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Smart IoT Rural Agricultural Innovations for Food Security through Digital Technology Transfer: Agro-Industrial Sector Reform

Ugochukwu Okwudili Matthew[1], Jazuli Sanusi Kazaure[2], Godwin Nse Ebong[3], Charles Chukwuebuka Ndukwu[4], Andrew Chinonso Nwanakwaugwu[3], and Ubochi Chibueze Nwamouh[5]

1. Computer Science Dept, Hussaini Adamu Federal Polytechnic, Nigeria
2. Electrical Engineering Dept, Hussaini Adamu Federal Polytechnic, Nigeria
3. Data Science Dept, University of Salford, United Kingdom
4. Mechanical Engineering Dept, Michael Okpara University of Agriculture Umudike, Nigeria
5. Electrical Engineering Dept, Kampala International University, Uganda

Abstract:
The goal of the Green Imperative programme is to use innovative Brazilian technology to mechanize agriculture, elevate farming among Nigerian rural residents, increase food security, and make farming a satisfactory occupation. The linking of Nigeria's agricultural value chain through an investment program established by the governments of Brazil and Nigeria is the country's option for improving the general agricultural innovations in the rural settlements. The Green Imperative is a south-south triangular cooperation initiative with long-term goals for food security, and is supported by the governments of Brazil and Nigeria through their respective Ministries of Foreign Affairs. The Green Imperative offers a macroeconomic strategy for generating sustainable economic growth, with a focus on investments, job creation, technology transfer and digital skills among farmers. The difficulties of the agricultural sub-sector's integration into international networks demonstrates how African countries struggle to get cutting-edge technologies and agro-innovation packages. The IoT smart technology and multi-stakeholder engagements are necessary for the growth of the green economy in order to speed up and solidify changes in consumption and agro production patterns. Implementing IoT Smart technologies for sustainable rural agriculture is a cutting-edge and innovative strategy to assist farmers, extension services, agribusiness, and policymakers in understanding innovative solutions to technology-driven food security. This study, employed survey technique, featured a sample size of 400 farmers from an extension block of the Agricultural Development Project in the Selected States of Jigawa, Katsina and Kano State in the North-Western Nigeria. In the study, IoT smart technology connectivity along the agricultural value chain will make it easier to precisely price goods, better position them on the market, and manage production better. The paper came to the conclusion that agricultural research and investment will have a significant impact on the growth of the food supply in Nigeria and Africa due to technological advancements, and that will be essential for ensuring future food security and sustainable food production through smart IoT farm management.

Keywords: Farm Mechanization, Android IoT Smart Technology, Digital Innovation, Food Security, Green Imperative, Sustainable Agricultural Economy, Extension Service and ICT for Development

INTRODUCTION

The Green Imperative is a south-south triangular cooperation effort with long-term goals for food security that is actively supported by the governments of Brazil and Nigeria through their respective Ministries of Foreign Affairs. This good practice involves numerous efforts from many sectors of activity, which combine to serve as a sustainability factor for its practical implementation. Participants include a learning institution (Getulio Vargas Foundation), an industry association (Brazilian Machinery Manufacturers Association), and banking organizations (Deutsche Bank and the Brazilian National Bank for Economic and Social Development). It is also supported with the right political commitment, a comprehensive strategy, and a clear mandate in the domains of agriculture and rural development. The project, which will last ten years, will be implemented in two stages: (a) spending more than $200 million to build 780 agricultural service centres, which will serve as hubs for training and equipment sharing to boost agricultural productivity; and (b) transferring technology from Brazil to Nigeria through procurement of agricultural equipment and inputs like tractors, planters, seeders, fertilizers, and pesticides.

For agricultural research and investment to achieve sustainable food production and food security in the future, the expansion of the food supply through technological advancements will be a key factor(Viana, Freire, Abrantes, Rocha, & Pereira, 2022). Investments in research, technology, and capacity building are needed, as well as a renewed focus on innovation, to increase sustainable agricultural productivity(Amaonwu et al.). The notion of "Greening the Economy with Agriculture " (GEA) refers to a comprehensive set of rights to sufficient food along with nutrition security in terms of food availability, access, stability, and utilization that may improve the standard of rural livelihoods while successfully managing natural resources and enhancing resilience and equity along the entire food supply chain, taking into account different nations' and individuals' particular circumstances(Musvoto, Nahman, Nortje, de Wet, & Mahumani, 2014). Managing agriculture, forestry, and fisheries in a way that satisfies a range of societal needs and desires without jeopardizing the likelihood that future generations will be able to utilize the full range of goods and services provided by terrestrial, aquatic, and marine ecosystems as part of global commons is imperative in order to achieve the goals set forth by the GEA(Weiskopf et al., 2020). As a matter of fact, the goals of GEA include:

1. Promoting regional, sub-regional, and national agricultural forums through application of a macroeconomic plan to achieve sustainable economic growth.
2. Enhancing the concepts of the "green economy" that are being presented, with a focus on financing, technology, and investment opportunities for the green sector.
3. Encourage countries to establish macroeconomic policies and mainstream them in order to facilitate the transition to a green economy.
4. By balancing domestic production, bilateral technology synergy, investment, and commerce, we can ensure that everyone will have access to food and nourishment. To that effect, everyone will have access to enough food and aid in the rural areas with sustainable economies.
5. Using traditional knowledge, scientific advancement, and technological changes to maintain healthy ecosystems that take food production into account and observe the rules of resource management.

The sample size the of current study consist of 400 rural farmers from an extension block of the Agricultural Development Project in the Selected States of Kano, Jigawa, and Katsina in the North-Western Nigeria. Four hundred (400) respondents were selected for the survey through the use of a number of pre-tested, structured questions administered in stages while using purposive

and random sampling techniques. The primary statistical information for this study came from these respondents, in addition to secondary data input. The results showed that the average age of farmers in the zone was 40 years old and that they had an average of 18 years of agricultural experience. With only one or two types of formal schooling and an average family size of ten members, men made up the majority of the respondents. The respondents identified as Muslims and claimed ancestry-related access to land. Although farming was their primary source of income, they did not belong to any farmer organizations. The majority of respondents (90%) also owned a mobile phone, with 40.5% of those being ordinary phone owners. Call apps (90 percent) and SMS apps (90 percent) were both used by the majority of the farmers in the area. According to additional study, call apps are preferred by farmers over SMS for family and friend communication (90 percent), purchasing agricultural goods (80 percent), and receiving general marketing information (79 percent). Farmers generally have positive opinions of using cell phones and related technology within the agricultural supply chains in the ongoing development.

RESEARCH AIMS AND OBJECTIVES

The following objectives were sought to be accomplished in this study:

1. To provide information on the social and economic effects of rural farmers' adoption of mobile technology as part of the continuing digital agricultural revolution.
2. Analyse the effects of the adoption of mobile technologies on the agricultural productivity of the rural farmers in the chosen states of North Western Nigeria and make recommendations for appropriate action.
3. To determine the relationship between farmers and the application of technology for agricultural globalization in the ongoing Brazil-Nigeria Green initiative that focused on agricultural transformation.
4. To develop technological techniques for enhancing rural agriculture productivity that will support local food sustainability and nutritional security via private sector extension services.
5. To define the responsibilities that academic institution partnerships, public/private involvement, and bilateral technology transfer will play in enhancing rural agriculture productivity through the green imperative initiative.

RESEARCH QUESTION

The term agriculture technology describes the application of knowledge to agricultural production systems in order to increase farm productivity, profitability, and labour efficiency through various automation. In light of that, the purpose of the current study was to address the following research issues in accordance with the green imperative initiative:

1. As part of the ongoing Brazil-Nigeria Green Imperative and South-South corporation on agro-innovation for food and nutrient security, to what degree will the services of agro-extension workers be sufficient for rural agricultural technology transfer using Android IoT Smart Mobile devices?
2. Do rural farmers in Nigeria accept this technology transfer and have the skills necessary to use it effectively for agricultural management that would lead to food security?
3. How far will rural agricultural practices' adoption of new technologies be sufficient to allow for cross-border connection within the agricultural supply chain?
4. What part does the Nigeria Incentive-Based Risk-Sharing System for Agricultural Lending (NIRSAL) play in strengthening the bond between finance and agriculture?

5. What roles does south-south triangular cooperation initiative play in the long-term goals for food security?

LITERATURE REVIEW

Academically, a literature review is a piece of academic writing that shows knowledge of a comprehensible academic compilations on a particular subject in relation to other sources(Nelson & King, 2022). It is considered a literature review rather than a literature report because it also involved a critical assessment of the sources(Gusenbauer & Haddaway, 2020). A literature review is intended to help readers understand the current research and discussions that are pertinent to a particular subject or field of study and to communicate that understanding in the form of a written report. Therefore, an author can increase the understanding of the field by conducting a literature review. In this context, we categorized the literature of the current paper into three; (i) Technology Transfer (ii) Agro-Based Technology Innovation (iii.)Agro-Based Extension Services

Technology Transfer

In a calculated attempt to increase annual agricultural production of rice, soya beans, dairy products, livestock and poultry farming, the federal government of Nigeria had engaged Brazil on the transfer of agricultural technologies. In 2018, the Getúlio Vargas Foundation (FGV) and the Nigerian government signed a Memorandum of Understanding, which gave rise to the "Green Imperative Project", For the construction of the largest agricultural project on the African continent, there is need for cooperation in agricultural technology between Brazil and Nigeria(Zhou, 2022),(Alves, de Oliveira, & Motta, 2022). The initiative seeks to increase local production of essential meals for the community while giving priority to the development of sustainable, low-carbon agriculture mechanizations(Okoh, 2020). It is a top priority initiative for the Nigerian government that aims to enhance food production and decrease rural emigration, promoting social harmony that should promote environmental ecosystem sustainability. The Brazilian technology package, which includes the provision of agricultural machinery, equipment, and services, will be used in order to increase the production and quality of food produced by small-scale farmers in Nigeria in the coming year(Sims & Kienzle, 2017).

Even while technology is still viewed as a crucial component of the transition to sustainable agri-economy, international attempts to facilitate this shift in developing nations with technology have not been successful in producing the necessary results. The focus of the current research was on how to have a dialogue about international technology transfer (ITT) that encourages more fruitful international cooperation in the pursuit of sustainable development in underdeveloped countries. With an emphasis on small and medium-sized farmers and extension agents, the International Centre for Innovation and Transfer of Agricultural and Livestock Technology (CIITTA) being a group that aims to promote agriculture in developing nations(Pandey, de Coninck, & Sagar, 2022). The professional management of CIITTA oversees a wide range of activities including business management tools, social and environmental sustainability, as well as training and capacity building for all stages of the agricultural and livestock value chains, from basic production to production processing. The activities of CIITTA aim to empower young people and women through inclusive professional development, technical skill development, and access to environmentally friendly technologies. Through South-South collaboration between Brazil and developing nations in Latin America, Africa, and Central America, CIITTA facilitates technological and cultural interactions between nations. In order to guarantee the dissemination of best

practices and access to new technologies in the industry, CIITTA maintains technical cooperation with the major research and technological diffusible institutions in Brazil.

Added to the mix of global technology transfer, scholarship opportunities and manpower development, the Nigeria Tertiary Education Trust Fund (Tetfund) had signed Memorandum of Understanding (MOU) with eight international institutions on research development, which include: University of Aberdeen, United Kingdom(UK), Cardiff University ,UK, University of Sheffield , UK, Durham University, UK, University of Turku , Finland, Sao Paulo Research Foundation (FAPESP),Brazil and Forum for Agricultural Research in Africa (FARA),Ghana. The object of the scholarship and collaboration include;

1. Encouraging collaboration in scientific and technological research between Nigeria and various institutions, including the nations that serve as their hosts.
2. The necessity of fortifying ties between the Nigerian scientific and other institutions' communities, including those of their host nations.
3. Supporting new venues for Nigeria and international research institutions to collaborate.
4. Fostering bilateral cooperation through encouraging cooperation in important areas of scientific research and technical manpower development.

Advances in Agro-Based Technology for Modern Agriculture

The FARA Holistic Empowerment for Livelihoods Program (HELP) aims to increase youth empowerment and livelihoods in Africa by fostering strategic human capital formation, through the Agricultural Knowledge & Innovation System (AKIS) and agribusiness(Molinari, Mena, & Ghiglione, 2022),(Kim, 2022). As a comprehensive model fueled by international collaboration, HELP creates livelihoods by relying on South-South and Triangular Cooperation (SSTC), a solidarity that build up the conventional donor-recipient relationship in which partners utilize pertinent technologies and innovations for their mutual advantages. The goal of HELP is to connect the private sector and African Agricultural Research for Development (AR4D) institutions with the necessary capacity for Science , Technology & Innovation(STI) and agribusiness to address problems in the continent's agri-food system and promote the development of the entire value chain(Swelam, Abdallah, & Salem, 2022),(Singh, Paroda, & Dadlani, 2022). Creating a strong and empowered agricultural workforce will alter the agribusiness in Africa by delivering agri-competencies, skills, innovative capacity, and knowledge to create future value chains and fit-for-purpose agricultural research.

The convocation of ARIFA, were to provide skill manpower innovative training for young African citizens on the 21st-century digital proficiencies regarding agricultural innovation, inaugurated in Brazil by FARA(Onu, Silva, de Souza, Bonatto, & da Costa, 2022). The launch of ARIFA in collaboration with Brazil Africa Forum 2019 highlighted the importance of technological innovation to increase Africa's agricultural productivity, which is at the core of the ARIFA initiative(Amaonwu et al.). This showed that without advancements in the deployment of technology in agriculture, it would be difficult for Africa to achieve food and nutrition security(Okello, Lamo, Ochwo-Ssemakula, & Onyilo, 2021). The African Union Commission and the African Union Development Agency official technical arm for matters pertaining to agricultural sciences, technology, and innovation and FARA, are the leading continental body in charge of coordinating and promoting agricultural research and development (R&D) in Africa (Singh et al., 2022). FARA is carrying out the Agricultural Research and Innovation Fellowship for Africa in order to restructure the African agri-food industry and offer the catalyst for swift

agricultural transformation within ten years implementation plan(Pavageau, Pondini, & Geck, 2020). ARIFA will assist the regular admission of cohorts of graduates and agri-preneurs into the innovation systems created by FARA through Innovative Platforms (IP) and rural learning paths found in and around African institutions, universities, technical colleges, and rural communities(Amaonwu et al.). The objectives of ARIFA and how they fit into the greater African development agenda were discussed by Dr. Irene Annor-Frempong, Director of Research and Innovation at FARA. Dr. Annor-Frempong has been in charge of FARA's development and coordination of programmes spanning the entire continent, such as the SCARDA (Strengthening the Capacity of Agricultural Research and Development for Africa) and UniBRAIN (Universities, Business Research in Agricultural Innovation) programmers, as well as the AHCSTAFF (African Human Capital for Science, Technology and Agri-preneurship for Food Security) programme. The Science Agenda for Agriculture in Africa (S3A), the underlying continental framework for addressing the Comprehensive Africa Agriculture Programme's (CAADP) goal of increasing productivity, and the STI Strategy's (STISA) priority one on reducing hunger and food insecurity in African countries, are both being addressed by the director of research and innovation at the moment.

According to the most recent data, agricultural technology and software innovation have contributed to new digital employment being created in a variety of economic sectors, in addition to helping to increase GDP(Rehman, Jingdong, Chandio, & Hussain, 2017). In Nigeria, the agricultural sector of the economy employs about 35% of the workforce as of 2020 (Osabohien, Olurinola, & Matthew, 2020). As described by the FAO,(Adegbite & Machethe, 2020) , even though Nigeria has large deposits of natural resources like oil and solid minerals, agriculture still forms the backbone of the country's economy. Most rural Nigerians rely on it as their primary source of income. Crop Production, Livestock, Forestry, and Fishing make up the four subsectors that make up the agricultural sector(Adewale, Lawal, Aberu, & Toriola, 2022),(Crumpler et al., 2022). The sector experienced a reduction of 3.44% points from the third quarter of 2018 in the third quarter of 2019, although it still experienced nominal year-over-year growth of 14.88%. Crop Production, which made up 91.6% of the industry in the third quarter of 2019 and experienced a quarterly growth of 44.12%, is still the key driver of the sector. In the third quarter of 2019, the agricultural industry made up 29.25% of the total real GDP(Ahmed, Yusuf, & Ahmed, 2020)

Agro-Based Extension Services

The current subheading in line with agricultural utilities is focused on the idea and practice of extension services alongside digital agricultural management. However, before delving into the numerous varied facets of extension practice in the following section, it is necessary to consider what the term "extension" means in the context of rural agricultural practice. The rural agricultural extension is currently a widespread practice in the majority of the world's nations and a fundamental component of projects and programmes designed to bring about change in the rural agricultural settlements(Geza, Ngidi, Slotow, & Mabhaudhi, 2022). The administrative framework of rural regions frequently includes extension services, which are tasked with guiding change-related projects and programmes in collaboration with farmers. Agricultural extension service is a loosely structured educational practice aimed at the rural populace(Sumani, Kanukisya, & Mwaikokesya, 2022). This procedure provides guidance and knowledge to assist people in resolving their issues as a microcosm of the larger society within the agricultural channels of distribution. According to agricultural economists, focusing more on small farms causes employment and overall economic output to rise more quickly(Agyemang, Ratinger, & Bavorová, 2022). Additionally, agricultural extension service strives to boost the productivity of

the family farm and generally raise the family's standard of living through additional earning when market distribution channel has been formed. The goal of extension is to alter farmers' perspectives on their challenges through government-private sector partnership(Jarial, 2022),(Yulo Loyzaga, Uy, Lo, & Porio, 2022). Extension focuses on the growth of rural communities as a whole, in addition to their physical and economic accomplishments. Therefore, extension agents engage in conversation with rural residents, assisting them in better understanding their issues and coming up with solutions.

Hassan et al(2022), observed that working with rural residents to enhance their quality of life is provided in the programme of extension services (Hassan, Hewidy, & El Fayoumi, 2022). This entails assisting farmers in raising the efficiency of their agricultural production as well as enhancing their capacity to shape their own future growth. Agricultural extension can provide farmers with additional knowledge and information that they do not already have, even when they already have a great deal of understanding about their environment and farming practices(Hörner, Bouguen, Frölich, & Wollni, 2022),(Smidt & Jokonya, 2022). For instance, the agent can help farmers by sharing knowledge about the reasons behind crop loss, basic pest control concepts, or the processes by which manure and compost decompose to release nutrients for plants. The application of this knowledge frequently requires the farmer to learn new skills of many different kinds, such as technical skills to operate unfamiliar agricultural equipment, organizational skills to manage a group project, the ability to evaluate the economic implications of technical advice, or farm management skills to keep track of usage of resources and equipment on the farm. The extension agent must take all necessary precautions to ensure success when imparting knowledge and skills to farmers and their families. He needs to identify the knowledge gaps or skills gaps that exist among the farmers in his region, and then he needs to set up learning opportunities that will help the farmers fill those gaps.

Through a dynamic learning process in the assimilation of new knowledge and skills, CIITTA seeks to equip technicians and extension workers to promote the finest agricultural production and processing techniques in their countries of origin. Every training program is designed to enhance knowledge through hands-on sessions delivered on CIITTA's own campuses. Workers in agricultural extension programs also give farmers guidance and information to help them make decisions and generally empower them to take action. For instance, it might include data on prices and marketplaces, or it might include details on the accessibility of financing and inputs. Technical guidance is likely to be more immediately applicable to the family farm's production operations and the actions required to increase or maintain this productivity. This technical guidance will be mostly based on the results of agricultural research. However, in many cases, farmers may also be trusted sources of guidance and knowledge for other farmers, thus agents should constantly make an effort to connect farmers. Farmers also require some kind of organization, both to represent their interests and to provide them with a way to take collective action, in addition to knowledge, information, and technical guidance.

Therefore, Extension should focus on assisting in the formation, organization, and growth of local farmer organizations. This should be a shared effort, and any organization of this kind should only be established after consulting the farmers. These groups will facilitate extension services' interactions with neighbourhood farmers in the future and act as a conduit for the communication of information and expertise. Isolation and the belief that there is nothing they can do to improve their circumstances are two major barriers to development that many farmers experience. Some

farmers may have spent their entire lives toiling away, with little help or encouragement, in trying situations in order to sustain their families. In order to effectively engage farmers in extension activities, it is crucial for extension to work directly with them, support their initiative, and generally encourage them to do so. Convincing farmers that they are capable of taking care of themselves, being in charge of their own lives, and having the power to escape poverty is equally crucial(Charatsari, Lioutas, Papadaki-Klavdianou, Michailidis, & Partalidou, 2022). In the developing world, extension operations are common, and most governments have established formally structured extension agencies to carry out extension projects and programs(Ankrah & Freeman, 2022).

SMART IOT AGRICULTURAL FRAMEWORK FOR GREEN IMPERATIVE

The **Fig.1** presents a framework for the smart IoT agricultural framework that consists of five key elements: IoT Data Collection, IoT Platform for Communication, Data Processing, Data Visualization, and System Administration. The network that has been converged from several communications networks makes up the data acquisition component. The communication medium may be a wireless technology like LoRa, Zigbee, NB-IoT, or Bluetooth, or it may be a wired technology like a controller area network(Tao, Zhao, Wang, & Liang, 2021). In the meantime, IoT mobile communication technologies were adopted which is further broken down into wide area network (WAN) sub-components, having the cellular communication of 4G/5G technology, which will alter the way agriculture is monitored by enabling high-speed data transfer, network control, and energy efficiency. In addition to transmitting the agricultural-related data gathered by the data visualization component, the IoT data collection component also delivers control instructions to the system management. By integrating numerous models and algorithms for the agricultural production process, the IoT Platforms component is responsible for decision making, data storage, and statistical analysis on agricultural data. The component has been further subdivided into (i) Edge Computing, (ii) Cloud Computing, and (iii) Big Data sub-components. Using information gathered through information mining and other methods, big data technology does predictive analysis by identifying internal connections between the data.

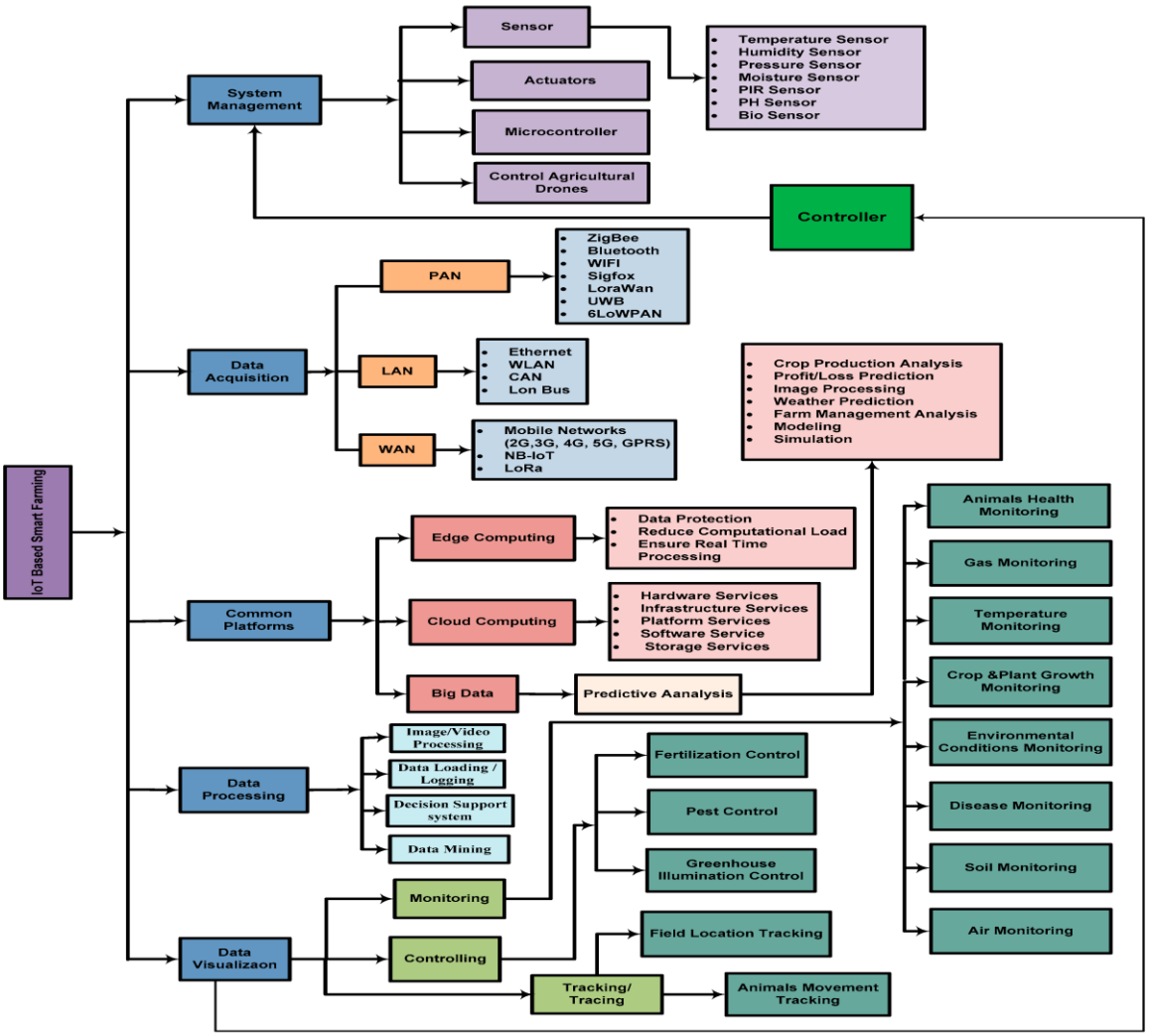

Fig 1: IoT Agriculture Framework(Farooq, Riaz, Abid, Umer, & Zikria, 2020).

Numerous IoT agricultural applications benefit from cloud computing's provision of platform, infrastructure, hardware, software, and service capabilities. Farmers can save their images, texts, videos, and other types of agricultural data on the cloud platform for a reasonable price, which helps agricultural businesses by cutting down on storage costs (Hua et al., 2023). Making decisions based on farmers' technical skills while using direct access to actual agricultural data is also challenging. On the other hand, agronomists are qualified to offer advice and form reliable conclusions based on data. Because of this, only cloud computing offers a wise and secure platform for monitoring crops. Farmers still experience technological losses associated to poor internet access and limited electricity, despite the fact that the cloud platform aids them through its advanced capabilities. One of the modern computing models called edge computing executes calculations at the network's edge. Additionally, this platform safeguards agricultural data because edge computing processing happens more often than in cloud computing, hence reducing computational burden and speeding up data transfer.

RESEARCH DESIGN & METHODOLOGY

Information for the current study were acquired from both primary and secondary sources. The government documents and digital archives from the ministry of agriculture are among the secondary sources, as memos from the TETFUND Abuja on the Memorandum of Understanding

between TETFUND and some foreign higher education institutions as well as other institutions whose mission is focused on research and development were all studied. The study went on to evaluate supplementary information from StatCounter Globalstats' open repository about the market share of Android and iOS smartphones in Nigeria and Africa. The agricultural production value in Brazil from 2010 to 2020 were obtained from Statista corporation open repository and interpreted to provide justification as per why the Brazil-Nigeria Green Imperative expectation. The distribution of questionnaires to participants in rural agriculture who were chosen at random within the study area were required as part of primary data sources.

This study focused on the socioeconomic and demographic characteristics of farmers, the accessibility of agricultural mobile apps, levels of awareness and usage, and the extent, intensity, purpose, and limitations of farmers' app usage. It also looked at the availability of mobile phone apps in general. A sample size of 400 farmers from an extension block of the Agricultural Development Project in the Selected States of Katsina, Kano, and Jigawa were included in the study, which used a survey methodology. Four hundred (400) respondents who provided the primary statistical data for this study through the application of a series of pre-tested and structured questionnaires were chosen using a multi-stage, combined with purposive and random sampling approaches. Descriptive statistics tools were used to assess and show and analyzed the data relevant to the study. The secondary sources of data, on the other hand, included digital archives with academic works that investigated the topic of agricultural technology innovation from the global data bank archives.

POPULATION AND SAMPLING

The study comprised of 400 Rural Agricultural participants from agro extension services of Jigawa state, Katsina state and Kano state, all in the North Western Region of Nigeria, that had successfully implemented digital agro economy systems made up the population of this study in the ongoing green imperative agricultural automation. The researcher chose the agricultural innovation within the green imperative implementation plans for digital agriculture systems from the general farmers population to participate in the study. A purposeful sampling approach was used to choose the instances for this investigation. Purposeful sampling is a non-random research technique in which a researcher includes in the sample particular examples that might produce data that is relevant to the study. Sampling is a planned process for choosing specific cases from a population of a given distribution. Flexible sampling is a method used by qualitative researchers. The choice of sampling approach is influenced by factors including the nature of the case, the population, and the logistical challenges of reaching instances. For this investigation, other sample techniques like convenience sampling and snowball sampling were inadequate. With convenience sampling, a researcher chooses easily accessible study venues and subjects. Convenience sampling is less time and resource-intensive for a researcher, but lacks rigor, which could have an impact on the validity of the study and the quality of the data collected. With the snowball sampling approach, a researcher invites past study participants to suggest more potential study participants.

There is enough information available at data saturation to guarantee the study's repetition. Information from many data sources can be brought together through the process of triangulation. By exploring and analysing several viewpoints on the phenomenon, triangulation aids in the saturation of data. For a researcher to come to any conclusions regarding a case study, additional sources of evidence beyond interviews are required. The study's credibility is improved by gathering enough data to achieve saturation. In this study, data redundancy occurred when

there was no more fresh material to be discovered after conducting participant interviews and reviewing corporate records as already stated in the research design and methodology. A multi-case study of the 30 rural farmers were conducted as part of the strategy to achieve data saturation, and case studies of additional agri-businesses were then conducted as a result of the failure to reach saturation. To find participants and cases that satisfied the following eligibility requirements, the researcher employed an intentional sampling technique. Participants must be owners or managers of agribusinesses with plans for deploying smart IoT digital systems within the study areas. Purposeful sampling is a non-random research technique in which a researcher includes in the sample particular examples that might produce data that is relevant to the study.

DATA COLLECTION INSTRUMENTS

Since the qualitative method was used for this study, the researcher became the main primary tool for data collection. Multiple data sources, including interviews, documents inspection, direct observation, participant observation, archival records, and physical artifacts, can be used by the case study researcher to assemble evidences. Face-to-face semi-structured interviews with study participants as well as document analysis were used to obtain the study's data. Interviews allow participants to directly respond to questions in their own words and can be structured, unstructured, or semi-structured. Information for case studies can be found from interviews, which are reliable sources. In a structured interview, participants are questioned in the same order and with the same questions; in an unstructured interview, participants are questioned first with a general inquiry and then with more specific questions based on their answers. Numerous case studies make use of semi-structured interviewing techniques. When conducting a semi-structured interview, a researcher employs a set of predefined questions but is free to add more if necessary for clarity. Through face-to-face, semi-structured interviews with open-ended questions, the researcher gathered primary data. Document analysis served as the primary source of secondary data for this investigation. In this study, document analysis involved going over pertinent corporate papers as already stated in the research design, including those found on corporate websites.

Finding pertinent documents, both printed and electronic, and combining the data they contain are steps in the methodical process known as document analysis. The purpose of papers as a tool is to support and confirm evidence from other sources. Document analysis may involve evaluating advertisements and reviewing manuals, books, brochures, company reports, event programs, charts, diaries, and other records that may be accessible in the public domain. The researcher improved the reliability and validity of the data collection instruments and process by (a) using an interview protocol to direct the process of interviewing participants, (b) using the technique of member checking to ensure correlative data, and (c) using a questionnaire to collect data from participants. The level of consistency in the outcomes obtained after repeating the same case study with similar data gathering techniques is known as reliability(Bolarinwa, 2015). The level of accuracy of data obtained from a measuring instrument is indicated by its validity(Rao, Su, & Chan, 2023).

DATA ANALYSIS

The most important component of any research is the data analysis, which involve summarizing all the meaningful details into an applicable information(Donaires, Cezarino, Liboni, Ribeiro, & Martins, 2023). It entails the analysis of acquired data using logical and analytical reasoning to identify patterns, correlations, or occurrences of events. As a result, descriptive statistical

techniques were utilized to evaluate the digital agricultural practice that the end-user needed in the ongoing green imperative. The charts were transferred to Microsoft excel and mapped to the table. To exhibit the data and interpret the tabulated results, pie charts and bar graphs were produced. The study's findings, which were identified in the research, include the identification of the essential end-user requirements as well as the implications and difficulties that aided in the development of the digital agricultural service portfolio and roadmap for green imperative implementation for agricultural productivity.

ANALYSIS OF FINDING

Nigeria now has the largest economy in Africa and is one of the most populous country with over 200million citizens, and it is predicted that by 2025, there will be over 140 million smartphone users in the country(Farouk, David, & David, 2019). There are currently about 40 million smartphone users in Nigeria, according to estimates from various sources(Otu, Ukpeh, Okuzu, & Yaya, 2021). Taking into account the social and economic makeup of the modern society, it may be challenging to pinpoint the exact number of IoT smartphone users in Nigeria(Amaonwu et al.). The number of smartphone users in Nigeria is expected to triple in the next five to ten years, looking at the highly impressive growth predictions for the sector(Aker & Fafchamps, 2015). From 85.1% in 2018 to 86.6% in 2019, the market share of Android Operating System had increased. Furthermore, the Chinese government's efforts to bring 5G to fruition are expected to re-energize the global smartphone market and propel it to growth in 2020. Additionally, markets like the United Kingdom, Canada, Korea, and the United States are anticipated to be the key markets boost to help the 5G Mobile Phone remain essentially dominant within global market spaces to sustain competitions and enable reasonably priced 5G devices for the consumers in the upcoming year. In July 2018, Android dominated the OS market globally with 85.1% of the total smartphone market. That proportion had increased to 87.0% as of January 2022, four years later, refer to Table 1. On the other hand, global iOS adoption decreased by 1.9% over the same four years, from 14.9% to 13.0%. Analysis by StockApp shows that other smaller-scale OS developers received the remaining 1.9% of iOS's loss.

Table 1: Market Share of iOS and Android Smartphones

Year	Android Powered	iOS Powered	Others	Total
2017	85.1%	14.7%	0.2%	100%
2018	85.1%	14.9%	0.0%	100%
2019	86.6%	13.4%	0.0%	100%
2020	86.6%	13.4%	0.0%	100%
2021	86.9%	13.1%	0.0%	100%
2022	87.0%	13.0%	0.0%	100%
2023	87.15%	12.9%	0.0%	100%

Source: https://www.statista.com/statistics/272307

Android tablets continued to rule the market in August 2017 in South America (57.46%), Africa (70.07%), and Europe (34.44%), according to data on the Stat Counter website. The Android operating system and related hardware will rule the mobile industry in the coming year (Schinle et al., 2017). Android will be very important when choosing a mobile device, much like Apple's iOS devices are to the Apple family of mobile devices (Giachetti, 2018). Android OS and Android devices will be the most popular in Africa in the future year (Coe & Yang, 2022). Techno Android Mobile and Infinix Mobile will spread over the mobile phone market with various adjustments and modifications. With Nigeria functioning as the main market for Android in the foreseeable future,

Techno Mobile and Infinix Mobile will prosper excellently in Africa(Qumer & Singh, 2019), refer to Fig 2 & Fig 3. Techno Android Mobile and Infinix Android Mobile will rule the continent of Africa as a result of the Nigerian origins of SLOT Technologies, one of the founding companies of Techno Mobile and Infinix. SLOT Systems Limited quickly gained notoriety as a top supplier of PCs, accessories, mobile Android phones, and various specialized gadgets that are both economical and reliable. With importance and dominance in Nigeria and the entire African market, it is widely recognized as crucial for cutting-edge digital technology on a worldwide scale (Vasudeva & Mogaji, 2020).

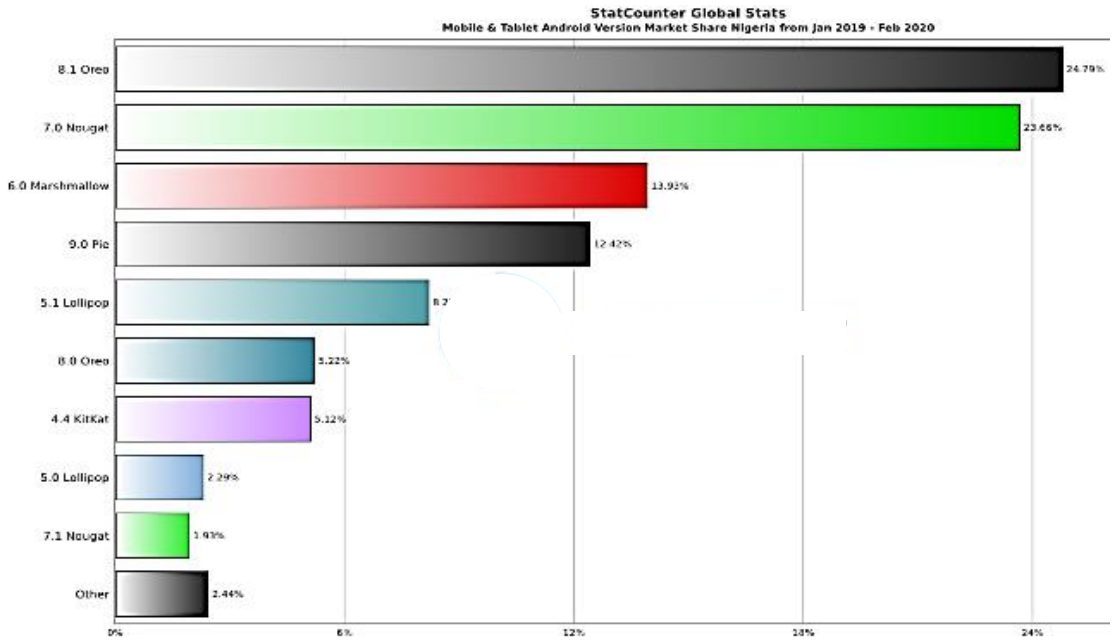

Fig 2: Mobile Phones & Tablet Android Version Market Share in Africa from Jan 2019 – Jan 2020

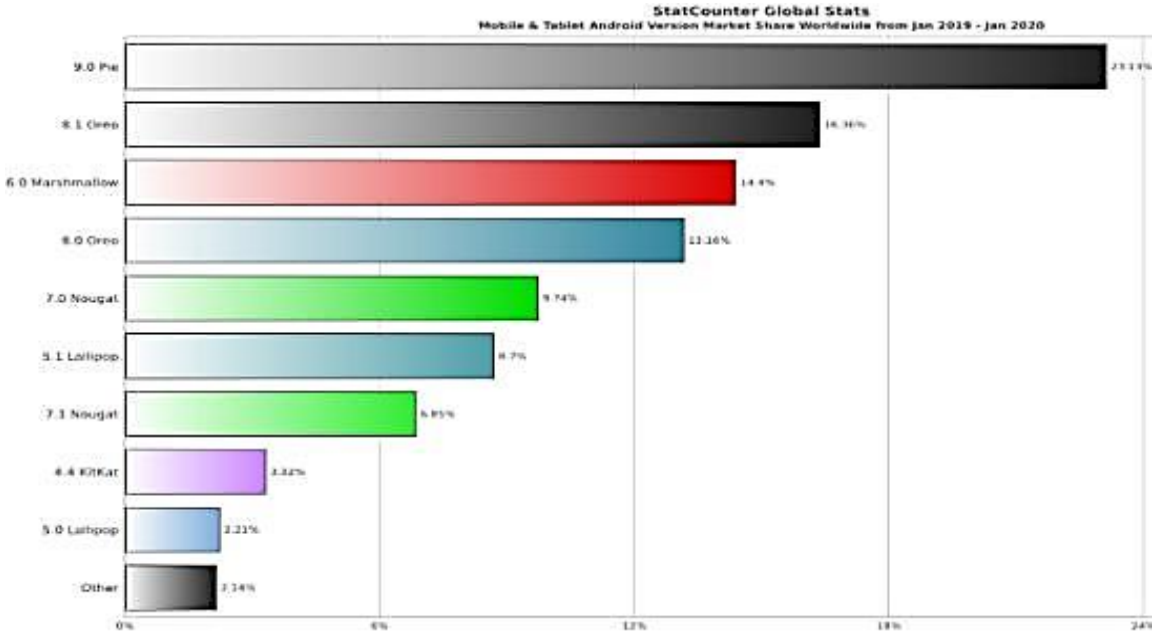

Fig 3: Mobile Phones & Tablet Android Version Market Share in Nigeria from Jan 2019 – Jan 2020

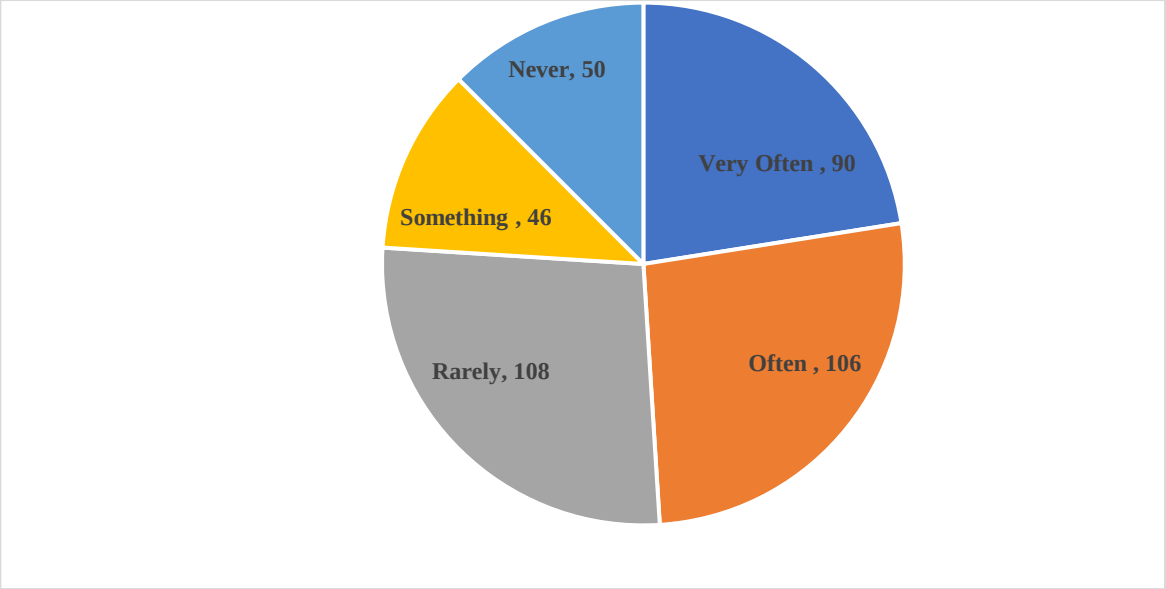

Fig 4: Rural Farmers Mobile Phones Accessibility under the Green Imperative Agro-Industrial Sector Reform.

Table 2: Information on Smartphones Availability to Rural Farmers

Responses	Frequency	Percentage
Very Often	90	22.5
Often	106	26.5
Rarely	108	27
Something	46	11.5
Never	50	12.5
Total	400	100

Research Survey 2021

Referring to Fig 4, Table 2, and Fig 5, descriptive statistics were used to analyse the important research issues identified in the current study. The study found that 23% (90 rural farmers) agreed that mobile digital devices are very often available, 27% (106 rural farmers) agreed that mobile devices are often available, 27% (108 rural farmers) agreed that mobile smart devices are rarely available, and 12% (46 rural farmers) agreed that mobile devices are occasionally available to the farmer to negotiate with the smart agricultural innovation in the selected study area, while 50 rural farmers representing 13% of the total distribution said they had never used mobile devices for farming.

Table 3: The use of digital gadgets by farmers in the agricultural supply chain.

Mobile Device Type	Frequency	Percentage
Non-Smart Phones	165	41.25
Smart Android Phones	205	51.25
PDA& Portables	5	1.25
Tablets	15	3.75
Laptops	10	2.5
Total	400	100

Research Survey 2021

Some of the barriers to mobile technology adoption for agricultural implementation in the study area were depicted in Fig 5. In fact, lack of digital literacy was highlighted by 120 rural farmers, or 30% of the distribution, as a barrier to smart agriculture adoption in their respective regions. The lack of government incentive is one of the problems impeding rural agricultural integration, according to 180 rural agricultural respondents, or 45% of the total distribution. While 50(13%) farmers identified financial difficulty as a barrier to the implementation of smart agriculture, 30 (8%) farmers claimed a lack of infrastructure, including roads, electricity, modern storage facilities, and telecommunication, water, irrigation, and drainage systems. At last, 20 (5%) of the farmers cited resistance to modern implementation as a reason hindering innovative farming in the study area.

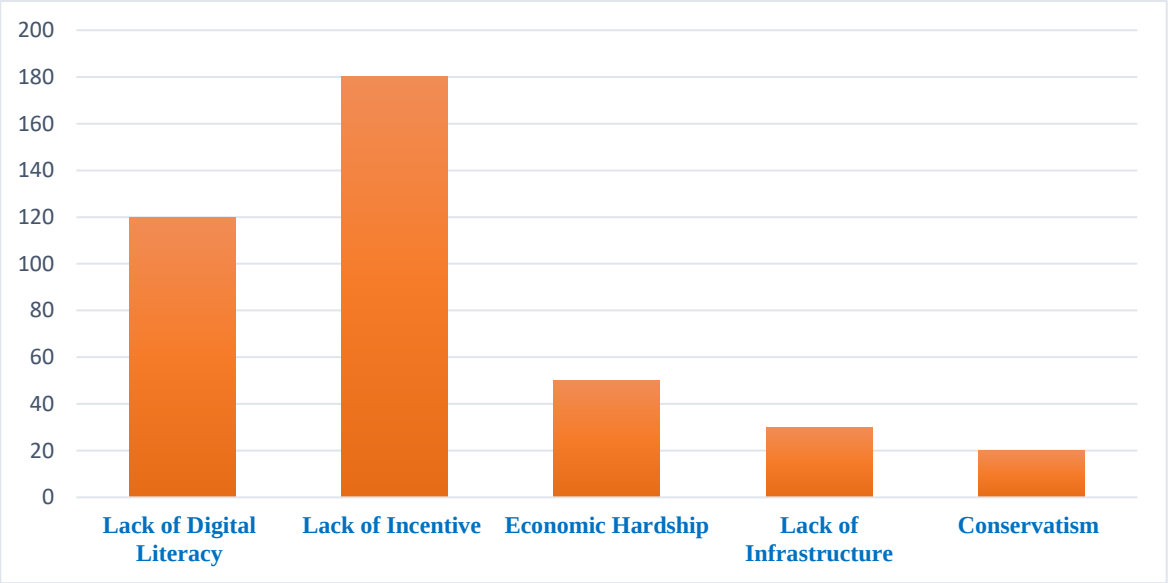

Fig 5: Factors preventing rural areas from adopting mobile technologies for agricultural implementation

DISCUSSION OF FINDINGS

On the account of Green Imperative programme and south-south collaboration, Brazil has the strongest economy in Latin America and the Caribbean and is a significant industrial and agricultural power(Koengkan et al., 2022). It is the world's fourth-largest producer of agricultural goods, ranking first in the production of citrus, coffee, and sugarcane, and second in the production of beef, soybeans, and chicken. Since the early 2000s, Brazil has made great strides toward reducing poverty. The population's overall poverty rate dropped from 35.8% to 27.6% between 1992 and 2015, while the population's incidence of extreme poverty fell from 7% to 4%. Brazil continues to be a nation of vast contrasts despite the fact that economic and social situations have greatly improved. The Northeast's semi-arid rural areas are where inequality is strongest. The second-worst economic recession to ever affect Brazil occurred in 2014. Although there are sluggish signs of recovery, the crisis is not predicted to end before 2021 and has put a pressure on attempts to eliminate poverty and inequality across the nation. Recent data indicates that between 2016 and 2017, the percentage of the population living in poverty rose from 25.7% to 26.5%, which indicates that about 2 million individuals have fallen into poverty. Brazil is a country with stark regional differences, and the northeast region is marked by a high concentration of poverty, with 44.8% of its 57 million residents living below the poverty line and 14.7% in extreme poverty.

Brazil, however, expanded its agricultural exports to feed the globe and preserve an equitable distribution of economic prosperity among its people(de Castro, de Lima, & Romano, 2022). The Brazil agricultural exports reached a historical highpoint of US$ 120.6 billion in 2021, surpassing Ecuador's GDP and rising by 19.7% from the previous year which altogether exceeded Nigeria annual budget from 2015-2025. As a result, the Brazil trade balance for agricultural businesses is in surplus by $105.1 billion. China accounted for 20.9% of Brazil's total exports in November 2021, followed by the European Union (16.3%) and the United States (9.8%). Other nations with noteworthy involvement included Egypt (4.4%), Vietnam (3%), South Korea (2.7%), Japan (2.5%), Chile (2.3%), Iran (2%), and Turkey (2%). As opposed to December 2020, certain destination countries performed significantly better in November 2021. Highlights on this list include Egypt (+102.5%) and Turkey (+98.7%). When looking at the entire year, exports to Iran (+70.3%) had the largest positive change in comparison to 2020, followed by Chile (+58.1%) and the US (+30.2%).

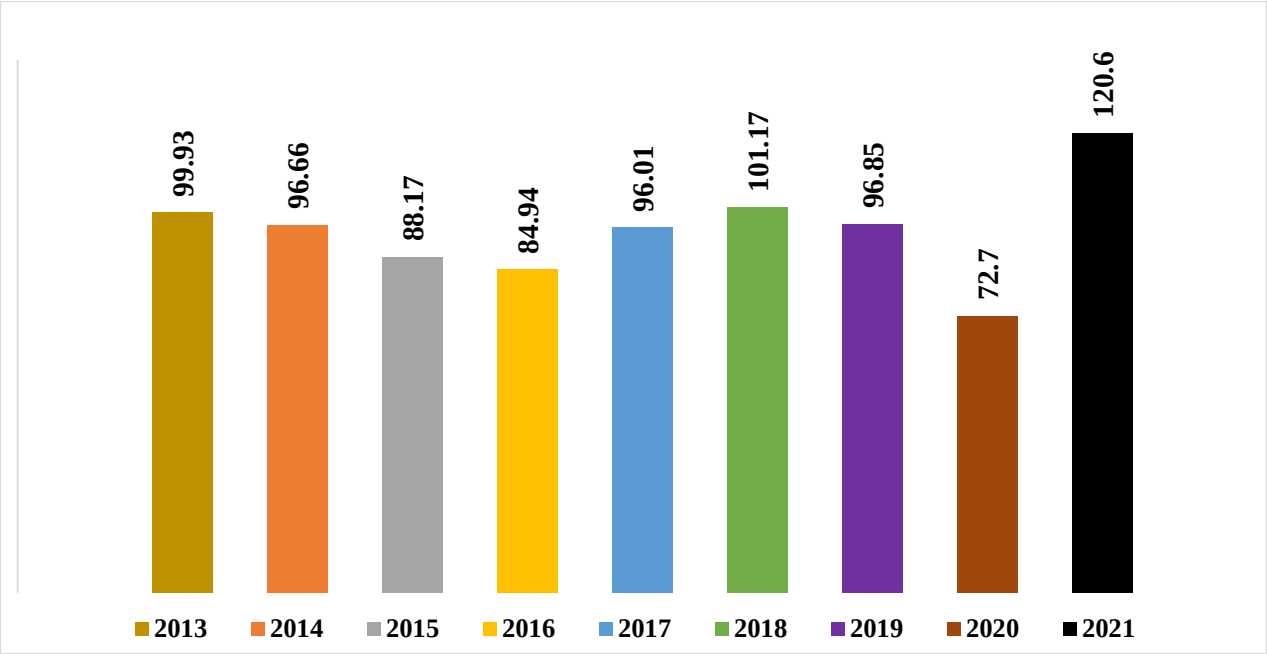

Fig 6: Exports of the Agribusiness in Brazil from 2013 to 2021(in billion U.S. Dollars)

Source: statista.com/statistics/1076723/export-value-agribusiness-brazil/

With reference to Fig 6, nearly 97 billion dollars in exported from the agribusiness in Brazil were recorded in 2019, which represents a decline of about 4.3 percent from 2018. The export further declined in 2020 from the previous year 2019 by 24.9%. Brazil exports more fresh chicken meat than any other country in the world, accounting for 30% of global exports and 14% of global production(Chatellier, 2021). Brazilian exports increased by 8.2% from 2020 to 2021, totalling over 4.4 million tons. It is notable that this is the highest volume during the time period under consideration (2013-2021). With a projected 3.4 million tons of exports in 2021, the United States will rank as the second-largest exporter in the globe(Chatellier, 2021). Brazilian exports recorded their best performance in terms of value in 2021, totalling US$ 7.2 billion, or 25.5% more than in 2020, refer to Fig 6. More than 40% of Brazilian exports in 2021 will be required by nations in East Asia (China and Japan) and the Middle East (Saudi Arabia and the United Arab Emirates)(Chatellier, 2021). The statistics on Gross Production Value (GPV) data demonstrate the consistent increase in agricultural exports from Brazil. According to the Brazilian Confederation

of Agriculture and Livestock (CAN), the GPV reached R$ 1.21 trillion (about US$ 224.1 billion) in 2021.

Taking into account the production of crops and livestock as well as the typical price paid to farmers across the nation, the GPV indicates the gross income in rural companies. Based on reports and data from December 2021, this prediction was made. Additionally, a 7.3% growth over 2020 is predicted by the prediction. The two goods that contributed most to the successful outcomes continue to be soy and corn. The GPV estimate for cattle farming for 2021 is R$ 402.8 billion, which is 0.7% more than the figure from 2020.

FUTURE RESEARCH FOCUS

The Green Imperative agricultural development program was a planned collaboration between Nigeria and Brazil to scale up the nation's agriculture in order to increase food production, enhance food security, create more jobs, and ultimately raise household income. Nigeria's agricultural industry, from processing to commerce to transportation, is primed for market-driven expansion. The industry has tremendous potential and already contributes significantly to food security in both West and Central Africa as a result of rising demand and population multiplicity. In addition to fostering economic growth, Green Imperative initiatives also provide employment possibilities, empower women and young people, encourage innovation, advance trade, and help people escape extreme poverty. Nigerians, especially women and young people, can find work and economic opportunities on the account of the country's booming agricultural sector under the ongoing reform. Women and young people are becoming more prevalent in agricultural markets, agricultural technologies and food systems due to government-supported activities in agricultural economy. On this note, every other future research should focus on the following agenda:

1. Encouraging collaboration in scientific and technological research between Nigeria and other foreign institutions on the technology transfer, in addition to the currently available developments.
2. Bridging gaps that fortifies ties between the Nigerian scientific evolution and other institutions of other nations.
3. Improving agricultural productivity by providing access to resources for smallholder farmers community through an intense capacity rural agro-extension program.
4. Strengthening inclusive policy frameworks in the areas of agriculture, nutrition, and resilience for people living in rural areas including women and youths.

RECOMMENDATION

The agricultural extension service, public sector commitment, private sector initiative, and rural farmers' consultation for grassroots mobilization for food security projection are essential to enhancing the capacity of the rural farmers towards improving agricultural productivity. A new and expanded understanding of the public sector's function in terms of food security, rural development, and agricultural extension is long overdue. The authors' five primary suggestions to governments and all significant stakeholders down the chain of command are as follows:

1. Development of a new policy agenda for agricultural extension services and the establishment of communication channels for rural development with a focus on agricultural production using digital technology methods.

2. Implementing a diverse and pluralistic national policy that encourages agricultural extension and communication channels for rural agricultural development, focusing on rural farmers' participation in the agricultural supply chain.
3. Establishment of a platform for interaction and collaboration with the relevant organizations that comprise the range of multi-sectoral agricultural extension services.
4. Implementing security measures that would stop the current threat to rural communities' sources of livelihood and way of life.
5. Formation of agro banks for microcredit facilities and other social amenities is a key social engineering tool that has the power to propel all other economic sectors along the agricultural supply chains.

CONCLUSION

This study has provided critical information on the discussion of IoT-based rural agricultural practice, with a focus on the transfer of agro-technology between Nigeria and Brazil under the green imperative. The examination of various IoT agriculture applications and IoT mobile communication-related rural agricultural supply chain considerations are then given. The fact that numerous governments are supporting this field of study and that many of them have IoT agriculture policies is the most encouraging factor. Aside from this, the framework has been contextualized for all the key elements of IoT-based agriculture. For further investigation by researchers working in the field of IoT-based agriculture, the promising future directions have been highlighted. The current study identified five questions which was focussed in directing the discussions to achieve the desired ends. On the part of the ongoing Brazil-Nigeria Green Imperative and South-South triangular Corporation on agro-innovation for food and nutrient security through technology transfer, the research discovered that the services of agro-extension workers should be made sufficient for rural agricultural technology transfer using Android IoT Smart Mobile devices through establishment of well-structured communication and feedback loop towards addressing issues of agricultural importance. On the rural farmers in Nigeria acceptance of the technology transfer and possession of digital skills necessary to use it effectively for agricultural management that would lead to food security, the paper discovered an essential digital characterization showing receptiveness of the rural farmers to implement the agenda of the green imperative. On the Nigeria Incentive-Based Risk-Sharing System for Agricultural Lending (NIRSAL) which supposed to strengthen the bond between finance and agriculture, the paper discovered the federal government of Nigeria commitment towards agricultural development through establishment of microcredit facilities to support the rural agro reform agenda.

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