert farmers about crop attacks or fires before they get out of control.

Farmers may use various smartphone-based decision support tools to help them plan for the upcoming farming season. These applications also assist farmers in diagnosing problems in crops and livestock and prescribe treatments for such ailments. Alternatively, villages can carry smart health cards when a farmer sees many veterinary authorities. Every time they visit the veterinary officer, these cards are updated with the latest information on their animals. Using their smartphones, rural farmers may utilize telemedicine to take pictures of their afflicted crops or livestock and send those photographs to specialists who can prescribe treatments.

Using public agriculture monitoring programs, decision-makers may direct agricultural actions, including stopping the spread of plant-eating pests or other plant diseases. Systems

They track and monitor agricultural animals and look for any symptoms of sickness using Internet of Things technology. Farmers may get pertinent information by integrating these technologies with a single system. Trends and outbreaks may be found with this. Furthermore, because animals might be stolen, a GPS-based monitoring system can be installed to track their travels and notify their owners if no animal activity is detected for a certain amount of time.

Sensors that use the Internet of Things technology, such as GPS and RFID, track and monitor agricultural goods as they are transported and stored, making it easier for them to reach

their destination. Due to their limited population, locating enough transportation to carry goods to their intended location in remote towns might be challenging. IoT devices can follow farmers who need transportation to get their agricultural goods to their desired locations.

Deeply remote places may be equipped with satellite broadcasting capabilities. Mesh connectivity allows this to be connected to other areas. Thanks to this connection, rural farmers now have access to information about government services, markets for their goods and pricing, and their rights.

The cell phones of buyers and sellers are outfitted with Internet of Things (IoT) technology, such as Near-Field Communications (NFC), which makes it easier to make purchases without using cash, to make it easier to acquire agricultural inputs and sell agricultural goods. Cash exchanges are replaced by electronic transactions that either credit or debit purchasers' and sellers' bank accounts. Additionally, these technologies make branchless banking possible, which helps farmers in rural areas who don't have easy access to banks. Farmers may be able to communicate with customers directly by eliminating the intermediary using inexpensive sensors and mobile internet. Kenya has created M-Pesa kiosks for mobile money transfers in remote communities. Farmers come to these kiosks to transact and pay for labor and inputs using the money they earn from local sales. Therefore, money circulates within the agricultural community [10].

III. RELATED LITERATURE

Even though industrialized nations have been the world leaders in ICT usage for over 20 years, ICT usage in developing nations has increased unparalleled during the last ten years. The ICT penetration rate in these countries has surpassed that of developed and transitional nations, and they are now boasting the highest rise in productivity. Public services and information that were hard to get ten years ago are now easily accessible, especially to marginalized and rural groups in Sub-Saharan Africa (SSA). The introduction of mobile phones, instant messaging services (SMS), and multi-media messaging systems (MMS) has eliminated waiting periods

for crucial decisions to be relayed in distant rural areas of SSA, where communication would often take several weeks. Internet, email, 3G, and 4G are examples of modern ICT.

In the twenty-first century, mobile phones, PDAs, and social networking sites like Facebook, MySpace, YouTube, and Twitter have expanded the boundaries of communication to previously underserved populations. Developing nations may now “leap-frog” rural development and agriculture thanks to these contemporary ICTs. Consequently, there is a growing focus on the potential contribution of ICT in facilitating market access, which is essential for achieving agricultural commercialization, ensuring food security, and reducing poverty in Sub-Saharan Africa [14]. In addition to lowering transaction costs and enhancing market efficiency, mobile phones may also present an opportunity for service delivery interventions [8].

The Internet of Things (IoT) is a technological development that impacts the present and will affect the future. The Internet of Things (IoT) concept involves connecting many devices over the Internet, including computers, actuators, mobile phones, RFID, GPRS, embedded sensors, and more. These items may address one other and confirm their identities thanks to their distinct addresses. The objects communicate, process, and transmit reports to users by tasks that have been defined [2]. In several scenarios, the Internet of Things’ ability to link devices together might be used in agriculture.

Several research studies have examined the application of IoT in agriculture to improve various agricultural processes. Using agricultural data and use cases as a point of reference, Xiaojing and Yuangua (2012) [25] primarily highlight using cloud-enabled systems to illustrate the link between the information cloud and IoT. They contend that intelligent agriculture is one of the many uses for the Internet of Things (IoT), which has a promising future.

ZigBee is an open standard for low-cost, low-power wireless mesh networking [24]. Because of its low cost and low power consumption, the technology may be widely used in wireless control and monitoring applications. Mesh networking offers

more dependability and an excellent range, requiring fewer batteries. ZigBee, a brand-new information-gathering and processing technology, has progressively crept into agricultural environmental monitoring. ZigBee technologies make it possible to identify agricultural pests, drought, and elevated moisture levels. With real-time access to this data, automated actuation systems may counteract unfavorable conditions by regulating pest management, fertilization, and irrigation. This technology is used wirelessly in agriculture. The ZigBee nodes may obtain real-time temperature, humidity, and lighting data, which can be relayed to a remote monitoring center.

According to research conducted by Joe-Air Jiang (2014) [12], precision agriculture (PA) has grown in importance. Because wireless sensor networks (WSNs) and the Internet of Things (IoT) may deliver high-resolution spatiotemporal sensing data retrieved from real-world physical/analog signals, these two technologies may be excellent instruments for monitoring environmental factors and plant development in agricultural applications. Precision farming involves managing the entire farm using information and communication technology (ICT) to maximize input returns while conserving resources in terms of crop science, environmental preservation, and economic considerations [16]. As a result, crucial data on farm record keeping may be supplied, which will also help with decision-making, increase the traceability process, and improve the marketing and intrinsic quality of farm goods.

Based on a comparison of South Africa's and Kenya's experiences, Maumbe (2010) [14] offers a framework for the growth of information and communication technology (ICT) applications in agriculture and rural development. According to the framework, the complete integration of ICT in agricultural and rural development would result from many modifications, commencing with the creation, advancement, and execution of e-government policies.

The author makes the case that ICT usage in rural and agricultural development is a potent tool for raising living standards in Sub-Saharan Africa and advancing these sectors. Acceptance and diffusion barriers must be removed to

implement ICT in agriculture successfully. These obstacles include a lack of knowledge, low literacy, inadequate infrastructure (such as a lack of energy to charge electronic devices), challenges related to language and culture while using ICT, a lack of e-inclusivity, and the requirement to accommodate the unique demands of specific users. The study examines practical ICT applications in agriculture and recommends increasing ICT-based agricultural interventions to promote rural development in Africa.

IV. BENEFITS OF IoT IN AGRICULTURE

This study aims to determine the requirements of rural communities in Zambia and South Africa and what Internet of Things (IoT) interventions might be made in response to those needs. IoT technology has the power to improve rural farmers' standards of living and reduce poverty. For instance, growing a variety of foods that may be exported to other nations in addition to being consumed locally is made feasible by organic greenhouses. As a result, farmers can increase their standard of living and contribute to the GDP by earning additional revenue. To raise their living level, rural farmers can also benefit from investments made in IoT technology that assist agriculture. For instance, harnessed solar and wind energy may be utilized for television and radio-based news consumption and lighting buildings.

IoTs may be used to conduct public agriculture surveillance programs, which allow decision-makers to direct agricultural interventions. For example, these programs can warn farmers of impending wildfires or stop the spread of plant-eating bugs and other plant diseases. This enables the farmers to take precautions before things go out of control. The governments of both nations might spend a great deal of money aiding the impacted farmers if there were no such interventions. Harvests may be abundant because of precision farming, even in dry times. Since the farmers will produce enough farm goods to feed the nations, the governments of both countries won't have to spend a lot of money importing agricultural items from other nations.

IoT technologies make it easier to follow agricultural products to their destination, which is perfect for farming items

that need more processing since purchasers can schedule the additional processing steps and know when the farm products will arrive. The sparse population in rural areas makes it challenging to transport agricultural products. IoT technology may empower the carriers by giving them access to information about farmers needing transportation. As a result, carriers don't have to wait to begin operating until they have a wholetruckload of agricultural goods; as long as they know that farmers are waiting for transportation ahead, they can go at any moment.

Farmers and buyers can benefit from paperless transactions using Near-Field Communications (NFC), which reduces theft and fraud. Similarly, this helps farmers in remote areas who don't have easy access to banks where they might deposit or withdraw money for supplies for their crops. Farmers and veterinary or agriculture officers can benefit from adopting livestock or crop smart health cards, which record information about sick livestock or crops. Given that the officer has access to all records about the impacted livestock or crop, this can result in a practical and successful diagnosis and medication prescription.

Suppose deep rural areas can receive satellite transmission. In that case, this might create jobs for nearby firms that could provide access, low-cost solutions, and wireless network services at a lower cost to the communities. In addition, satellite broadcasting may help remote farmers learn about pricing and markets for their goods, the government services they can use, and their legal rights. Additionally, the systems can be linked to local and global markets and government agencies. The advent of low-cost sensors and mobile internet connectivity allowed farmers to communicate directly with customers, eliminating the intermediaries who typically take advantage of them. Farmers will benefit from this as their product earnings will increase.

CONCLUSION

Potential uses of IoT in agriculture for sustainable rural development have been found in this study. It has shown the

financial advantages that IoT may bring to different agricultural sectors. These disciplines include water management, weather forecasting, wildlife management, finance, forestry, plant and animal disease control, agricultural product transportation and storage, extension services, etc. The research aims to impact policy about IoT deployment in agricultural and rural development. Developers of new IoT technologies may also use the research to construct technologies customized to each nation using the findings. The rural population will grow when technology is created to help reduce poverty and raise people's quality of life.

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