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Promoting Dissemination of Agricultural Information to Farmers in Benin

BACHELOR'S THESIS

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Declaration

I do hereby declare that I have done this thesis entitled **"Promoting Dissemination of Agricultural Information to Farmers in Benin"** independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged using complete references and according to Citation rules of the FTA.

In Prague, 18 April 2024

Ayassou Y. Geoffroy

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Abstract

Agriculture is the backbone of many economies worldwide, particularly in developing countries like Benin, where a significant portion of the population depends on agriculture for their livelihoods. However, accessing timely and relevant agricultural information remains challenging for many farmers, hindering their ability to make informed decisions and optimise productivity. In response to this challenge, this study reviews potential ways to promote the dissemination of agricultural information to farmers in Benin, with a specific emphasis on harnessing Information and Communication Technology (ICT)-based models. By conducting a comprehensive review of existing literature, the general overview outlines the importance of agricultural information in facilitating decision-making processes, improving farming practices, and enhancing overall agricultural productivity. Additionally, it underscores the significance of leveraging ICT tools, such as mobile phones, internet platforms, and digital applications, to bridge the information gap and reach a wider audience of farmers efficiently. However, several challenges impede effective information dissemination in the agricultural sector of Benin. These challenges include limited access to ICT infrastructure, low digital literacy among farmers, language barriers, and the reliability of information sources. Furthermore, socio-economic factors, such as gender disparities and unequal access to resources, exacerbate the disparities in information access among farming communities. Based on the findings, recommendations are provided to stakeholders involved in agricultural information dissemination in Benin. These recommendations encompass strategies to optimize ICT-based platforms, enhance existing channels, and foster greater collaboration among relevant institutions to empower farmers with timely, relevant, and actionable information, thereby contributing to the overall advancement of agriculture and rural development in Benin.

Keywords: ICT, information, dissemination, knowledge, farmers, Benin.

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Abbreviations

ARCEP-BENIN: Regulatory Authority for Electronic Communications and Post

FAO: Food and Agricultural Organization

GDP: Gross Domestic Product

GIZ: German Development Cooperation

ITU: International Telecommunication Union

ICT: Information and Communications Technology

MAEP: Ministry of Agriculture, Livestock and Fisheries

MND: Ministry of Digital Affairs

1. Introduction

Agriculture plays a vital role in the economy of Benin, with a significant portion of the population relying on farming as their primary source of income (Kokoye et al. 2013). Despite the recognised importance of the agricultural sector, many African countries, including Benin, need to do more to improve the sector. Due to ineffective coordination of agricultural extension services, small-scale farmers' access to accurate information appears inadequate even when some attempts are made (Mkenda et al. 2017).

Today, it is widely acknowledged that information and knowledge play pivotal roles in driving numerous production sectors within the global community. According to Nicholas-Ere (2017), agricultural information and knowledge are key resources and enablers changing the agricultural sector. Providing farmers with relevant and up-to-date agricultural information is key to ensuring the success of the agricultural sector. This information helps farmers make informed decisions, adopt sustainable practices, and mitigate environmental impacts, which is particularly important for maintaining agricultural sustainability and preserving natural ecosystems (Naika et al. 2021).

Benin, located in West Africa, is predominantly characterised by smallholder farming, with over 70% of the population engaged in agricultural activities. However, smallholder farming systems face numerous challenges, including limited access to agricultural information, inadequate extension services, climate change-induced uncertainties, and pressure on land resources. Also, most farmers need more agricultural knowledge due to insufficient coordination between institutions, agricultural extension staff, and farmers, which accelerates all the aforementioned issues. Without fresh information, producers are limited to using conventional agricultural practices. The only alternative left was a combination of customary behaviours, first-hand knowledge, indirect advice from other farmers, and trial-and-error methods. It provides access to and uses agricultural knowledge and information that may affect change and gives smallholder farmers the authority to properly structure their farms and make wise decisions (Mtega & Ngoepe 2019; Mwantimwa 2020). Ndimbwa et al. (2019) concur that access to timely, accurate, and pertinent agricultural information is essential for bringing about significant progress in the agricultural sector.

Innovative ideas for transforming smallholder farming systems in Sub-Saharan Africa are continually being created by the vibrant revolution and widespread use of Information and Communication Technologies (ICTs), such as web-based and mobile applications (Mapiye et al. 2021). ICTs are depicted as enforcers of participatory innovation, modernisation, and socioeconomic growth within the agricultural sector, particularly farming systems (Drafor 2016; Mapiye et al. 2021).

This study seeks to provide insights and recommendations for improving the flow of information to farmers. Understanding the significance of disseminating agricultural information and addressing the obstacles in its dissemination is essential for enhancing agricultural practices, increasing productivity, and ultimately improving farmers' livelihoods in Benin.

2. Aims of the Thesis

The main objective of the study is to review the potential of enhancing ICT-based information dissemination models in Benin. The specific objectives are to:

1. Identify the significant source of agricultural information for farmers;
2. Analyse the effectiveness of agricultural information models to the farmers.

2.1. Research Questions

In achieving these objectives, the study seeks to answer the following research questions:

1. What is the potential of different ICT channels for disseminating agricultural information on a large scale in Benin (sub-Saharan Africa)?
2. What information do small-scale farmers need most and where do they currently access it?
3. Which of these models of information dissemination have been most effective in improving farmers' livelihoods, and how can they be improved?

3. Methodology

This study used secondary data from a variety of sources to analyse the effectiveness of ICT-based agricultural information dissemination models for farmers in Benin and sub-Saharan Africa. Secondary data sources that were reviewed and analysed include previous studies, reports, surveys and longitudinal data from databases that track trends in ICT use.

The original search employed Boolean search words 'information dissemination' AND 'ICTs revolution' AND ‘Benin’ AND' smallholder farmers' AND 'Sub-Saharan Africa'.

Previous studies on agricultural information dissemination provide valuable insights into the models that have been implemented and their effectiveness. A review of studies conducted in Benin and other sub-Saharan African countries over the past decade helped to identify best practices and the limitations of different approaches. Reports from organisations involved in agricultural extension such as the FAO, and national ministries of agriculture contain data on existing information channels and their use by farmers.

Longitudinal data on ICT access and use over time were extracted from databases managed by the International Telecommunication Union (ITU), the World Bank and national regulatory authorities. Trends in mobile phone ownership, Internet access and the use of ICTs for agricultural purposes in Benin and comparable countries were analysed.

3.1. Data Analysis

Both quantitative and qualitative secondary data analysis methods were used. Quantitative indicators of effectiveness from impact evaluations and previous surveys were synthesised using descriptive statistical analysis. Qualitative information on factors influencing adoption and farmers' perceptions was examined through thematic and content analysis. Case studies of exemplary information dissemination projects and programmes implemented in Benin and other countries complete the analysis. The mixed approach aims to provide a comprehensive assessment of the information dissemination approaches tested in the context of small-scale agriculture in Benin.

4. Literature Review

4.1. Overview of Benin

4.2. Geography and Climatic Features

Benin is a West African country with a surface area of 114,760 square meters, sharing land borders with Niger, Burkina Faso, Togo and Nigeria (World Bank 2023). In 2023, the country's population is 13.35 million inhabitants, including 6.3 million women.

The country experiences a tropical climate with distinct wet and dry seasons that are controlled by the movement of the inter-tropical convergence zone (ITCZ). The country's characteristics are influenced by its proximity to the equator and the presence of the Atlantic Ocean to the south. The wet season typically lasts from April to October. During this period, the country receives most of its annual rainfall 200-300mm monthly. The rain is heavy and frequent, especially in the country's southern regions. The north usually receives less rainfall this season (World Bank 2021). The dry season occurs from November to March. This period is characterised by lower humidity and little to no rainfall. During the dry season, Benin experiences the influence of the Harmattan winds. These dry and dusty winds blow from the Sahara Desert and can lead to reduced visibility and cooler temperatures in the country's northern parts. There is a noticeable north-south climatic gradient in Benin. It's happening in the southern part of the country, which is closer to the coast and the Atlantic Ocean, tends to be more humid and receives higher amounts of rainfall compared to the drier and hotter northern regions. The average temperatures in Benin range from around 24°C (75°F) to 31°C (88°F) throughout the year (World Bank 2021).

4.2.1. Benin's Economy

Benin's economy is primarily based on agriculture, with 45% of the population involved in primary agricultural production (FAO et al. 2018; World Bank 2023b). However, poverty remains prevalent due to limited per capita growth (only 1.80% over the period 2016-2022). The national per capita deprivation rate was estimated at 55% in 2022.

Female-headed households experience lower levels of poverty (28% compared to 38% for male-headed households), but women generally suffer from a lack of economic opportunities and are under-represented in leadership positions (MAEP et al. 2019). The education and health sectors absorb a large share of public spending (23% on average for education and 7% for health) (Nonvide & Gbêtondji 2023). However, there is a need for greater equity in their geographical distribution, as well as greater effectiveness and efficiency in the management of these two sectors. According to World Bank (2024), Benin is not ranked very highly 149 out of 190 countries in 2024 but it has recently made progress in terms of business creation and electricity production. As for agriculture, it is a core component of Benin's economy with a share of 27% in the Gross Domestic Product (GDP) (World Bank 2023a). It is the mainstay of 54.8% of the population and accounts for 75 to 90 % of official exports (MAEP et al. 2019; World Bank 2023b). The agricultural sector remains dominated by small-scale subsistence farming, with around 80% of the rural population depending on agriculture for their livelihoods (FAO 2017). Cotton is one of Benin's most important cash crops, accounting for nearly 40% of GDP and around 80% of export earnings as reported by the (World Bank 2023a). However, Benin's heavy reliance on cotton makes the economy vulnerable to fluctuations in global cotton prices. Other key agricultural commodities produced in Benin include cashews, maize, yams, cassava, rice, cowpeas, palm oil, and cocoa (FAO et al. 2018). Despite the importance of agriculture, yields remain low in Benin, averaging around 1.5 metric tons per hectare for cereals between 2011 and 2019 according to data from (MAEP et al. 2019). This is well below the average yield for Sub-Saharan Africa of 2 metric tons per hectare, indicating there is a significant potential to boost agricultural productivity through improvements to farming techniques and investment in irrigation infrastructure (Misaki et al. 2018). While agricultural production has been increasing gradually, domestic production is still not enough to meet national demand, resulting in Benin remaining a net importer of food such as rice according to the (World Bank 2023b). Strengthening the agricultural sector through yield-enhancing initiatives and the development of agro-processing industries could therefore help improve food security and support greater economic growth and development in the future.

4.2.2. Agricultural System of Production & Farmers Characteristics

Farmers in Benin are influenced by various factors such as agroecological aspects, tenure systems, farm sizes, crop and livestock production, levels of technology adoption, management practices, and income levels (FAO et al. 2018). The three main agricultural production systems in Benin are subsistence farming, market-oriented farming, and agro-pastoralism (FAO 2018). Subsistence farming is prevalent in rural areas and involves small-scale cultivation of staple crops like maize, millet, and yams for local consumption. Farmers use traditional methods and limit modern inputs, and the focus is on food security for the household (FAO et al. 2018). Yields from subsistence farming are typically low due to the use of local varieties and lack of fertilizer and mechanization (Loko et al. 2022).

Market-oriented farming, on the other hand, targets cash crops and is practised by larger-scale farmers in more accessible regions. Cash crops such as cotton, cashew nuts, and oilseeds are grown for sale in local and international markets, contributing significantly to the country's export earnings. Market-oriented farming often integrates modern technologies and inputs to maximize yields and quality (Zhang et al. 2021).

Agro pastoralism is common in the northern and central regions of Benin, where livestock rearing and crop cultivation are combined. Herders raise cattle, sheep, and goats, which graze on communal lands, while farmers cultivate crops like sorghum, maize, and groundnuts in the same areas (FAO 2024). This integrated approach benefits both livestock and crop production, as the animals contribute to soil fertility through manure, while crop residues serve as feed for the livestock. As reported by FAO et al. (2018) poor infrastructure, flooding, and lack of access to markets are major challenges faced by Beninese farmers.

4.3. Understanding the Agricultural Information

Agricultural information encompasses a wide range of subjects relating to agricultural practices, production methods, technologies, policies, markets, etc. Several important authors have provided definitions that help us to better understand agricultural information. Ndimbo et al. (2023) defined agricultural information as information that farmers, their advisors, and families require to make informed decisions in their farming operations and improve their livelihoods.

This broad definition encompasses information needed at all stages of agricultural production from inputs like seeds and fertilizers to post-harvest handling and marketing. Abubakar et al. (2010)focused more on communication aspects, describing agricultural information as the communication of knowledge and technology between individuals or groups to adapt farm management and rural life to changes in the economic and natural environment. This highlights the role of information sharing in helping farmers adapt to changing conditions.

Major actors involved in the generation and dissemination of agricultural information include government agricultural ministries, extension services, private consultant universities, non-governmental organizations, credit organisations, training and education institutions input suppliers, traders, and farmer organizations (Kamara et al. 2023). The main internal structures within agricultural information include research stations that develop new technologies and practices, extension services that disseminate this information to farmers, agricultural libraries and documentation centres that collect and organise relevant publications and reports, and information and communication technology departments that develop applications, websites and other digital solutions (Kamara et al. 2023). The number of actors and their involvement in a given innovation system can largely influence the success of the system and are considered important in promoting an effective agricultural innovation system.

4.3.1. Types of Agricultural Information Dissemination

For generations, agricultural information dissemination models have played a key role in the transfer of information to small-scale farmers in sub-Saharan Africa. Various methods are used to disseminate important agricultural data and knowledge to farmers. Referring to Figure 1, ICTs are defined as any innovation using channels such as radio, telephone, television or satellites, to collect, analyse and share decision-making information for rural stakeholders. One of the primary means of dissemination is through agricultural extension services. The agricultural extension services were the most formal and institutionalized approach used by governments and development projects. These services act as a bridge between the latest scientific knowledge and practical farming techniques, ensuring that farmers have access to the best methods for growing crops, managing pests, and taking care of their land (Mapiye et al. 2021). Extension agents disseminate information through farm visits, demonstration farms, field days, farmer training programs, and printed materials like pamphlets, posters, and manuals (Olayemi et al. 2020).

They also utilise information and communication technologies (ICTs) like telephone hotlines, radio, television, and the internet to spread advisories and updates on weather, prices, pests and disease outbreaks. Agricultural field schools and training programmes organised by research centres also pass on new techniques through experimentation (Olanrewaju & Farinde 2014). In Benin, the agricultural extension services are primarily provided by the MAEP, along with various non-governmental organizations (NGOs) and international agencies like GIZ (German Development Corporation) which work closely with farmers at the grassroots level (MAEP-Benin 2024). However, this top-down, transfer-of-technology model faced numerous challenges including limited resources, poor access in remote regions, a high ratio of farmers to extension agents, and a lack of consideration for indigenous knowledge and farmers' needs and priorities (Olayemi et al. 2020).

Mass media like newspapers, radio, television, and are widely used platforms for broadcasting agricultural programs and disseminating advisories. Radio remains one of the most accessible and widely used media in rural communities, providing timely information on weather forecasts, market prices and best farming practices (Lwoga 2010). This media represents a powerful and accessible medium that effectively reaches diverse audiences, including those in remote and rural areas thanks to its wide coverage and low cost of access. According to Mtega & Msungu's (2013) investigation into rice production in Kilosa district of Tanzania, it was discovered that 97% of smallholder farmers consider radio to be a trustworthy source for receiving agricultural knowledge and information, followed by television 67% and mobile phones 66%. Ndimbwa et al. (2019) further stated that it also addresses challenges related to illiteracy and language diversity, making it an inclusive medium for information dissemination. Mumuni et al. (2023) highlight the necessity to improve the use of television by strategically optimising the program content based on the diffusion time as television's reach is more limited by infrastructure, but it can have an impact where it is available. Similarly, Ndimbwa et al. (2019) reported that a lack of electricity, battery expenses, and poor time of radio and TV programmes limit smallholder farmers' access to agricultural knowledge and skills acquired through electronic media. For example, while radio is widely available, it allows only one-way communication (Mapiye et al. 2021). The two-way communication enabled by mobile phones and internet platforms can enable real-time feedback and information sharing between users.

According to ITU (2024), mobile cellular subscription rates have increased significantly in the region over the last decade, with more than 70% of the population covered by a mobile cellular network. A study conducted by Kaske et al. (2018) revealed that mobile phones have proven to be effective in reaching many farmers, including those in remote areas. It overcomes barriers of distance and limited access to physical extension services providing a cost-effective and scalable solution for knowledge transfer in agriculture. This interactive and accessible platform ultimately contributes to improved agricultural practices, by providing opportunities to disseminate timely agricultural advisories and market price information to farmers via SMS, voice calls, or mobile applications. Several models have demonstrated success, such as Nigeria's Esoko platform which transmits localized weather forecasts, pest and disease outbreak alerts, and commodity prices to over 250,000 registered farmers (Abdullahi et al. 2021). In Benin, the ongoing Programme d'Appui aux Filières Agricoles project uses a similar ICT-based model to share best practices on improved seeds and fertilizers with maize and soybean farmers (Présidence de la République du Bénin 2023). On the other hand, while mobile phone ownership is widespread, internet penetration is still relatively low in rural areas where the majority of farmers live and work (ITU 2024). Additionally, precision farming techniques such as sensors and drones collect real-time data on soil conditions, weather patterns, and crop health, enabling informed decision-making for precise resource allocation (Tyagi & Pandey 2024).

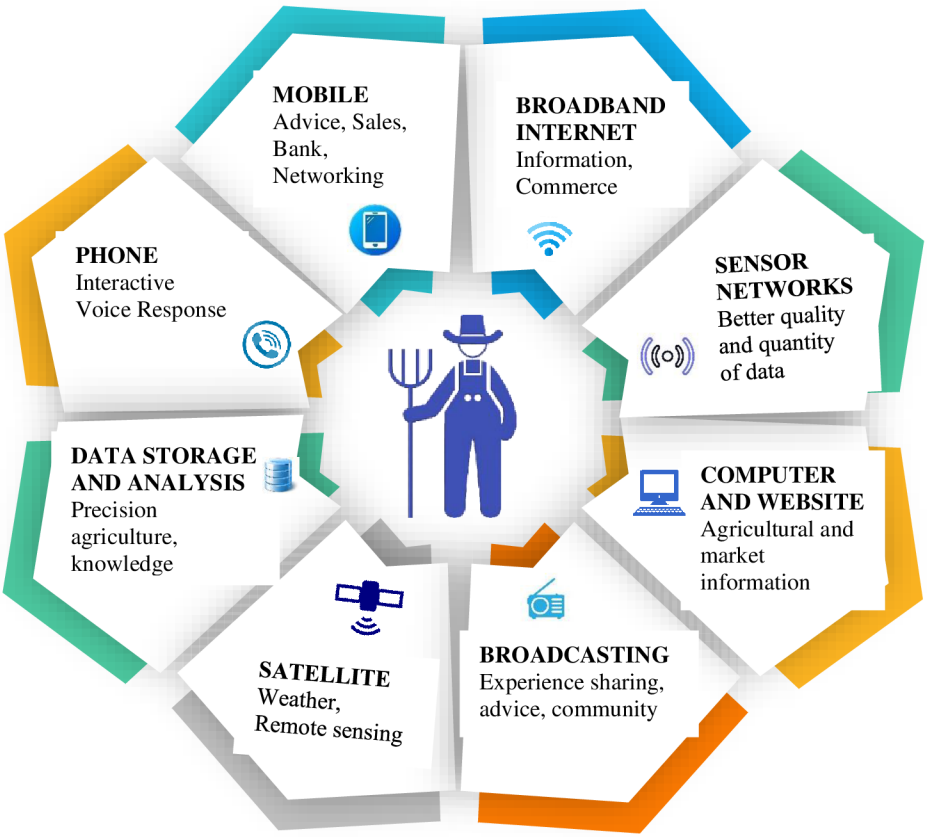

Figure 1 Different media for access to digital agricultural solutions

Source**:** Elaborated from MAEP et al. (2019)

4.3.2. Major Actors in Agricultural Information Dissemination in Benin

The primary actors involved in disseminating agricultural information to farmers in Benin include governmental organisations, non-governmental organisations (NGOs), farmer organisations, and research institutions. The Ministry of Agriculture, Livestock and Fisheries (MAEP) and the Ministry of Digital Affairs (MND) are the main governmental bodies responsible for agricultural extension services and disseminating new technologies and best practices to farmers (Gouroubera et al. 2020). Within the MAEP, the Directorate of Agricultural Extension and Training (DEFC) plays a lead role in training extension agents and supporting farmer field schools.

However, the public extension system in Benin faces challenges including limited funding, lack of transportation for extension agents, and low agent-to-farmer ratios which hinder effective information delivery (Kokoye et al. 2013). As a result, NGOs have become increasingly important partners in complementing public agricultural extension.

A total of 121 organisations are involved in Benin's e-agriculture ecosystem, largely made up of private companies (34%), NGOs (17%), government organisations (13%) financial partners (13%), and to a lesser extent agricultural inter-professional organisations (7%), incubation/acceleration structures (8%) and research and teaching centres (8%) (ACED-BENIN 2023). However, 74% of respondents to a survey carried out by the same NGOs indicated a low level of collaboration between all the players in the ecosystem. The low level of collaboration can be explained by the fact that the players know little or nothing about each other and are generally suspicious of each other. Inadequate reliability is a key factor in sharing information within a network and in inter-organisational cooperation.

4.3.3. Importance of Agricultural Information Dissemination

Agricultural information is key to empowering smallholder farmers and improving agricultural productivity. As shown in Figure 2, timely access to relevant information helps farmers make informed decisions at various stages of farming from seed selection and sowing to pest management, harvesting, post-harvest handling and marketing (Singh & Dey 2023). Information related to improved farming practices, weather forecasts, market prices and availability of inputs can significantly impact yields and incomes. For example, lacking information about high-yielding seed varieties or effective pest control measures results in suboptimal production. Nicholas-Ere (2017) added that a lack of market information makes farmers vulnerable to exploitation by middlemen and prevents them from getting better prices for their produce. With changing climate patterns, timely information about expected rainfall patterns, droughts or floods allows farmers to choose appropriate crops and adjust sowing times (Musafiri et al. 2022). Early warning systems based on weather forecasts help farmers protect their crops and livestock from extreme weather events. Information related to water and soil management practices is also crucial for building the long-term resilience of smallholder farms to climate change impacts.

For instance, knowledge about mulching, composting, rainwater harvesting, and conservation agriculture techniques can improve soil health and moisture retention capacity of soils (Issahaku & Abdulai 2020). Agricultural information dissemination is hence an essential tool not only for managing the risks associated with price anomalies but also for promoting sustainable and resilient food systems through incentives for good practices, disaster support, market interventions and rural development programs.

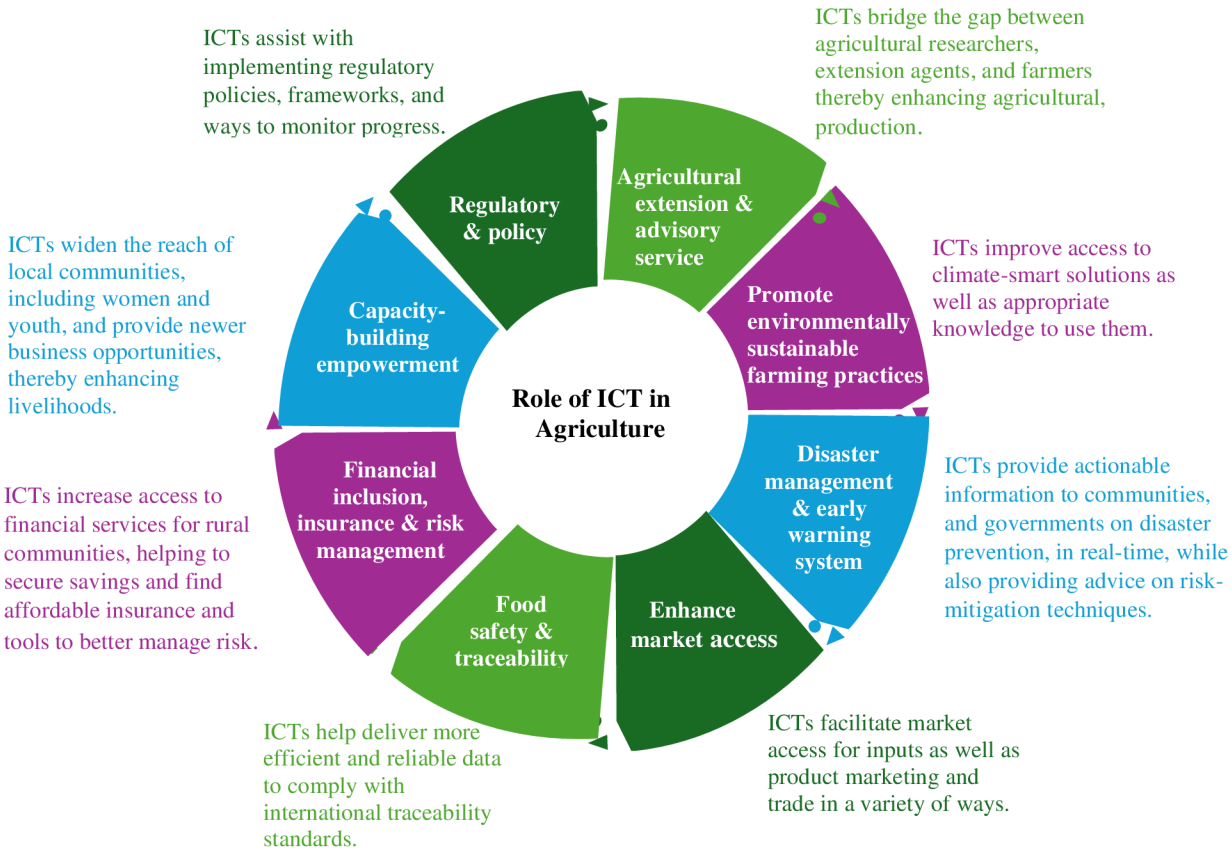

Figure 2 Role of ICT in agriculture elaborated by MAEP et al. (2019)

4.4. ICTs in Sub-Saharan Africa & Benin

ICTs have become increasingly important drivers of economic and social development in sub-Saharan Africa in recent decades. ICTs have become increasingly important drivers of economic and social development in sub-Saharan Africa in recent decades.

While access to ICT infrastructure such as the Internet, mobile phones, and computers has traditionally lagged behind other regions of the world, connectivity in Africa has expanded rapidly due to major investments and innovations. According to the ITU (2024), only about 25% of individuals in Sub-Saharan Africa use the Internet, compared to global rates of around 50%. The rapid expansion of wireless networks has helped to close the digital divide in Africa, providing more remote and rural populations with access to communication tools and online services for the first time. Alongside infrastructure development, ICT use has also proliferated in sectors such as education, healthcare, agriculture, and finance. A study made by Abdullahi et al. (2021) showed how mobile phones have improved productivity and welfare for smallholder farmers through better access to market information, weather forecasts, and extension services.

Although access to and use of ICTs is growing, barriers to their access and adoption are prevalent in the region. According to the field data gathered by Mubofu & Elia (2017a), a large majority of farmers, specifically 88 out of 90 (97.8%), identified inadequate funding as the primary obstacle to the spread of agricultural research information. In contrast, a smaller proportion of farmers, only 65 (72.2%), attributed the issue to a limited number of extension officers. The study also uncovered that 79 (87.8%) of the farmers believed that a lack of reliable information sources hindered the effective dissemination of agricultural research information. Additionally, 78 (86.7%) mentioned the absence of information centres, and 76 (84.4%) cited political interference as key challenges. Another significant barrier identified by 72 (80%) of the farmers was the unavailability of electricity. These findings demonstrate the various obstacles that hinder the successful distribution of agricultural information.

4.4.1. ICT Smart Usage in Agricultural Practices in Benin

ICT usage in agricultural practices is paving the way for a more efficient and sustainable farming sector. It represents a transformative approach that leverages Information and Communication Technology (ICT) to revolutionise traditional farming methods. This integration of digital solutions, data analytics, and automation aims to enhance productivity, sustainability, and efficiency across various facets of agriculture. Ever since it acceded to independence, Benin has witnessed a transformative wave of technological integration, particularly in the field of information and communication technologies.

This integration, while promising immense opportunities for growth and innovation, has also presented a series of challenges, ranging from infrastructural limitations to digital literacy gaps and accessibility issues, highlighting the complex interplay between technology adoption and societal development (see Table 2). The extent of ICT use in agriculture has evolved as a result of the technological revolution in agriculture around the world. Based on an analysis of Table 1, we can see that the country has taken several different approaches to reforming its agricultural policies, from 1960 to 2020. Outlined below (see Table 3) are the significant barriers that have impeded the effective utilization of Information and Communication Technology (ICT) in Benin over the past 15 years, highlighting the multifaceted challenges faced by the farmers in harnessing the potential of digital tools and technologies. Several studies have shown that using ICTs such as mobile phones, radio, television, and the Internet can help improve agricultural productivity, market access, and rural incomes for smallholder farmers. In Benin, where most of the population depends on agriculture for their livelihoods, promoting greater access to ICTs is seen as a key part of the government's strategy to modernize the agricultural system and reduce poverty in rural areas (Nonvide & Gbêtondji 2023). To achieve this, the government has prioritized ICT development, launching initiatives like the Universal Access to Information and Communication Technologies project in 2015 to establish community access centres in rural areas previously underserved (MAEP et al. 2019). He also added that ICTs are being used by farmers in several ways.

Mobile phones are the most widely adopted technology and are mainly used to gather market price information, stay in touch with buyers and sellers, and coordinate the logistics of transporting produce (Harris & Cooper 2019; Nonvide 2021). As of 2022, there were around 7 million mobile cellular subscriptions in Benin, equivalent to about 80% of the population, representing a mobile penetration rate of 52.7% (ARCEP-Benin 2022). In addition, the number of subscribers Internet subscribers is estimated at 5,435,257, representing a mobile penetration of 42.1%. The number of 3G and 4G users has increased compared with 2021. From 51.47% in 2021, this proportion has risen to 57.87% in 2022, an increase of 6.4 points (ARCEP-Benin 2022). When it comes to mobile money, services like MTN Mobile Money have also grown in popularity as they enable for financial inclusion of those without bank accounts (GSMA 2023). However, internet access outside the major cities remains limited due to infrastructure gaps, with rural penetration still only around 15% (MAEP et al. 2019).

The price of internet access and mobile data remains high and unaffordable for most citizens (MAEP et al. 2019). Digital literacy is a challenge, with over 30% of the population lacking basic computer skills (Gbètoton et al. 2022). To address these challenges and harness the potential of ICTs for agricultural development, a multi-faceted approach is needed to maximise the socio-economic benefits of ICT development in Benin.

Table 1 Summary of approaches and ICT used over time in Benin

Approaches	**Definition**	**Type of ICT used**	**Level of valorization**	**Period**
Sector-based approach	It is focused on promoting a specific sector using a top-down approach	Radio	High	1960
Training and visit	A top-down approach based on mass agricultural extension and demonstration plots as the main tool	Radio	High	1986
Village-Level farm Approach	More participative approach than the previous ones. It aimed at involving farmers but remained low led to other approaches	Radio	Moderate	1996
Farmer-to-farmer approach	Endogenous approach based on the dynamization of farmers' organizations. Farmers get knowledge through mutual exchange.	Radio	Moderate	1998
Advisory services to the family farm	This approach helped farmers to decide for themselves considering the whole farm	Radio, GPS	Moderate	1998
Farmers Field School	It is an approach based on certain principles of the APNV to induce farmers to adhere to agro-ecological principles. Local knowledge is valued.	Radio, phone, TV and GPS	Moderate	2000
Demand-pull approach	Farmers themselves initiate their requests and choose the appropriate approach.	Radio, phone, TV and GPS	High	2004
Faire-Faire approach	It is a multi-stakeholder approach based on the valorization of potential value chains of each territory at a national level. The government intervenes through service providers (Fait-Faire approach)	Radio, phones, projectors exchange platforms, tablets, smartphones, drones, GPS	Low	2017-2020

Source: Elaborated from Gouroubera et al. (2020)

Table 2 Challenges resulting from the use of ICT in Benin over the last 15 years

Challenges	Description	References
Low rates of technology adoption	• With only 56% of households owning a phone and just 0.8% owning a computer • Illiteracy that limits the ability to fully utilize ICTs for tasks	(Nonvide 2021)
Poor infrastructure	Weak infrastructure such as unreliable electricity supply and poor internet connectivity in rural areas of Benin pose major barriers to accessing and using ICT technologies for agriculture	(Nonvide Armel & Gbêtondji Melaine 2023; Akpa & Chabossou 2024)
Lack of digital skills	Many smallholder farmers in Benin have low levels of digital literacy and lack the skills needed to effectively use technologies like smartphones, computers, and internet platforms for obtaining agricultural information and services	(Gbètoton et al. 2022)
High costs	The costs associated with devices, internet access, and related services are still quite high for many farmers in Benin, limiting their ability to adopt and regularly use ICT.	(Aminou et al. 2018) (Adégbidi et al. 2012)
Lack of relevant content	Even when ICT access is available, farmers do not adopt technologies because the information and services provided are not in local languages, tailored to local conditions, or address their priority needs.	(Affougnon 2009) (Moutouama et al. 2022)
Trust and awareness	Farmers are hesitant to adopt new technologies if they do not trust the sources of information or fully understand the potential benefits.	(Aminou et al. 2018)

Source: Elaborated by the author from various articles on the challenges facing ICT in Benin

Table 3 Barriers encountered in using ICT in Benin over the last 15 years

Barriers	Description	References
Limited access to Information and Communication Technologies (ICTs)	• Access to technologies like computers, the internet, mobile phones, etc. is still limited for many farmers in Benin., • Only about 37% of individuals in Benin use the internet • 27% of rural households in Benin have access to the internet, compared to 65% in urban areas	(ITU 2024) (Nonvide & Gbêtondji 2023)
Lack of infrastructure	• Benin has poor rural infrastructure like roads, electricity, and internet connectivity which limits access to agricultural extension services and up-to-date information.	(Akpa & Chabossou 2024a)
Inadequate extension services	• The ratio of extension agents to farmers is very low in Benin at 1:1000, making it difficult to reach all farmers. The extension system is also ineffective and top-down in approach	(MAEP et al. 2019 ; Gouroubera et al. 2020)
Low literacy levels	• Literacy rates are relatively low, especially for older farmers; • over 60% of farmers in Benin have not received any formal education. • The lack of extension materials in local languages like Fon, Adja and Bariba limits their uptake among smallholder farmers.	(Zoundji et al. 2018) (MAEP et al. 2019)
Language barriers	• Over 40 different ethnic groups and over 100 local languages spoken in Benin in addition to the official languages of French and Fon • an adult literacy rate of only 42.4% in Benin, with rural rates even lower.	(MAEP et al. 2019) (Gbètoton et al. 2022)
Lack of funding	• The government of Benin allocates under 5% of its budget to the agriculture sector, • Limited budgets restrict the hiring of enough extension workers and hamper the development and dissemination of new information resources for farmers	(MAEP et al. 2019) (Gbètoton et al. 2022)
Gender inequalities	Female farmers in Benin face additional barriers like lower literacy rates and restrictions on their mobility. Extension services do not always adequately consider their needs and constraints.	(Aminou et al. 2018; Loko et al. 2022)
Limited farmer organizations	Most farmers in Benin work as individuals rather than cooperating through strong community groups. This makes disseminating information on a larger scale more challenging	(Zoundji et al. 2018)

Source: Elaborated by the author from various articles on the use of ICT in Benin

4.4.2. Factors Associated with the Adoption of Modern Usage of ICT

The adoption of modern usage of ICT in agriculture is influenced by several factors that shape the willingness and ability of farmers to embrace these technologies (see Table 4). One key factor is the costs involved in utilizing ICT services. Radio and television serve as valuable communication tools for farmers, but their usage is often hindered by the high costs of fuel and maintenance for generators. The less well-off communities resort to using expensive dry cells, which can cost up to 3 US dollars each and only last for a week or two. Furthermore, the frequency that television is used is heavily impacted by the availability of electricity. In locations with insufficient rural electricity, the use of television has declined substantially, particularly for the majority of farmers in these rural areas. This is supported by Van Heddeghem et al. (2014) the prevalence of restricted access to electricity in rural areas has been identified as the main reason for the limited television consumption. A study conducted by Abubakar et al. (2010) in Kebbi state in Nigeria revealed that 35% of respondents found the high cost of obtaining and upkeeping media sources (such as batteries, televisions, and radios) was a major concern for them. Additionally, 20% of the participants cited an inability to quickly respond to media as a constraint, while an equal percentage pointed to power outages as a hindrance to receiving information. Surprisingly, 13.75% reported no issues with their media experience, while 11.25% highlighted poor signal quality as a problem when it comes to the information they receive from media sources. In a similar investigation, Ndimbwa et al. (2021) discovered that obtaining information from media sources posed several challenges. These included limited airtime for programs (47.62%), expensive electronic devices (17.86%), and insufficient electricity (15.48%). These issues emerged as major constraints in accessing media information. According to Mapiye et al. (2021), it has not only affected the integration of new technologies in various fields but also the economic growth of the country.

Economically, the high costs associated with infrastructure development, laying cables, and ensuring a stable power supply require massive capital investments that many countries in the region cannot afford on their own (Awad & Albaity 2022). This negatively impacts the ability of smallholder farmers to access technologies. However, some countries have seen success through public-private partnerships that share the financial burden of expanding low-cost access through initiatives.

For example, a project co-funded by the government of Rwanda and private telecom companies expanded 3G coverage to over 90% of the population within just 3 years (Kimanuka 2009). On the other hand, ICT also enables the development of digital financial services like mobile money, which has been shown to increase household welfare in countries like Cameroon by facilitating financial assistance between family members (Atangana Ondoa et al. 2023). Aminou et al. (2018) also demonstrated that maize farmers in Benin who owned mobile phones were able to increase their agricultural yields and productivity. More broadly, Appiah-Otoo & Song (2021) examine the impact of ICT on economic growth by comparing rich and poor countries (123 countries consisting of 45 high-income countries, 58 middle-income countries, and 20 low-income countries indicating that greater ICT infrastructure and utilization is associated with overall economic growth and diversification across industries in economic growth in both countries, however, poor countries tend to gain more from the ICT revolution.

Political figures played a critical role in the challenges they faced while seeking access to information about agricultural research. Contrary to their expected role as facilitators in establishing a positive relationship between extension agents and local farmers, these leaders were found to exacerbate communication barriers and hinder effective service delivery, as their political ideologies clashed. This situation corroborates the study of Mubofu & Elia (2017b), who pointed out that the most pernicious issues affecting the dissemination of agricultural research results are people's inability to think and come to rational decisions as a result of interference. Benin has not been spared from this problem as according to Affougnon (2009), the ICT sector in Benin has been characterized by an absence of legal and institutional framework. As stated by Kathryn Toure et al. (2008), the institutional arrangements regarding the use of ICT in Benin were only intentional statements. In contrast, since 2014 there has been a strong will of the government to revolutionize agriculture in Benin by the introduction of three phases of political innovations (selection, implementation and the connection to the institutional context). This resulted in the initiation of several pilot projects like the Esoko platform which is a multi-sector communication platform to share knowledge, Owodara sim platform to inform farmers about agricultural product prices…) (Gouroubera et al. 2020). Aside from these initiatives, the Ministry of Agriculture has established a specialized department focused on integrating ICT into agriculture.

At the same time, certain socio-cultural factors have hampered the widespread adoption of ICTs. For example, gender, age, and low levels of digital literacy, particularly in rural areas, have hampered farmers' ability to access and make full use of online agricultural resources (Ogisi & Begho 2023). Additionally, traditional gender norms that view technology as a male domain have meant lower ICT access and skills among female farmers (Marwa et al. 2020). The results of Siyao (2012) on the small-scale sugarcane growers in Tanzania indicated that the lack of knowledge and skills in information retrieval was a constraint in accessing agricultural information. It was highlighted in this study that twice as many women (18%) as men (9%) indicated that they lacked skills and knowledge on how to search for agricultural information. The same study revealed that two women (2.6%) were illiterate, but only one man (1.28%) was illiterate. This reflects the fact that women's literacy levels are lower than men's. Recent research has revealed that there was a cultural restriction concerning women since they are controlled by their husbands and as such it limits their chances of making contact easily with a male extension officer (Ogisi & Begho 2023). Another issue is the lack of availability of localized content in local languages. In many rural areas of Benin and other francophone West African nations, the predominant languages spoken are local dialects rather than French, despite it being the official language (Adégbidi et al. 2012). The digital divide is exacerbated by this language divide, as rural farmers without French literacy skills are unable to make full use of ICT resources available only in French. To address this, initiatives like Esoko in Ghana have worked to provide price and weather information to farmers via voice and SMS messages in multiple local languages like Twi, and Ewe, to overcome low literacy rates as a way of more effectively disseminating information (Etwire et al. 2021).

Table 4 Review of Factors influencing the implementation of ICT in Benin

Factors influencing the implementation of ICT in Benin	Description		References
	Positive	**Negative**	
Technological	Increased Productivity; Affordability of Devices Market Opportunities Increased digital literacy through training programs; Affordability of devices and services	Digital Divide: Economic disparities among farmers may widen the digital divide, with wealthier farmers benefiting more from ICT adoption while marginalized groups are left behind Cost-Benefit Concerns Limited Connectivity in Rural Areas: High cost of services; Low level of digital literacy to use ICT tools	(Nonvide 2021) (MAEP et al. 2019) (Akpa & Chabossou 2024a)
Political	Supportive Government Policies that expand access Well-defined regulatory framework Effective extension services integrating ICT Investment in ICT Infrastructure	Limited government investment Restrictive regulation relative to the use and data management; Insufficient coordination between different government agencies involved in ICT that create barriers to adoption and innovation among farmers;	(MAEP et al. 2019) (Gouroubera et al. 2020)
Socio-cultural	Adoption improves yields; social networks; Tailored information; trust in technology providers; peer influence; perceive relevance and utility, education and digital literacy	Resistance to change; language and literacy barriers;	(Aminou et al. 2018) (Zoundji et al. 2018) (Nonvide & Gbêtondji 2023)
Economic	Market access and better prices; increase productivity; digital market opportunities; enhance financial inclusion and facilitate transactions within the agricultural value chain;	Economic disparities among farmers; Concerns about the initial costs of the device; Uncertainty about the long-term benefits; Scarce financial resources and budget constraints hinder Investment in ICT infrastructure and projects, slowing down implementation efforts	(Akpa & Chabossou 2024a) (Nonvide & Gbêtondji 2023) (Aminou et al. 2018) (MAEP et al. 2019) (Jimmy et al. 2016)

Source: Elaborated by the author from various articles on the use of ICT in Benin

4.5. Effectiveness of Agricultural Information in Benin

The dissemination of timely and relevant agricultural information to smallholder farmers is crucial for improving agricultural productivity and food security in sub-Saharan Africa. However, studies have shown mixed results on the effectiveness of different channels used for information dissemination in the region. The studies conducted by Aminou et al. (2018) found that mobile phone ownership has a significant positive impact on agricultural productivity among maize farmers in Benin. The results indicate that owning a mobile phone increases maize production as it allows extension workers to effectively provide farming techniques and information to farmers whilst not having to be physically present, thereby improving productivity.

Furthermore, mobile phones also showed potential as a moderately effective channel, as over 50% of farmers in the study cited them as useful for receiving agricultural tips and market price information (Aminou et al. 2018; Akpa & Chabossou 2024). As mobile phone ownership continues to rise across Africa, this channel could become more impactful over time. Additionally, radio training sessions, meetings with extension agents, and interpersonal communication between farmers were among the most effective channels for delivering agricultural knowledge to smallholders (Adégbidi et al. 2012; Perpétus & Houngbo 2015; Paul Jimmy et al. 2016). Radio in particular was found to be very effective due to its widespread reach, even in remote rural areas. However, the relevance and frequency of information broadcast on radio can be inconsistent.

In contrast, the Internet was found to be only slightly effective currently due to low Internet access among smallholder farmers (Nonvide & Gbêtondji 2023). However, the Internet represents a promising avenue for the future as connectivity improves. For example, a study found that providing farmers with smartphones loaded with agricultural apps and information significantly increased their knowledge and productivity compared to a control group (ACED-BENIN 2023). While over 40% of farmers in the country study cited extension agents as very effective conduits of information, other research has found issues with timeliness, relevance, and the frequency of agent visits that reduce their impact in some areas (FAO et al. 2018). Utilizing a mix of both modern ICT channels and traditional face-to-face approaches may be most effective currently for information dissemination depending on the local context and farmers' needs. As technologies continue to spread, a gradual shift towards more digital solutions also holds promise.

4.6. Policy/Program and Major Actors of ICT in Benin

4.6.1. Policy toward ICT in Benin

Benin has recognized the importance of integrating ICT into the agricultural sector and has implemented several policies and strategies to facilitate it. This integration is influenced by national policy innovations, which can be classified into three dimensions: innovation propensity, innovation capacity, and innovation practice. These dimensions are as follows: (i) the government's propensity to innovate, which represents the series of decisions, laws, decrees, and strategic documents taken by successive governments; (ii) the capacity to innovate, which represents the policies taken to facilitate the integration of ICTs; and (iii) innovation practice - the ability to effectively use of the idea (Gouroubera et al. 2020). This helped lay the foundation for future ICT integration efforts. In 2014 Benin established Law no 2014-22, related to digital broadcasting in Benin Republic regarding ICT utilization which aimed to regulate and support the development of ICT across sectors (MAEP et al. 2019). Additionally, institutions like the Commission for Information Technology and Telecommunications were established to develop, implement and monitor ICT policies (Gbètoton et al. 2022). More specifically for agriculture, in 2019 Benin adopted the National Strategy for the Development of Digital Agriculture in Benin 2020-2024 which sought to promote ICT integration into the agricultural sector inclusively and sustainably (MAEP et al. 2019). The implementation of this strategy is divided into three (03) components: (i) the development of connectivity infrastructures and equipment and the large-scale dissemination of agricultural e-services, (ii) the promotion of the adoption of digital agricultural solutions, and (iii) the strengthening of the MAEP steering, information and monitoring and evaluation systems for the development of intelligent agriculture.

Despite these policies and initiatives, studies show that the level of ICT institutionalisation remains low in Benin's agricultural system (Gouroubera et al. 2020; Akpa & Chabossou 2024). Challenges remain around ICT access, lack of tailored ICT skills training for farmers, and poor coordination between actors (Nonvide & Gbêtondji 2023). Moving forward, fully implementing the existing ICT policies and strengthening multi-sector collaboration could help address these challenges and barriers to disseminating agricultural information to farmers via ICTs in Benin. The policies provide a framework but require dedicated resources and coordination across institutions to realize their goals and potential impact on farmers.

4.6.2. Program of Agricultural Information

The latest reforms in the digital sector have seen the creation of an Information Systems Department (DSI) within the MAEP (Gbètoton et al. 2022). However, creating a central Information Technology system for all the sector's activities represents a significant and effective improvement for the country, as well as facilitating access to information. To this end, fifty (50) Digital Agricultural Solutions divided into four non-exclusive categories are currently being promoted in Benin. These initiatives are encouraged by the annual "Salon des TIC" for agriculture. Table 5 gives some examples of start-ups that are helping to integrate ICTs into agriculture as a solution to the current challenges facing Benin's agricultural sector. These programmes are mainly supported by the private sector (76%), followed by NGOs to a lesser extent (17%), then development and cooperation services (GIZ) and the public sector (7%) (ACED-BENIN 2023).

The first category represents 56% of the total number of Digital Agricultural Solutions, including those aimed at agricultural advice training and information for producers. Among these, are agricultural production advice solutions (for example App céréale, Agricef, Crop management, and Benin riz); weather information solutions available on Agrimétéo, traceability and market information systems with sim Owodara,. These systems enable producers to optimise the cost of selling their agricultural products, avoiding any devaluation or devaluation through better knowledge of prices on the various markets (MAEP et al. 2019; Kudama et al. 2021). In addition, certain market information systems (like Our Voice, Access Agriculture, Interactive Voice Server, and Benin Riz) provide farming advice in different local languages, to increase farmers' interest in these digital farming solutions.

The second major category, which accounts for 16%, includes those focused on the distribution of agricultural and agri-food products. of the total number of digital farming solutions, including those focused on the distribution of agricultural and agri-food products. The effective marketing of these products is a major issue for farmers and, in tackling this problem, these digital farming solutions seek to have a significant impact on food systems, by establishing beneficial and sustainable working relationships between producers and buyers. According to Kudama et al. (2021), this initiative is designed to reduce the middlemen in the value chain and to ensure that producers receive a fair price for their products.

The third category (14%) includes the various agricultural players (like producers, processors, aggregators, and agricultural advisors) by highlighting the services they offer and/or identifying potential customers. Trotro Civa an initiative of GIZ, is the perfect example of this, as it enables farmers to buy a tractor from a private operator simply by using a mobile phone.

The fourth category (32%) includes other services such as the monitoring of crops (such as Précis-agri, Drone4AG, and Drone Analyst), farm mapping, as well as payment and money transfer solutions. No solutions for opting for digitisation or automation of agri-food processing have been proposed in Benin, due to the high cost of setting up by and their subsequent acquisition by farmers. It is also significant to emphasise that more than half (54%) of the digital agricultural systems offered are currently available on the market thanks to the financial support of various organisations (see Figure 3). Similarly, Tsan et al. (2019) stated that the development of digital agriculture in Africa is significantly facilitated by financial support from development partners such as GIZ, or the World Bank.

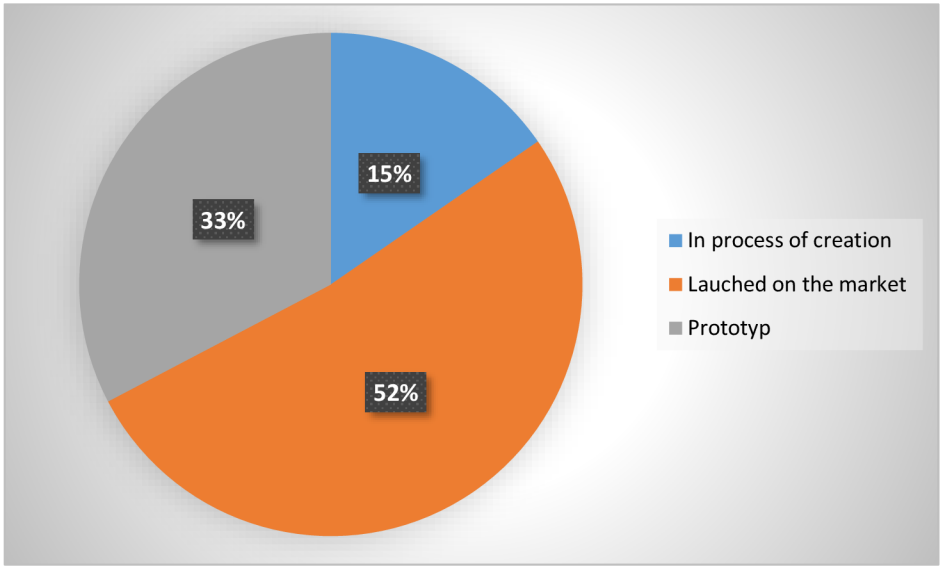

Figure 3 Agricultural digital solution development course

Source: Elaborated from (ACED-BENIN 2023)

Table 5 List of startup operating in the field of e-agriculture in Benin

Startups	Description
Zoom Agro	Agricultural Newspaper in Benin.
Vart-lab Benin	Software that allows the sharing of crop production requirements based on their characteristics and production preferences.
Afrique Cereagro	AppRice is an intelligent assistant which makes it possible to inform, make forecasts and especially alert farmers during unfavourable climatic conditions.
Jinukun Sarl	BtoC is an e-commerce platform for marketing agricultural products from local farms and agrifoods.
Adiyeaba	Adiyeaba is a connected and automatic incubator to increase poultry production in rural areas.
Art Creativity	A system called AgriDroneFlow which detects areas infected with insects in the fields, detects the level of humidity in each area of the field and estimates the agricultural yield of the fields before harvest.
Apiservices Monde	ApisLabTech" digital platform for the promotion of beekeeping in Africa. It is a platform that offers training and support in beekeeping and the e-commerce of beekeeping products worldwide.
Precis AgriC2I Start-up	It is a solution that solves the problems of agricultural land management, poor water management and soil fertilization to face climate change.
Epouvantail connecté	A system that simulates human presence to deter pest animals from devastating the farm.
Social Farming Benin	Agricultural advisory and extension through the use of ICT.
CGA (Agricultural Management Advisor)	Promotes precision agriculture using drones to monitor, and collect data, images, temperature etc. It also helps to control pests, spread fertilizer and irrigate.
AGRIYOUTH	African agricultural entrepreneurship promotion platform for the integration of young people in agriculture.
TIC AGRO BUSINESS	TIC-Agro Business Center (TIC-ABC) is a social enterprise that promotes ICT in agriculture by providing farmers with web and mobile solutions, animation tools (card games), videos as well as voice messages all in local languages.
ISADA Consulting	It is a project that aims at spreading agricultural information in rural areas using farmers learning videos.
Afrique-learning	The training platform is very applied and dedicated to the youth of West Africa. More than 60 courses, mainly in the agriculture sector, are given free of charge.

Source: Elaborated from (Gouroubera et al. 2020; ACED-BENIN 2023)

5. Conclusion & Recommendations

This study sought to review the potential of enhancing ICT-based information dissemination models, identify significant sources of agricultural information for farmers in Benin, and analyse the effectiveness of existing agricultural information dissemination models in reaching farmers. Based on the findings, several conclusions can be drawn.

First, the review showed that ICT-based models such as SMS, mobile apps, and online platforms have great potential to enhance the scale and effectiveness of information dissemination when integrated with traditional methods (Objective 1). These digital technologies allow for timely, targeted messages to reach large audiences at low cost. While ICTs such as mobile phones and community radio show potential, current models have had limited effectiveness in reaching farmers due to issues such as complex technical information, poor rural network infrastructure, and low digital literacy. It is recommended to simplify content for dissemination via these channels, improve rural networks, and provide training to strengthen digital skills among farmers and extension agents. Developing partnerships between different stakeholders could also help support more sustainable ICT models for agriculture.

Second, the study identified key sources of agricultural information for Beninese farmers, including the Ministry of Agriculture, the Ministry of Digital Affairs, extension agents, input suppliers, fellow farmers, radio, and SMS (Objective 2). However, access to and awareness of these sources varied significantly depending on location, demographic factors, and resource constraints faced by different farmer groups. It is recommended to strengthen farmer-to-farmer networks and platforms for peer learning. Extension services could also be revitalized through improved training, resources, and integrated approaches using ICT and farmer field schools. Engaging input dealers through public-private initiatives may further enhance their role as information providers. Expanding agricultural programming on community radio while involving farmers in content development could also increase outreach.

Third, the analysis of ICT models in Benin highlights their potential to transform agricultural practices despite challenges such as limited infrastructure and digital literacy. These interventions have shown tangible benefits including improved market access, crop management, and climate resilience. However, addressing barriers to access and ensuring relevance are crucial for maximizing their effectiveness (Objective 3).

By leveraging lessons learned and implementing targeted strategies, ICT models can drive sustainable agricultural development in Benin. Pilot testing multi-channel models can help identify the most cost-effective approaches for disseminating different agricultural innovations to smallholder farmers in Benin. Implementing these recommendations would help strengthen information flows to support improved productivity, incomes and livelihoods in the agricultural sector.

Overall, this study provides insights into opportunities to strengthen agricultural information dissemination in Benin through strategic integration of ICT and traditional extension approaches. More targeted, multi-channel models tailored to different farmer segments could help promote inclusive rural development and food security if scaled effectively. Further research on best practices, implementation challenges, and impact assessment is still needed.

6. References

Abdullahi KA, Oladele OI, Akinyemi M. 2021. Attitude, knowledge and constraints associated with the use of mobile phone applications by farmers in North West Nigeria. Journal of Agriculture and Food Research **6**. Elsevier B.V.

Abubakar BZ, Ango A, Buhari UH. 2010. The Roles of Mass Media in Disseminating Agricultural Information to Farmers in Birnin Kebbi Local Government Area 0f Kebbi State: A Case Study of State Fadama II Development Project. The Journal of Agricultural Extension **13**.

ACED-BENIN. 2023. ÉCOSYSTÈME DE L'AGRICULTURE NUMÉRIQUE AU BENIN. Available from https://www.acedafrica.org/wp-content/uploads/2023/06/Ecosysteme-de-l-agriculture-numerique-au-Benin_une-analyse-de-l-environnement-institutionnelle-des-solutions-numeriques-et-des-acteurs.pdf (accessed February 18, 2024).

Adégbidi A, Mensah R, Vidogbéna F, Agossou D. 2012. Determinants of ICT use by rice farmers in Benin: from the perception of ICT characteristics to the adoption of the technology.

Aminou FAA, Houensou DA, Hekponhoue S. 2018. Effect of Mobile Phone Ownership on Agricultural Productivity in Benin: The Case of Maize Farmers. Journal of Economics and Development **6**.

Appiah-Otoo I, Song N. 2021. The impact of ICT on economic growth-Comparing rich and poor countries. Telecommunications Policy **45**. Elsevier Ltd.

ARCEP-Benin. 2022. Rapport annuel d'activités. Available from https://arcep.bj/wp-content/uploads/2023/06/Rapport-Annuel-dActivit%C3%A9s-2022-ARCEP-BENIN.pdf (accessed February 8, 2024).

Atangana Ondoa H, Ambombo Bella GL, Mbenga Bindop KM. 2023. Mobile money, family assistance and welfare in Cameroon. Telecommunications Policy **47**. Elsevier Ltd.

Awad A, Albaity M. 2022. ICT and economic growth in Sub-Saharan Africa: Transmission channels and effects. Telecommunications Policy **46**. Elsevier Ltd.

Barnabé Affougnon. 2009. État des lieux des télécommunications au Bénin… pour un engagement plus structurant. Available from

https://www.apc.org/sites/default/files/CICEWABenin_20090911_0.pdf (accessed February 7, 2024).

Drafor I. 2016. Access to Information for Farm-Level Decision-Making. Journal of Agricultural and Food Information **17**:230–245. Taylor and Francis Inc.

Etwire PM, Martey E, Goldsmith P. 2021. Factors that drive peer dissemination of agricultural information: evidence from northern Ghana. Development in Practice **31**:606–618. Routledge.

FAO. 2017. BUILDING Agricultural Market Information Systems: A literature review. Available from https://www.fao.org/3/i7151e/i7151e.pdf (accessed March 25, 2024).

FAO. 2024. Pastoralism knowledge hub. Available from https://www.fao.org/pastoralist-knowledge-hub/pastoralist-networks/regional-networks/west-and-central-africa/en/ (accessed February 14, 2024).

FAO, ICRISAT, CIAT. 2018. Climate-Smart Agriculture in Benin. Available from https://www.fao.org/3/CA1323EN/ca1323en.pdf (accessed March 24, 2024).

Fréjuis Akpa A, Foster Chabossou A. 2024a. Effect of information and communication technology on cashew nut export in Benin. Research in Globalization **8**:100197.

Fréjuis Akpa A, Foster Chabossou A. 2024b. Effect of information and communication technology on cashew nut export in Benin. Research in Globalization **8**. Elsevier B.V.

Gbètoton Nadège Djossou, Sylvain Hekponhoue, Melain Modeste Senou, Bernadin G. C. Ahodode. 2022. Digitalisation des Services Publics au Benin : Challenges et Opportunités. Available from https://includeplatform.net/wp-content/uploads/2022/11/Digitalisation-des-Services-Publics%E2%80%AFau-Benin%E2%80%AF-Challenges-et-Opportunite%CC%81s.pdf (accessed February 15, 2024).

Gouroubera MW, Idrissou L, Moumouni IM. 2020. Political Innovations for ICT Institutionalization in Benin Agricultural System. Asian Journal of Agricultural Extension, Economics & Sociology:264–277. Sciencedomain International.

GSMA. 2023. The Mobile Economy 2023. Available from https://www.gsma.com/solutions-and-impact/connectivity-for-good/mobile-economy/wp-content/uploads/2023/03/270223-The-Mobile-Economy-2023.pdf (accessed April 15, 2024).

Harris A, Cooper M. 2019. Mobile phones: Impacts, challenges, and predictions. Human Behavior and Emerging Technologies **1**:15–17.

ITU. 2024. ITU. Available from https://www.itu.int/en/mediacentre/Pages/2016-PR53.aspx (accessed February 4, 2024).

Kaske D, Mvena ZSK, Sife AS. 2018. Mobile Phone Usage for Accessing Agricultural Information in Southern Ethiopia. Journal of Agricultural and Food Information **19**:284–298. Taylor and Francis Inc.

Kathryn Toure, Therese Mungah Shalo Tchombe, Thierry Karsenti. 2008. ICT and Changing Mindsets in Education / Repenser l'éducation à l'aide des TIC. ERNWACA/ ROCARE.

Kimanuka O. 2009. The Role of ICTs in Rwanda's Development. Pages 87–93 Sub-Saharan Africa's Development Challenges: A Case Study of Rwanda's Post-Genocide Experience. Palgrave Macmillan US, New York.

Kokoye SEH, Yabi JA, Tovignan SD, Yegbemey RN, Nuppenau EA. 2013. Simultaneous modelling of the determinants of the partial inputs productivity in the municipality of Banikoara, Northern Benin. Agricultural Systems **122**:53–59.

Kudama G, Dangia M, Wana H, Tadese B. 2021. Will digital solution transform Sub-Sahara African agriculture? Artificial Intelligence in Agriculture **5**:292–300.

Loko YLE, Gbemavo CDSJ, Djedatin G, Ewedje EE, Orobiyi A, Toffa J, Tchakpa C, Sedah P, Sabot F. 2022. Characterization of rice farming systems, production constraints and determinants of adoption of improved varieties by smallholder farmers of the Republic of Benin. Scientific Reports **12**. Nature Research.

Lwoga ET. 2010. Bridging the Agricultural Knowledge and Information Divide: The Case of Selected Telecenters and Rural Radio in Tanzania. Electronic Journal of Information Systems in Developing Countries **43**:1–14. John Wiley and Sons Inc.

MAEP, MENC, FAO, ITU. 2019. Strategie Nationale pour l'e-agriculture au Benin 2020-2024. Available from https://faolex.fao.org/docs/pdf/ben210399.pdf (accessed February 14, 2024).

Mapiye O, Makombe G, Molotsi A, Dzama K, Mapiye C. 2021. Information and communication technologies (ICTs): The potential for enhancing the dissemination of agricultural information and services to smallholder farmers in sub-Saharan Africa. Information DevelopmentDOI: 10.1177/02666669211064847. SAGE Publications Ltd.

Marwa ME, Mburu J, Oburu REJ, Mwai O, Kahumbu S. 2020. Impact of ICT Based Extension Services on Dairy Production and Household Welfare: The Case of iCow Service in Kenya. Journal of Agricultural Science **12**:141. Canadian Center of Science and Education.

Misaki E, Apiola M, Gaiani S, Tedre M. 2018. Challenges facing sub-Saharan small-scale farmers in accessing farming information through mobile phones: A systematic literature review. Electronic Journal of Information Systems in Developing Countries **84**. Wiley-Blackwell.

Mkenda PA, Mbega E, Ndakidemi PA. 2017. Accessibility of agricultural knowledge and information by rural farmers in Tanzania-A review. J. Bio. & Env. Sci **2017**:216–228. Available from http://www.innspub.net.

Moutouama FT, Tepa-Yotto GT, Agboton C, Gbaguidi B, Sekabira H, Tamò M. 2022. Farmers' Perception of Climate Change and Climate-Smart Agriculture in Northern Benin, West Africa. Agronomy **12**. MDPI.

Mtega WP, Msungu AC. 2013. Using information and communication technologies for enhancing the accessibility of agricultural information for improved agricultural production in tanzania. Electronic Journal of Information Systems in Developing Countries **56**. City University of Hong Kong Press.

Mtega WP, Ngoepe M. 2019. A framework for strengthening agricultural knowledge systems for improved accessibility of agricultural knowledge in Morogoro Region of Tanzania. Journal of Librarianship and Information Science **51**:629–642. SAGE Publications Ltd.

Mubofu C, Elia E. 2017a. Disseminating Agricultural Research Information: A case study of farmers in Mlolo, Lupalama and Wenda villages in Iringa district, Tanzania. Salaam Library Journal **12**:80–97.

Mubofu C, Elia E. 2017b. Disseminating Agricultural Research Information: A case study of farmers in Mlolo, Lupalama and Wenda villages in Iringa district, Tanzania. Salaam Library Journal **12**:80–97.

Mumuni E, Alhassan A, Sulemana N. 2023. Success Factors of Electronic (E) Agriculture in Ghana: Lessons from MoFA and Cowtribe. Technology and Development | **9**:2343–6727.

Musafiri CM, Kiboi M, Macharia J, Ng'etich OK, Kosgei DK, Mulianga B, Okoti M, Ngetich FK. 2022. Adoption of climate-smart agricultural practices among smallholder farmers in Western Kenya: do socioeconomic, institutional, and biophysical factors matter? Heliyon **8**. Elsevier Ltd.

Mwantimwa K. 2020. Livelihood information and knowledge needs, access, and exchange in rural communities in the Bunda District, Tanzania. Rural Society **29**:30–43. Routledge.

Naika MBN, Kudari M, Devi MS, Sadhu DS, Sunagar S. 2021. Chapter 8 - Digital extension service: quick way to deliver agricultural information to the farmers. Pages 285–323 in Galanakis CM, editor. Food Technology Disruptions. Academic Press.

Ndimbo GK, Yu L, Ndi Buma AA. 2023. ICTs, smallholder agriculture and farmers' livelihood improvement in developing countries: Evidence from Tanzania. Information DevelopmentDOI: 10.1177/02666669231165272. SAGE Publications Ltd.

Ndimbwa T, Mwantimwa K, Ndumbaro F. 2021. Channels used to deliver agricultural information and knowledge to smallholder farmers. IFLA Journal **47**:153–167. SAGE Publications Ltd.

Ndimbwa T, Ndumbaro F, Mwantimwa K. 2019. Delivery mechanisms of agricultural information and knowledge to smallholder farmers in Tanzania: A meta-analysis study. Salaam Library Journal **14**:87–98.

Nicholas-Ere O. 2017. Dissemination of Agricultural Information to Farmers using ICT. International Journal of Computer Applications **179**:27–31.

Nonvide Armel, Gbêtondji Melaine. 2023. Impact of information and communication technologies on agricultural households' welfare in Benin. Telecommunications Policy **47**. Elsevier Ltd.

Nonvide GMA. 2021. Adoption of agricultural technologies among rice farmers in Benin. Review of Development Economics **25**:2372–2390. John Wiley and Sons Inc.

Ogisi OD, Begho T. 2023. Adoption of climate-smart agricultural practices in sub-Saharan Africa: A review of the progress, barriers, gender differences and recommendations. Farming System **1**:100019. Elsevier BV.

Olanrewaju KO, Farinde AJ. 2014. Factors influencing use of traditional communication methods in information dissemination among farmers in Osun state, Nigeria. Journal of Agricultural and Food Information **15**:54–68. Taylor and Francis Inc.

Olayemi S, Olusola S, Merianchris E. 2020. Farmers' Perceptions of Agricultural Extension Agents' Performance in Sub-Saharan African Communities. Page International Journal of Environmental & Agriculture Research (IJOEAR) ISSN.

Paul Jimmy, Ismail Moumouni, Florent Okry, Latifou Idrissou, Mohamed N. Baco, Guy S. Nouatin. 2016. Déterminants de la diffusion des technologies en milieu rural avec les vidéos : Cas des bonnes pratiques de transformation de soja en fromages au Bénin. Sciences Naturelles et Agronomie **6**:59–66.

Perpétus J, Houngbo P. 2015, March. État des lieux de l'usage des Technologies de l'Information et de la Communication au Bénin.

Présidence de la République du Bénin. 2023. Projet d'appui à la Formation Agricole et Rurale (ProFAR) : La révolution agricole au Bénin s'accélère. Available from https://www.gouv.bj/article/2273/projet-appui-formation-agricole-rurale-profar-revolution-agricole-benin-accelere/ (accessed March 24, 2024).

Singh N, Dey K. 2023. A typology of agricultural market information systems and its dimensions: Case studies of digital platforms. Electronic Markets **33**:42. Available from https://doi.org/10.1007/s12525-023-00665-0.

Siyao PO. 2012. Barriers in accessing agricultural information in Tanzania with a gender perspective: The case study of small-scale sugar cane growers in Kilombero district. Electronic Journal of Information Systems in Developing Countries **51**. City University of Hong Kong Press.

Tsan Michael, Dalberg Swetha Totapally, Dalberg Michael Hailu, Benjamin K Addom, CTA. 2019. THE DIGITALISATION OF AFRICAN AGRICULTURE REPORT 2018–2019.

Available from file:///C:/Users/geoff/Dropbox/PC/Downloads/CTA-Digitalisation-report.pdf (accessed February 17, 2024).

Tyagi R, Pandey PC. 2024. Chapter 21 - Applications of drones in precision agriculture: future of smart and sustainable farming. Pages 429–453 in Lamine S, Srivastava PK, Kayad A, Muñoz-Arriola F, Pandey PC, editors. Remote Sensing in Precision Agriculture. Academic Press.

Van Heddeghem W, Lambert S, Lannoo B, Colle D, Pickavet M, Demeester P. 2014. Trends in worldwide ICT electricity consumption from 2007 to 2012. Computer Communications **50**:64–76. Elsevier.

World Bank. 2021. Climate Change Knowledge Portal. Available from https://climateknowledgeportal.worldbank.org/country/benin (accessed March 25, 2024).

World Bank. 2023a. The World Bank in Benin. Available from https://www.worldbank.org/en/country/benin/overview (accessed March 25, 2024).

World Bank. 2023b, September 29. The World Bank in Benin. Available from https://www.worldbank.org/en/country/benin/overview (accessed February 10, 2024).

World Bank. 2024. Doing Business. Available from https://archive.doingbusiness.org/en/rankings?region=sub-saharan-africa (accessed February 18, 2024).

Zhang J, Mishra AK, Hirsch S. 2021. Market-oriented agriculture and farm performance: Evidence from rural China. Food Policy **100**. Elsevier Ltd.

Zoundji GC, Okry F, Vodouhê SD, Bentley JW. 2018. Towards sustainable vegetable growing with farmer learning videos in Benin. International Journal of Agricultural Sustainability **16**:54–63. Taylor and Francis Ltd.