Digitalization of Agriculture: What Relevance and Challenges in Enhancing Climate Smart Agriculture in Nigeria

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Abstract:

The digitalisation of agriculture is critical in solving various challenges in Nigeria’s agriculture. Climate change is unfavourable to agriculture which employs about 70% of Nigerians. The country is food insecure, and its population of over 200 million people will double in three decades. The distortion of the environment and biodiversity is inevitable with aggravated climate change disasters. Climate-smart agriculture powered by digitalisation is promising, but its adoption is low. The study examines the critical barriers to involvement in digital agriculture for CSA and farmers’ uptake of digital technologies in Nigeria. Two Focus Group Discussions were conducted virtually involving 18 stakeholders in farming, climate change and digitalisation fields from public and private sectors across the geopolitical zones to elicit information about strengths, challenges, and opportunities in the country’s digital space as it affects agriculture. However, a low level of skill in the agriculture sector and a high level of internet poverty, energy poverty, poor technological infrastructure, high technology costs, poor e-literacy and digital skills, and limited access to services make the digitalisation process a problem. Nevertheless, over 80% of the discussants believe digitalisation would enhance information sharing and speedy dissemination of innovations. Digitalisation would enhance the benefits of Nature financialisation projects, Geoengineering efforts and other Nature-Based Solutions to climate change. The study recommends that digitalisation efforts in the agriculture sector should avoid widening the digital divide between sectors and urban and rural locations that differ in adopting new technologies.

Keywords: Digitalisation; Nature-based solutions; financialisation of nature, Climate Smart Agriculture

Introduction

Climate change brings about adverse events, proving undaunted in the face of several adaptation and mitigation measures targeted toward earth resilience. Disasters (floods, storms, forest fires, among others), huge humanitarian responses, livelihood/income loss, low crop yield, and high cost of adaptation and mitigation approaches funding are some of the threats and prices paid by the entire global people [1-5]. Pressures stemming from climate change and other environmental issues pose an increasing threat to agrifood systems [6,7]. Food production is not commensurate with the global demand, and water and land have been overstretched [8,9]. With the population growing fast, cropland area per person dropping across all countries [9] and those unable to afford a healthy diet rising – about 3.1 billion, which has been aggravated by agriculture’s extraordinary sensitivity to climate change, a phenomenon to which
agriculture also contributes [9], the world heads towards a precipice, therefore, needing urgent interventions.

Moreover, agriculture contributes significantly to greenhouse gas (GHG) emissions and land degradation [9]. However, allowing agriculture to aid climate change and environmental degradation is suicidal, but agriculture cannot be abandoned because the world needs food, shelter, and economic growth. Therefore, ensuring increased food output with little or no effect on the environment is a necessity that requires innovative approaches that integrate digital and physical solutions to help farmers grow more, better, and with fewer inputs, improve food safety and nutrition through cutting-edge technology, and provide a sustainable, profitable, and inclusive future for farmers.

Climate Smart Agriculture is promising because it seeks to enhance food security and general development goals based on productivity, adaptation, and mitigation enhancement approaches [10]. Even though the CSA concept is new and constantly evolving, the techniques involved already exist and are used by farmers worldwide to handle a range of production risks [11]. It aims to increase agricultural output and resilience while lowering greenhouse gas emissions and improving the ability to adapt to climate change using methods and tools such as irrigation systems, drought-tolerant crops, soil preservation approaches, and data to monitor and manage agricultural systems. [12, 13]. Studies are numerous on the benefits and effectiveness of CSA; increases in yield and income are the most common ones [14 - 16], but its adoption is low in Nigeria, and upscaling is the direction to focus upon [15], which could be achieved through proper digitalisation policy.

Using digital tools and technology in agriculture to increase production, sustainability, and efficiency is essential. Agricultural digitalisation involves monitoring and managing crops, soil, and water resources using sensors, drones, GPS, and other technology. It also uses artificial intelligence and data analytics to make more informed choices regarding planting, irrigation, and pest control. Digitalisation in agriculture can help farmers save time, cut expenses, and boost crop yields. Less chemicals and other inputs can also aid environmental protection [17]. Agriculture's digitalisation could increase the impact of CSA on productivity and hasten the achievement of CSA targets. Digitalisation guarantees improved access to information, increased productivity, lowered operational cost and improved evidence-based decision-making, among other benefits. Digitalisation could help Nigeria’s Smallholder Farmers (SHFs), who lack access to vital information, keep pace with modern trends relative to Good Agronomy Practices (GAP). There is always a dearth of accurate meteorological and climate data for SHFs farming [18]. The ratio of extension agents to SHFs is low and ineffective at closing the information gap [18]). Getting the needed speed and output is also expensive and time-consuming.

Significant expenditures and efforts have been made in digitalisation for the most important benefits, but some grey areas exist [19]. Essentially, complementing CSA with digitalisation could soften burdens from the various problems faced by Nigeria’s agriculture. Nigeria’s population is estimated to grow by 63 million additional people by 2030 and reach 400 million by 2050 [8]; without climate-smart agriculture fueled by digitisation, the pursuit of food security could lead to the destruction of the ecosystem and biodiversity with worsening climate change disasters, which may result in a domino effect. Therefore, the study delves into the critical barriers to involvement in digital agriculture for smart climate agriculture and farmers’ uptake of digital technologies in Nigeria. It discusses succinctly issues surrounding agricultural digitalisation enhancement and rural farmers’ involvement.

1.2 Climate Smart Agriculture Concept
Climate Smart Agriculture is an improved and expanded version of prior knowledge and principles in agriculture. Managing food insecurity and chains of effects of climate change brought about climate-smart agriculture [20, 21]. It combines approaches to manage crops, animals, forests, and fisheries for
increased productivity, enhanced resilience, and reduced emission. The central thematic areas of CSA include its Practices, system approaches and enabling environment, each of which can be appraised in terms of productivity, adaptability, and mitigation [21]. The entry points for climate-smart agriculture (CSA) concerning Practices are soil management, crop management, water management, animal management, forestry, fisheries and aquaculture, and energy management. CSA can be through approaches where systems like landscapes, ecosystems and value chains are brought into play to provide synergies between the elements of the system for effectiveness and efficiency [22,23]. The third aspect of CSA is about stimulating the enabling environment that eases climate-smart technologies adoption in regulatory policies, stakeholder engagement, infrastructure, gender and vulnerable groups considerations, climate information services and other related issues [15].

The novelty of CSA is in tackling climate change challenges, balancing the relationship between production, adaptability, and mitigation, and filling investment gaps by attracting financing from the Green Climate Fund, Global Environment Facility, and other international climate finance sources [22]. CSA is proven to positively influence the nutrition security and earnings of most of the world's poor rural farmers by increasing the output and quality of food production. Additionally, it may lessen susceptibility to drought, pests, diseases, and other climate-related threats and shocks and increase capacity for growth and adaptation to prolonged pressures from harsh weather patterns [24]. It also promises to deliver on emission reduction through methods that can remove carbon from the atmosphere and retard agriculture-imposed deforestation.

CSA in Nigeria has focused more on the Sahelian states for obvious reasons - climate change, desertification, conflict, and food crisis. Adamawa, Borno, and Yobe States have their CSA profiles developed [25, 26, 27]. The states are ranked highest in terms of the number of malnutrition cases, poor yield, and low harvest. The states have also witnessed drought and soil fertility depletion, poverty, and inequality, which call for CSA interventions. CSA technologies and practices adopted are common to the three states: micro-dosing, conservation agriculture, intercropping and crop diversification, planting pits, erosion control techniques, improved seed, integrated soil fertility management, and livestock production. In terms of CSA policy, none was in existence in the states. However, CSA practices have relied on some Federal government and related regional policies such as the National Adaptation Strategy and Plan of Action on Climate Change, National (NASPA-CCN), National Policy on Climate Change and Response Strategy (NPCCRS), National Forest Policy, National Policy on Drought and Desertification and the Agricultural Promotion Policy [27].

1.3 Digitalization and Agriculture in Nigeria
The agricultural sector is very complex and dynamic. As such, sophisticated management systems are required. Digitalisation encompasses soil, irrigation, robotics, farm machinery, and food post-harvest processing in the agricultural field. Economic pressure on the farming sector, labour, environmental, and climate change issues are increasing in Nigeria. Thus, the need for enhancing agricultural practices through digitalisation [28]. There is increased demand for digital farming to augment the subsistence and fragmented agriculture in the country, and this has led more experienced and new-entry stakeholders to introduce digitalisation into the sector. Nigeria earned an overall score of 49.17 in 100 in the World Bank's Enabling the Business of Agriculture (EBA) and an ICT index score of 4.5 out of 9 [28]. The above reveals that there are improved efforts by the public and private sectors to ensure a very conducive digital space through enabling policies. Policies and plans to support digitalisation exist, including the Cybersecurity Policy, Nigeria Digital Economy Policy and Strategy (NDEPS), Nigeria Economic Sustainability Plan (NESP), National eGovernment Master Plan, and the National Broadband Plan. They were developed to assist in making Nigeria a sustainable digital economy through the provision of regulations, enhancement of digital literacy and skills, services and processes transformation, creation of enabling environment for digital innovation and entrepreneurship, strengthening of cyberspace, facilitation of the
adoption of emerging technologies, and promotion of indigenous content [29]. However, issues of coverage, digital infrastructure, digital skills, digital literacy, and affordability are contending against adopting digital technologies in Nigeria. For instance, poor power supply has hampered increasing broadband access by installing fibre networks nationwide [30]. Likewise, the nationwide rollout of fibre would have significantly increased broadband penetration and, as a bonus, drove down the cost of broadband access, but the country's uneven deployment of fibre infrastructure has prevented achieving low broadband cost [30].

With over 400 million people expected to live in Nigeria by 2050, which would result in a nearly 300% rise in the consumption of agricultural products, digitalisation of agriculture may be necessary to harness the full benefits of CSA [31]. Poor adoption of the technologies might result in a full-blown case of food insecurity in the country. Higher agricultural yields are undoubtedly required to support the growing population. Achieving that requires digital solutions to support agricultural transformation efforts such as CSA and millions of SHFs who need better livelihoods.

Mobile applications and web-based tools are available to farmers and have proven to influence productivity and support farm management decisions at the farm and national levels. Firms have developed digital platforms to help SHFs in the country. Babban Gona, Thrive Agric and Agro Rite are indigenous digital platforms created to give SHFs access to resources vital to their livelihood and the growth of the agricultural sector in Nigeria. However, only a tiny percentage of these smallholder farmers across Nigeria can access them. Mobile-phone-based services can ease farmers' access to knowledge on extension services, market information, weather forecasts and agronomic advice. Furthermore, they can offer price information services for inputs and outputs, enable demand and supply aggregation, and facilitate e-marketplaces. However, issues surrounding digital infrastructure, digital literacy, and affordability have denied SHFs to reap these benefits fully. Though detailed information on the degree of digital literacy in Nigeria is currently lacking, data on technology use and broadband penetration in rural areas point to a low level of digital literacy [32]. For a successful CSA implementation adoption, creating a significant population of digitally literate farmers may be crucial. Nigeria has a sizable youth population; there is a possibility of producing “digital natives” who could turn the nation into a digital powerhouse.

2. Materials and Methods

Focused Group Discussion (FGD), a qualitative methodology, was used in knowing the relevance and challenges of agricultural Digitisation to CSA FGD has been used in research on the perception of health promotion programs [33], online studies [34], issues linked to conflict and refugee situations [35], knowledge of women empowerment in agriculture [36]; and biodiversity and conservation research [37]. All the authors cited concurred on using it to unearth various in-depth information. It is ideal for this study since it can reveal a plethora of in-depth knowledge and insightful understanding required for the digitalisation of agriculture in Nigeria. Four major steps were adopted: research design, data collection, data analysis and results, and report writing [38].

2.1. Research Team

The study includes four researchers. It involves one computer data scientist and a conservation and biodiversity management expert. Two agricultural economists, whose areas of interest include climate change, adaptation, and mitigation, are also involved, and one from the private sector. Agricultural economists have extensive experience conducting qualitative research and preparing reports. In addition, they have lectured on approaches relating to FGD and participated in seminars and conferences.

2.2. Research Participants
Two focus group discussions were held virtually through Zoom with the assistance of extension agents and National Youth Service Corps members in the area, and nine people participated in each. Virtual conferencing for FGD offers remote access by the researcher, which modifies power dynamics and promotes more logical conversation between participants [38]. The extension agents connected with the participating farmers. Participants included academics, farmers, and providers of information services. Extension agents called individual farmers to discuss the study’s objectives and specific details. They chose those who consented to participate. We used three people to code the responses and discuss the results with peers to avoid response bias. The participants knew the reason for the study, and all consented to participate.

2.3 Data Collection
The researchers created the interview guide and tested it using two respondents who were not involved in the study. Two interpreters were also used in the data collection. The three questions centred on the perceived improvements to CSA adoption through agricultural digitalisation efforts, important obstacles to agricultural digitalisation, and how agricultural digitalisation can support other nature-based solutions to climate change. Probe questions were posed to understand better significant issues related to the study. The discussions in each 60-minute session of the FGD were recorded on the system for analysis.

2.4 Method of Analysis
The study is qualitative and adopted directive content analysis. Each question was read repeatedly to stimulate a proper understanding of the focus. The FGD discussion transcripts and notes were reviewed severally; likewise, the produced concepts and disagreements between the two researchers’ viewpoints were resolved through solid debate. Another researcher looked at the notions that the two researchers who took part in the initial analysis came up with and categorised those comparable among those coming from agreements. Codes were developed, and those having similar patterns were categorised and subcategorised. Meanings were extracted, reinterpreted, and inferences were drawn. All academics then analysed the investigation findings focusing on the overall category’s framework. The co-authors addressed every step of the analysis for accuracy and coherence in interpreting the data.

3. Results

Demographic Characteristics
The demographic characteristics of the participants in the two FGDs conducted are contained in Table 1. About 61% and 38.8% of the participants are from the northern and southern parts of the country, respectively. Approximately 17% are females, while 83% are males. Half (50%) are in their 40s, while 33.3% are in their 50s. Only 16.6% are in their 30s. (see Table 1).

<table>
<thead>
<tr>
<th>S/N</th>
<th>Gender</th>
<th>Age (years)</th>
<th>Distribution by Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FGD₁</td>
<td>FGD₂</td>
<td>FGD₁</td>
</tr>
<tr>
<td>1.</td>
<td>Male</td>
<td>Male</td>
<td>45</td>
</tr>
<tr>
<td>2.</td>
<td>Male</td>
<td>Male</td>
<td>33</td>
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</tbody>
</table>
3.2 Analysis of results

The following three themes were developed; the perceived improvements to CSA adoption through agricultural digitalisation efforts, essential obstacles to agricultural digitalisation; and how agricultural digitalisation can support other nature-based solutions to climate change. Four categories were initially developed but later reduced to three to avoid confusion due to similar answers given when tested. Three categories and eight subcategories were produced as a consequence of the analysis. For each category and subcategory, extracted codes from the replies are shown in Table 2. It summarises the analysis's findings and outlines the essential elements related to each category and subcategory.

<table>
<thead>
<tr>
<th>S/N</th>
<th>Main Category</th>
<th>Subcategory</th>
</tr>
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<tbody>
<tr>
<td>1.</td>
<td>perceived improvements to CSA adoption through agricultural digitalisation efforts</td>
<td>1-1; enhanced value chain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1-2; enhanced information sharing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1-3; improved soil management</td>
</tr>
<tr>
<td>2.</td>
<td>important obstacles to agricultural digitalisation</td>
<td>2-1; low level of digital skill in the agriculture sector</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2-2; high level of internet and energy poverty</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2-3; poor technological infrastructure</td>
</tr>
<tr>
<td>3.</td>
<td>agricultural digitalisation support for climate change mitigation and adaptation efforts</td>
<td>4-1; nature financialisation projects, geoengineering, and REDD+</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4-2; enhancement of agricultural digitalisation</td>
</tr>
</tbody>
</table>

Source: Authors computation, 2022

3.2.1 perceived improvements to CSA adoption through agricultural digitalisation efforts

Software applications and web-based tools are available to farmers and have proven to influence productivity and support farm management decisions at the farm and national levels. In addition, mobile phone-based services can ease farmers’ access to knowledge on extension services and CSA technologies and practices.

"The adoption of CSA has been improving through digital technologies, such as mobile phones in our area (Participants 2,3,4,7,8,9 -FG1) and was supported by participants (2,3,4,5,8 -FG2)"
3.2.1.1 Enhanced value chain
The participants were able to move their products for processing with reduced waiting time being able to acquire information about the schedule of the processors (mills) through digitalisation. They also make decisions in a coordinated way, which has helped them shift to crops less susceptible to climate change – drought (participants 7 FG1; 8 FG2).

"The use of new storage technique has effectively help grain storage in my area" (participant 4 FG1)

3.2.1.2 Enhanced information sharing
Climate information gets to them through radio and extension agents using mobile apps to advise them on weather variables. The effective climate service has enabled them to transit to more climate-smart agricultural systems and better manage the negative impacts of weather-related risks in poor seasons. However, they suggest a need to scale up the climate advisory services for efficiency (2,3,5,7,9 FG1)

"I have adopted coping strategies using information gathered from the extension agents" (Participant 1,3,4,5 FG1)

3.2.1.3 Improved soil management
Farmers have maintained their soil health through practices learned from CSA activities from the extension agents. The development has also proven to reduce soil nutrient loss, run-off and soil erosion leading to improved productivity. This resulted in other farmers using the CSA techniques to protect their soil health better and manage their farms. They also get soil nutrient information through text messages from extension agents attached to their area. (Participants 2,3,4,5 FG2)

3.3 Important obstacles to agricultural digitalisation
Participants are unequivocal on the issues critical to agricultural digitalisation in the country. They have, however, come across some digital platforms. On the other hand, they mentioned the low level of digital skills, high internet and smartphones costs, high level of internet poverty, energy poverty level and poor technological infrastructure (participants 2,3,4,5,7,8,9 FG1 and participants 1,2,3,4,5,6,7,8,9 FG2).

3.3.1 low level of digital skill in the agriculture sector
All the participants agreed that there is a low level of digital skills among farmers in Nigeria, most of whom are old. Some use their children in secondary schools to interpret information from their mobile apps. But, again, few with smartphones have low manoeuvrability of the smartphones. The language barrier has been a bane in their digitalising farming activities in their farming businesses, participants FG1 and FG2.

"Handling the smartphone given to me by my son has been difficult, and I usually rely on the neighbours to operate the phone. (Participant 3 FG2)"

3.3.2. high level of internet and energy poverty
Affordability, quantity, and quality issues are common to participants 2,3,7,8 (FG1) and participants 2,3,4,5,8 (FG2) as they could not afford 1 GB per month and could not access 10Mbps download speed. In addition, they all agreed that poor internet prevented them from accessing information that would have aided their adoption of certain CSA technologies. They also agreed that lack or inadequate electricity supply is equally a bane as they usually rely on their neighbours’ generators to charge their phones.

"I practically rely on my neighbours for the charging of my phone and..."
lamps due to inadequate supply of electricity.” (Participant 7 FGi)

3.3.3 poor technological infrastructure

Some participants (participants 2,3 FG2) complained about the inexistence of basic telecom infrastructure, such as cellular base station, which hinders communication effectiveness in their area. They are deeply affected by the crisis in the country. Few rely on mouth-to-mouth information as internet access and electricity are unavailable (participants 2,3 FG2). Powering the “last mile” would undoubtedly improve access to electricity and open the door to adopting CSA in such areas of the country.

“I know of a place without electricity in the past ten years in Nigeria. People there rely on diesel and petrol engines for electricity supply (Participant 1 FG1).”

3.4 Agricultural digitalisation support for climate change mitigation and adaptation efforts

The participants are positive that the digitalisation of agriculture can benefit nature financialisation projects, geoengineering and sustain REDD+ when the terminologies were explained to them (participants 2,4,5,7,8).

3.4.1 nature financialisation projects

Participants feel that since the focus now is on directing financial flows to projects that mitigate the negative impact on the ecosystem or pursue positive environmental impact as a co-benefit, agricultural digitalisation can enhance the efforts since it can raise the adoption of CSA, which would, in turn, raise rural income. Therefore, generating funds at the community level to support greening finance may not be difficult and could bring about a nature-smart community economy. (Participant 1,5,6 FG1). Participants believe that agricultural digitalisation can benefit geoengineering indirectly by reducing greenhouse gases emission from agriculture through the adoption of CSA technologies. (Participant 1,6,8,9) FG2

"a concerted effort to digitalise agriculture would invariably enhance reduction of CO2 emission" (Participant 1 FG2)

3.4.2 enhancement of agricultural digitalisation

Participants believe that government should prevent widening the digital divide for a speedy agricultural digitalisation adoption in the country. They also suggest concrete priority actions to support agricultural digitalisation in Nigeria should be embarked upon. Digital Literacy & Skills enhancement was believed to address the need to support a program for widespread digital literacy.

4. Discussion

The study examines the applicability and challenges of digitalising agriculture to enhance Climate Smart agriculture adoption in Nigeria. Two focused group discussions were conducted, and content analysed to gain in-depth information on the issue. The perceived benefits of CSA adoption through agricultural digitalisation efforts, significant barriers to agricultural digitalisation, and how agricultural digitalisation can support other environmentally friendly climate change solutions are just a few of the issues that were brought up and discussed. The study is significant because it identifies the key obstacles to agricultural Digitisation that could influence climate-smart agriculture and provides benefits and solutions for the issues raised. The main finding is that the participants’ Agric value chain was enhanced through digitalisation [39]. In addition, digitalisation enhanced the climate information advisory role, and participants got information through radio, which improved the adoption of CSA. The digital advisory
service information usually catalyses the advancement of technology and its adoption (Jakku et al., 2016; Jakku et al., 2019). Agricultural digitalisation also helped the participants maintain agricultural land management and soil health maintenance. This was reported to have aided productivity and led to the adoption of CSA in the study area. Another finding is that a low level of digital skills, high internet cost and the cost of smartphones hindered the agricultural digitalisation efforts of the government. Others mentioned a high internet poverty level, energy poverty, and infrastructural problems. Currently, challenges in agriculture and the environment are tracked and diagnosed using digital technologies like data pooling and artificial intelligence. Agribusinesses and farmers can advance their enterprises through digital agricultural technologies (DATs), making accessing markets, improving nutritional outcomes, and strengthening their climate change resilience easier. Therefore, the government should create enabling environments that promote agricultural digitalisation for enhanced productivity at the farm level. Lastly, agricultural digitalisation was believed by the participants to indirectly influence nature financialisation at the community level and enhance greening finance.

5. Conclusions
This study provides an in-depth understanding of the relevance of digital agriculture to Climate-smart agriculture and the critical barriers to agricultural digitalisation. Some suggestions were made for the effectiveness of the digitalisation efforts and climate-smart agriculture adoption. The study findings are expected to explain the importance of agricultural digitalisation to the expansion of climate-smart agriculture towards enhancing smallholder farmers’ productivity, income, and food security.

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