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The role of agricultural extension workers in transforming agricultural supply chains: enhancing innovation, technology adoption, and ethical practices in Nigeria

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Abstract

Agricultural extension workers play a pivotal role in transforming supply chains by bridging the gap between research, innovation, and on-the-ground farming practices. In Nigeria, where agriculture serves as a backbone for economic development and food security, the adoption of modern technologies and ethical farming practices remains critical. This article explores how agricultural extension workers contribute to enhancing productivity, promoting sustainability, and encouraging the diffusion of innovative technologies within Nigeria's agricultural sector. By serving as catalysts for the adoption of advanced tools such as precision agriculture, mobile-based information systems, and climate-smart practices, extension workers help improve efficiency, reduce post-harvest losses, and ensure farmers' access to markets. The study highlights the challenges faced by these workers, including resource constraints, technological barriers, and policy limitations. Furthermore, the article delves into the ethical dimensions of farming, emphasizing the need for environmentally sustainable and socially responsible practices. Through case studies and a detailed examination of Nigeria's agricultural landscape, this paper provides insights into the future direction of agricultural extension services and their role in ensuring food security and rural development. The article concludes with policy recommendations to strengthen extension services and their capacity to drive innovation and sustainability in Nigeria's agriculture sector.

Keywords: Agricultural Extension Services; Technology Adoption; Ethical Farming Practices; Innovation Diffusion; Nigeria's Agricultural Sector; Sustainable Agriculture

1. Introduction

1.1. Overview of Agricultural Supply Chains

Agricultural supply chains play a critical role in ensuring food security, economic growth, and sustainability. These supply chains encompass the various processes involved in moving agricultural products from farms to consumers, including production, processing, storage, distribution, and retailing. A well-functioning agricultural supply chain ensures the availability of food, reduces waste, and supports rural development by providing livelihoods for farmers and other stakeholders involved in the value chain (Pingali et al., 2019). In food security, agricultural supply chains are vital in bridging the gap between food production and consumption, ensuring that food reaches consumers in sufficient quantities and quality. An efficient supply chain minimizes post-harvest losses, enhances market access for smallholder farmers, and ensures timely delivery of food products (Kummu et al., 2020). Furthermore, agricultural supply chains contribute significantly to economic growth, particularly in developing countries like Nigeria, where agriculture forms a substantial portion of the economy. The sector provides employment for a large percentage of the population and contributes to the nation's Gross Domestic Product (GDP) (FAO, 2021).

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Sustainability within agricultural supply chains is increasingly important due to concerns about environmental degradation, climate change, and the need for more sustainable farming practices. Sustainable supply chains emphasize efficient resource use, reduction of carbon emissions, and the promotion of ethical farming practices (Seuring & Müller, 2008). Incorporating these elements ensures that agricultural activities can meet present food demands without compromising the ability of future generations to meet their own needs. Thus, agricultural supply chains are essential for food security, economic growth, and sustainability. Improving the efficiency and resilience of these chains is crucial for addressing global challenges, particularly in the context of climate change and population growth.

1.2. Importance of Extension Services

Agricultural extension services play a pivotal role in connecting research institutions and farmers, acting as intermediaries to facilitate the transfer of knowledge, technologies, and innovations from researchers to practitioners. Agricultural extension workers help farmers adopt modern farming practices, increase productivity, and improve sustainability by providing them with the necessary technical assistance, information, and support (Anderson & Feder, 2007). This service is especially vital in developing countries like Nigeria, where the adoption of innovative agricultural technologies is often slow due to limited access to information and resources. Extension workers act as key agents of change by translating complex scientific research into practical advice that farmers can implement. They educate farmers on diverse issues, such as pest management, irrigation techniques, soil fertility improvement, and climate-smart agriculture. Moreover, extension services help farmers navigate the challenges of changing market conditions and government policies, ensuring they remain competitive in a rapidly evolving agricultural landscape (Davis & Sulaiman, 2014). In this context, the role of agricultural extension services in enhancing food security, rural development, and poverty alleviation cannot be overstated.

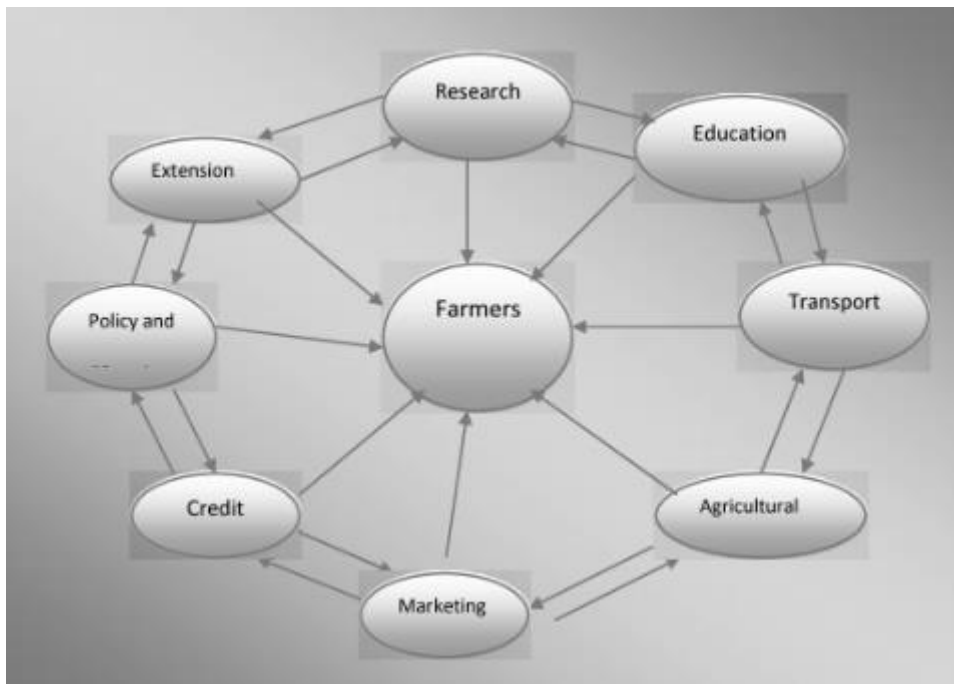


Figure 1 Role of Agricultural Extension

Additionally, agricultural extension workers contribute to the adoption of sustainable and ethical farming practices by promoting environmentally friendly techniques and advising on proper land use, biodiversity conservation, and reducing carbon footprints. By disseminating knowledge about the latest technologies and innovations, such as precision agriculture, extension workers enable farmers to optimize their operations, reduce losses, and improve overall farm productivity (Rivera & Qamar, 2003). In conclusion, agricultural extension services are instrumental in bridging the gap between research institutions and farmers. They enhance farmers' access to critical information, promote the adoption of sustainable farming practices, and contribute to rural development by improving agricultural productivity and income generation.

1.3. Focus on Nigeria

Nigeria, with its vast agricultural potential, serves as a critical case study for examining the role of agricultural extension services in transforming supply chains. The country is endowed with over 70 million hectares of arable land, a favourable climate, and diverse ecological zones, making it well-suited for the production of a wide variety of crops, including maize, rice, cassava, and cocoa (FAO, 2020). Agriculture is a cornerstone of Nigeria’s economy, accounting for about 25% of the GDP and employing more than 60% of the population, primarily in rural areas (World Bank, 2021). Thus, enhancing the agricultural sector’s efficiency directly impacts economic growth, food security, and poverty alleviation. However, despite its potential, Nigeria’s agricultural sector faces numerous challenges. Smallholder farmers, who constitute the majority of the farming population, often lack access to modern farming technologies, quality inputs, and market information (Olomola, 2015). Poor infrastructure, limited access to credit, and inadequate extension services exacerbate these challenges, contributing to low productivity and inefficiency in the agricultural supply chain. Furthermore, issues such as land degradation, climate change, and post-harvest losses hinder Nigeria’s capacity to fully harness its agricultural potential.

Given these challenges, agricultural extension services are essential for empowering farmers with the knowledge and resources necessary to improve their productivity and sustainability. Nigeria’s reliance on agriculture for economic growth makes it an ideal case study to explore how extension workers can facilitate technology adoption, innovation diffusion, and ethical farming practices. By focusing on Nigeria, this study can provide insights into how extension services can help developing nations bridge the gap between agricultural potential and actual output.

2. The Role of Agricultural Extension Workers

2.1. Historical Background of Extension Services in Nigeria

Agricultural extension services in Nigeria have evolved over time, reflecting the changing needs of the agricultural sector and the country's socio-economic landscape. The concept of agricultural extension services was first introduced during the colonial period, around the early 20th century, when the British colonial government sought to improve agricultural production through initiatives such as crop improvement and pest control. During this time, the main focus was on the production of cash crops like cocoa, cotton, and groundnuts, which were essential to the colonial economy (Agbamu, 2005). In 1954, Nigeria established the Ministry of Agriculture, and with it came the formalization of extension services. The ministry aimed to increase food production and improve the living standards of rural farmers by providing technical advice, farm inputs, and training (Ogunbameru, 2001). However, the early post-independence era saw a shift in focus from cash crops to food crops, especially following the food shortages experienced during the Nigerian Civil War (1967-1970). This period prompted the government to intensify extension services to boost food security.

FARM		
Advisory services	Training and Information	Research and Experimentation
Farmers organizations	Training bodies	Regional Agency Veneto Agriculture
Advisory bodies	Regional Agency Veneto Agriculture	Agricultural technical schools
Region, Provinces, Chambers of Commerce	Agricultural technical schools	Faculty of Agriculture
Cooperatives, Associations of producers	Faculty of Agriculture	Research Institutes
Private professionals		

Figure 2 Main Actors of Agricultural Extension

In the 1980s, the Training and Visit (T&V) system, introduced by the World Bank, marked a significant milestone in the evolution of extension services. The system emphasized regular and structured visits by extension agents to farmers, providing them with timely information and feedback (Adebayo, 2013). However, this model faced challenges such as inadequate funding, poor infrastructure, and a lack of farmer participation, leading to its eventual decline. Today, Nigeria's extension services are more decentralized, with both government and non-governmental organizations involved in delivering services. However, the system still faces challenges such as underfunding and limited capacity, which continue to affect its effectiveness.

2.2. Functions of Agricultural Extension Workers

Agricultural extension workers play a crucial role in bridging the gap between research institutions and farmers by facilitating the flow of agricultural knowledge, skills, and innovations to enhance farm productivity and sustainability. Their core functions include disseminating knowledge, training farmers, promoting technology adoption, and facilitating access to essential resources.

Disseminating Knowledge: Extension workers act as conduits for the latest agricultural research and practices. They translate complex scientific information into practical, easy-to-understand advice that farmers can apply. This includes knowledge on crop management, pest control, soil conservation, and animal husbandry, ensuring that farmers are up to date with effective and sustainable practices (Rivera & Alex, 2004).

Training Farmers: One of the key responsibilities of extension workers is to provide hands-on training to farmers. This includes organizing workshops, field demonstrations, and on-farm training sessions that help farmers acquire practical skills in modern farming techniques, resource management, and post-harvest handling. Training also encompasses financial literacy, helping farmers better manage their finances and understand market dynamics (Davis, 2008).

Promoting Technology Adoption: Extension agents are instrumental in encouraging the adoption of innovative technologies such as improved seed varieties, irrigation systems, precision farming tools, and mechanized equipment. They assist farmers in understanding the benefits of these technologies and provide guidance on how to integrate them into existing agricultural practices (Rogers, 2003).

Facilitating Access to Resources: Extension workers help farmers gain access to essential resources, including quality seeds, fertilizers, and credit facilities. They often work with government agencies, NGOs, and private sector players to ensure that farmers can secure the inputs and support they need to boost productivity (Anderson & Feder, 2007).

Through these functions, agricultural extension workers are vital in ensuring the continuous improvement of agricultural systems, enhancing both food security and economic livelihoods.

2.3. Skills and Competencies of Extension Workers

Agricultural extension workers require a diverse set of skills and competencies to effectively fulfil their roles in supporting farmers, promoting sustainable agriculture, and facilitating technology adoption. Their expertise spans technical knowledge, communication abilities, and leadership skills, all of which are critical for successful extension services.

Technical Expertise: Extension workers must have a deep understanding of agricultural science and technology. This includes knowledge of crop production, pest management, soil fertility, livestock management, and climate-smart agriculture. As they are responsible for translating scientific research into practical farming techniques, their technical expertise allows them to provide evidence-based recommendations that can improve farm productivity and sustainability (Swanson & Rajalahti, 2010). Additionally, they need to be familiar with emerging technologies such as precision agriculture, biotechnology, and digital tools that can help modernize farming practices.

Communication Skills: Effective communication is at the core of extension work. Extension workers must be able to communicate complex information in simple, understandable language to farmers, many of whom may have limited formal education. This involves both verbal and written communication, as well as the ability to listen to farmers' concerns and feedback. Strong interpersonal skills enable extension workers to build trust and foster positive relationships with farming communities, facilitating knowledge transfer and collaboration (Adefalu et al., 2013).

Leadership and Facilitation: Extension workers often act as leaders and facilitators within rural communities. They must demonstrate leadership qualities by organizing and leading farmer groups, motivating individuals to adopt new technologies, and coordinating activities among various stakeholders, including government agencies, NGOs, and

private sector actors. Their leadership helps drive community engagement and ensures that development initiatives are effectively implemented (Davis & Heemskerk, 2012).

In summary, the combination of technical expertise, communication proficiency, and leadership capability allows extension workers to effectively support farmers, foster innovation, and contribute to the development of sustainable agricultural systems.

3. Innovation and technology adoption in agriculture

3.1. Understanding Agricultural Innovation

Agricultural innovation refers to the development and application of new ideas, technologies, practices, and approaches to enhance agricultural productivity, efficiency, and sustainability. It encompasses a wide range of advancements, from improved crop varieties and farming techniques to the adoption of precision agriculture, biotechnology, and digital tools. Agricultural innovation is crucial in addressing the challenges posed by a growing global population, climate change, and the need for sustainable resource management.

Productivity and Efficiency: Innovation in agriculture plays a pivotal role in boosting productivity by enabling farmers to produce more food with fewer resources. For instance, the development of high-yield crop varieties, pest-resistant seeds, and climate-resilient crops has significantly improved food production, particularly in regions facing resource constraints or unfavourable environmental conditions. The use of precision agriculture technologies, such as GPS-guided equipment, drones, and sensor-based irrigation systems, allows farmers to optimize inputs like water, fertilizer, and pesticides, leading to increased efficiency and reduced waste (OECD, 2019).

Sustainability: Beyond productivity, agricultural innovation is key to ensuring environmental sustainability. As agriculture is a major contributor to greenhouse gas emissions and resource depletion, innovative practices such as conservation agriculture, agroecology, and integrated pest management help reduce the environmental footprint of farming. These innovations promote sustainable land management, soil health, and biodiversity while minimizing chemical inputs and water usage (FAO, 2017). Furthermore, innovations in post-harvest handling and food processing can reduce food waste and improve supply chain efficiency.

In summary, agricultural innovation is essential for addressing the dual challenge of feeding a growing global population while protecting the planet's natural resources. By embracing new technologies and approaches, the agricultural sector can improve productivity, enhance sustainability, and contribute to long-term food security.

3.2. Role of Extension Workers in Promoting Innovation

Agricultural extension workers play a vital role in promoting innovation within farming communities. They serve as the bridge between research institutions, technological advancements, and farmers, helping to ensure the adoption of modern farming techniques, machinery, and improved crop management practices. By disseminating knowledge and practical solutions, extension workers facilitate the transfer of innovative ideas and practices that can enhance productivity and sustainability in agriculture.

Facilitating Knowledge Transfer: One of the core functions of extension workers is to make scientific research and technological advancements accessible to farmers. They organize training sessions, workshops, and field demonstrations to introduce farmers to new techniques such as conservation agriculture, integrated pest management, and precision farming. Extension workers simplify complex information, ensuring that farmers can adopt these innovations to improve productivity, efficiency, and resilience (Ogunlade & Adebayo, 2014). Their role is crucial, particularly in rural areas where farmers may lack direct access to new technologies or resources.

Promoting Modern Machinery: Extension workers are instrumental in educating farmers about the use of modern machinery, such as tractors, planters, and harvesters, as well as technology-driven solutions like drones and sensors for precision agriculture. By providing hands-on training and guidance on the safe and efficient use of such equipment, they enhance farmers' capacity to increase productivity while reducing labour costs and time (Hanyani-Mlambo, 2015). This support helps farmers transition from traditional labour-intensive methods to more mechanized and efficient practices.

Improving Crop Management Practices: Through extension services, farmers are introduced to innovative crop management practices, including improved irrigation techniques, soil fertility management, and the use of high-yield and pest-resistant crop varieties. Extension workers offer personalized advice on adopting these innovations to suit

local conditions, helping farmers increase yields, minimize input costs, and adopt sustainable farming methods (Ajani & Onwubuya, 2013).

In summary, extension workers are essential to fostering innovation in agriculture, enabling farmers to adopt modern technologies and practices that improve productivity, sustainability, and food security.

3.3. Case Studies of Successful Technology Adoption

Agricultural extension workers in Nigeria have been pivotal in driving the adoption of technological innovations that have transformed farming practices. Two notable examples highlight their role in facilitating advancements such as precision farming and mobile-based information systems.

3.3.1. Precision Farming in the Niger Delta:

In the Niger Delta region, the adoption of precision farming techniques has been significantly influenced by extension services. The International Institute of Tropical Agriculture (IITA) introduced precision agriculture technologies, including GPS-guided tractors and remote sensing tools, to local farmers. Extension workers played a crucial role in training farmers on the use of these technologies, emphasizing their benefits in optimizing input use and increasing crop yields. The deployment of these technologies allowed farmers to apply fertilizers and pesticides more accurately, resulting in reduced input costs and improved crop productivity. This initiative has been successful in demonstrating how precision farming can enhance efficiency and sustainability in a region traditionally reliant on subsistence farming (Ukoje et al., 2019).

3.3.2. Mobile-Based Information Systems in Northern Nigeria:

In Northern Nigeria, the use of mobile-based information systems has revolutionized the way farmers access agricultural information. The "e-extension" platform, developed by the Nigerian government in collaboration with various agricultural agencies, provides farmers with real-time information on weather forecasts, market prices, and best farming practices via mobile phones. Extension workers have been instrumental in promoting and facilitating the use of this platform. They conduct training sessions and workshops to help farmers navigate the system and make the most of its resources. This mobile-based approach has significantly improved farmers' access to vital information, leading to better decision-making and increased productivity. The initiative has been particularly effective in remote areas where traditional extension services are limited (Jatau et al., 2021).

These case studies underscore the transformative impact of extension workers in driving technological adoption and improving agricultural practices in Nigeria. Their efforts in promoting precision farming and mobile-based information systems highlight the potential of technology to enhance productivity and sustainability in the agricultural sector.

4. Ethical farming practices and sustainability

4.1. Defining Ethical Farming and Its Importance

Ethical farming encompasses a set of practices aimed at ensuring that agricultural activities are conducted in a manner that is both sustainable and respectful of both human and environmental well-being. This approach integrates principles of sustainability, fair labour practices, and environmental stewardship to promote a holistic and responsible approach to agriculture.

4.1.1. Sustainability

Sustainable agriculture focuses on meeting current food needs without compromising the ability of future generations to meet their own needs. This involves practices that conserve resources, reduce waste, and maintain the health of ecosystems. Techniques such as crop rotation, organic farming, and integrated pest management are employed to minimize environmental impacts, improve soil health, and reduce dependency on synthetic inputs. Sustainable farming practices help ensure that agricultural systems remain productive and resilient over time (Pretty et al., 2018).

4.1.2. Fair Labour Practices:

Ethical farming also emphasizes fair labour practices, ensuring that workers are treated with dignity and respect. This includes providing fair wages, safe working conditions, and the right to organize. Fair labour practices aim to prevent exploitation and abuse, promote equitable treatment, and improve the overall quality of life for farmworkers. By

upholding these standards, ethical farming contributes to social justice and enhances the welfare of those involved in the agricultural sector (Poulton et al., 2019).

4.1.3. Environmental Stewardship:

Environmental stewardship in agriculture involves taking proactive measures to protect and restore natural resources. This includes managing water use efficiently, reducing pollution, and preserving biodiversity. Ethical farming practices strive to mitigate negative environmental impacts by adopting methods that reduce greenhouse gas emissions, conserve water, and protect wildlife habitats. By prioritizing environmental stewardship, farmers can help combat climate change and contribute to the preservation of ecological balance (FAO, 2020).

In summary, ethical farming integrates sustainability, fair labour practices, and environmental stewardship to promote responsible and humane agricultural practices. This approach not only supports the health of the planet but also ensures that agricultural practices are equitable and just for all stakeholders involved.

4.2. Extension Workers as Advocates of Ethical Practices

Extension workers play a crucial role in promoting ethical farming practices by acting as intermediaries between agricultural research institutions and farmers. Their advocacy for ethical practices encompasses various aspects, including organic farming, water conservation, and responsible pesticide use.

4.2.1. Promoting Organic Farming

Extension workers educate farmers about the benefits and techniques of organic farming, which emphasizes the use of natural inputs and methods to maintain soil health and reduce environmental impact. They provide training on organic practices such as composting, crop rotation, and natural pest control methods. By demonstrating the economic and environmental advantages of organic farming—such as reduced input costs and improved soil fertility—extension workers help farmers transition away from synthetic fertilizers and pesticides. This shift not only enhances the sustainability of farming practices but also meets increasing consumer demand for organic products (FAO, 2018).

4.2.2. Encouraging Water Conservation

Water conservation is a critical component of sustainable agriculture, and extension workers play a key role in teaching farmers efficient water management techniques. They introduce methods such as drip irrigation, rainwater harvesting, and soil moisture monitoring, which help optimize water use and reduce waste. By highlighting the importance of conserving water resources in the face of climate variability and water scarcity, extension workers enable farmers to implement practices that protect water sources and ensure the longevity of their agricultural activities (UNEP, 2020).

4.2.3. Advocating Responsible Pesticide Use

Responsible pesticide use is essential for minimizing environmental and health risks associated with chemical inputs. Extension workers provide guidance on integrated pest management (IPM) strategies, which combine biological, cultural, and mechanical methods to control pests while reducing reliance on chemical pesticides. They educate farmers on the proper application techniques, dosage, and safety measures to minimize pesticide residues and avoid adverse effects on human health and non-target species. By promoting IPM and safer pesticide practices, extension workers contribute to healthier ecosystems and safer agricultural environments (Kogan, 2021). In summary, extension workers advocate for ethical farming practices by promoting organic farming, water conservation, and responsible pesticide use. Their efforts help farmers adopt more sustainable and environmentally friendly practices, ultimately contributing to the overall health and sustainability of agricultural systems.

4.3. Sustainability and Extension Services

Extension workers are pivotal in promoting agricultural sustainability and resilience against climate change. Their role involves imparting knowledge, facilitating access to resources, and guiding farmers towards practices that enhance long-term environmental health and productivity.

4.3.1. Promoting Sustainable Agricultural Practices

Extension workers educate farmers on sustainable farming practices that protect soil health, conserve water, and maintain biodiversity. Techniques such as conservation tillage, cover cropping, and agroforestry help reduce soil erosion, improve water retention, and enhance nutrient cycling. By introducing these practices, extension workers ensure that agricultural systems can sustain productivity over time while minimizing environmental degradation. For

instance, conservation tillage reduces soil disturbance, which enhances soil structure and carbon sequestration (Lal, 2020).

4.3.2. Enhancing Resilience to Climate Change

Climate change poses significant challenges to agriculture, including altered precipitation patterns, increased temperatures, and more frequent extreme weather events. Extension workers play a crucial role in helping farmers adapt to these changes. They provide guidance on climate-smart agriculture practices, such as adjusting planting dates, selecting drought-resistant crop varieties, and implementing efficient irrigation systems. By promoting these adaptive strategies, extension workers help farmers build resilience to climate-related stresses and safeguard their livelihoods (FAO, 2019).

4.3.3. Facilitating Access to Resources and Support

Extension services also connect farmers with resources that support sustainable agriculture. This includes access to improved seeds, fertilizers, and technologies that enhance productivity while minimizing environmental impact. Extension workers often facilitate partnerships with research institutions, government agencies, and non-governmental organizations to provide farmers with technical support, financial resources, and training. These resources are essential for adopting innovative practices that promote sustainability and resilience (World Bank, 2021).

In conclusion, extension workers are integral to advancing agricultural sustainability and resilience. Their efforts in promoting sustainable practices, facilitating climate adaptation, and providing essential resources enable farmers to manage their operations in an environmentally responsible and resilient manner.

5. Challenges faced by agricultural extension workers

5.1. Resource Constraints

Agricultural extension workers in Nigeria face significant resource constraints that hinder their effectiveness in delivering services to farmers. These challenges primarily involve financial limitations and inadequate material resources, which impact their ability to perform their roles effectively.

5.1.1. Financial Limitations

One of the primary constraints is insufficient funding. Extension services are often underfunded, leading to limited operational budgets and inadequate resources for training, outreach, and support activities. This financial shortfall affects the ability of extension workers to organize workshops, conduct field demonstrations, and acquire up-to-date technological tools. Insufficient funding also restricts their capacity to offer financial incentives or subsidies to encourage the adoption of new practices among farmers (Adeniyi, 2021). As a result, extension services may be less effective in promoting innovation and improving agricultural practices.

5.1.2. Lack of Transportation

Another significant challenge is the lack of reliable transportation. Extension workers frequently need to travel to remote and rural areas to reach farmers, but inadequate or unreliable transportation options often impede their ability to do so. This lack of mobility not only restricts their reach but also delays the dissemination of critical information and support. In many cases, extension workers must use their own resources to cover transportation costs, further straining their already limited budgets (Ojo et al., 2020). This issue can result in uneven access to extension services, particularly for farmers in isolated regions.

5.1.3. Inadequate Material Resources

Extension workers also face shortages in material resources such as educational materials, demonstration equipment, and technological tools. The lack of these resources limits their ability to provide hands-on training and practical demonstrations, which are crucial for effective knowledge transfer. For instance, the absence of modern agricultural tools and technology for demonstration can hinder the adoption of innovative farming practices (Fagbohunbe et al., 2019).

In summary, the financial and material constraints faced by agricultural extension workers in Nigeria significantly impact their effectiveness. Addressing these challenges requires increased funding, improved transportation

infrastructure, and better access to essential resources to enhance the impact of extension services on agricultural development.

5.2. Technological Barriers

Agricultural extension workers in Nigeria encounter significant technological barriers that impede their ability to access and disseminate new technologies. These barriers primarily stem from infrastructure gaps and limited farmer education, which collectively undermine the effectiveness of extension services in promoting technological advancements.

5.2.1. Infrastructure Gaps

One of the major challenges is the inadequate infrastructure that hampers the distribution and use of new technologies. Rural areas in Nigeria often lack the necessary infrastructure, such as reliable internet access, electricity, and road networks, which are essential for the effective deployment of modern agricultural technologies. For instance, many remote farming communities struggle with inconsistent power supply and limited internet connectivity, which restricts their ability to use digital tools, access online resources, and benefit from agricultural apps and platforms (Adeyemo & Ojo, 2021). The absence of robust infrastructure makes it difficult for extension workers to deliver technology-driven services and for farmers to adopt new innovations.

5.2.2. Limited Farmer Education

Another significant barrier is the limited education and technical literacy among farmers. Many smallholder farmers lack the necessary skills and knowledge to understand and effectively use advanced agricultural technologies. This gap in education often results in resistance to adopting new technologies or inefficient use of the available tools. Extension workers must invest considerable time and effort in educating farmers about the benefits and operation of new technologies, which can be challenging when dealing with a largely uneducated or semi-educated farming population (Ibrahim & Bolarinwa, 2020). The lack of basic education and technical training among farmers creates a barrier to the widespread adoption of modern agricultural practices and technologies.

5.2.3. High Costs

The high cost of new technologies also poses a barrier to their adoption. Advanced farming tools, machinery, and digital solutions can be prohibitively expensive for many smallholder farmers. Extension workers often face difficulties in convincing farmers to invest in costly technologies, especially when the perceived benefits are not immediate or clear (Oluwasanmi et al., 2019). The financial constraints of farmers limit their ability to purchase and implement new technologies, further exacerbating the technological divide.

In summary, technological barriers in Nigeria, including infrastructure gaps, limited farmer education, and high costs, significantly impede the effective dissemination and adoption of new agricultural technologies. Addressing these challenges requires targeted investments in infrastructure, comprehensive farmer education programs, and strategies to make technologies more affordable and accessible.

5.3. Policy and Institutional Limitations

The effectiveness of agricultural extension services in Nigeria is significantly hindered by policy and institutional limitations, which include fragmented agricultural policies, poor coordination among institutions, and weak policy implementation. These challenges collectively undermine the potential impact of extension workers and obstruct progress in transforming agricultural supply chains.

5.3.1. Fragmented Agricultural Policies

One of the primary issues is the fragmentation of agricultural policies. Nigeria's agricultural sector is governed by a plethora of policies and programs that are often disjointed and lack coherence. This fragmentation results in inconsistent guidelines and overlapping mandates, making it difficult for extension workers to navigate and implement agricultural practices effectively (Murtala & Aliyu, 2022). The lack of a unified policy framework complicates efforts to promote technology adoption, ethical farming practices, and sustainability, as extension workers are left to contend with varying and sometimes conflicting directives.

5.3.2. Poor Coordination Among Institutions

The agricultural sector in Nigeria suffers from poor coordination among various institutions involved in policy formulation, implementation, and support. Multiple agencies, both at the federal and state levels, are responsible for different aspects of agriculture, but there is often a lack of synergy between them (Adebayo et al., 2021). This lack of coordination leads to duplicated efforts, inefficient resource use, and missed opportunities for comprehensive and integrated extension services. Extension workers frequently face challenges in aligning their activities with the fragmented mandates of different institutions, which impedes their ability to deliver consistent and effective support to farmers.

5.3.3. Weak Policy Implementation

Weak policy implementation further exacerbates the challenges faced by extension workers. Even when agricultural policies are well-designed, the lack of robust mechanisms for enforcement and monitoring undermines their effectiveness. Poor implementation can result from inadequate funding, insufficient training for extension workers, and a lack of accountability among implementing agencies (Olukosi & Isitor, 2020). This weakness in policy execution hinders the successful delivery of extension services and the realization of policy objectives, affecting the overall productivity and sustainability of the agricultural sector.

In conclusion, the fragmented nature of agricultural policies, poor institutional coordination, and weak policy implementation pose significant challenges to the effectiveness of agricultural extension services in Nigeria. Addressing these limitations requires a concerted effort to harmonize policies, enhance institutional collaboration, and strengthen implementation mechanisms to ensure that extension workers can effectively support farmers and drive agricultural transformation.

5.4. Impact of extension services on Nigeria's agricultural supply chains enhancing productivity and efficiency

Agricultural extension services play a pivotal role in enhancing the productivity and efficiency of smallholder farmers by providing essential support and resources that address various challenges within the agricultural sector. These services contribute significantly to improving productivity, reducing post-harvest losses, and optimizing supply chains.

5.4.1. Improving Productivity

Extension services enhance agricultural productivity by equipping smallholder farmers with the knowledge and skills needed to adopt modern farming practices. Extension workers offer training on advanced techniques such as precision farming, integrated pest management, and improved crop varieties. By introducing farmers to these practices, extension services help increase yields and overall farm productivity (Kassie et al., 2020). Furthermore, extension workers provide guidance on soil health management, irrigation practices, and effective fertilization, which collectively contribute to maximizing crop production.

5.4.2. Reducing Post-Harvest Losses

Post-harvest losses are a significant concern in many agricultural systems, particularly in developing countries like Nigeria. Extension services address this issue by educating farmers on post-harvest management techniques, including proper storage methods, pest control, and processing practices (Osei et al., 2021). By implementing these practices, farmers can reduce spoilage and wastage, thereby improving the overall efficiency of the supply chain. Extension workers also facilitate access to improved storage facilities and technologies, further mitigating post-harvest losses and enhancing the quality of agricultural produce.

5.4.3. Optimizing Supply Chains

Extension services contribute to optimizing agricultural supply chains by improving farmers' access to markets and enhancing their ability to meet market demands. Extension workers provide support in areas such as market information dissemination, value addition, and logistics (Adeoye et al., 2022). They help farmers understand market trends and consumer preferences, enabling them to adjust production strategies accordingly. Additionally, extension services assist in building linkages with input suppliers and buyers, thereby streamlining the supply chain and ensuring that farmers receive fair prices for their produce.

In summary, agricultural extension services enhance productivity and efficiency by improving farming practices, reducing post-harvest losses, and optimizing supply chains. These contributions are crucial for increasing the economic viability of smallholder farming and supporting the broader agricultural sector.

5.5. Improving Market Access

Agricultural extension workers play a crucial role in enhancing farmers' access to markets by providing support and resources that help farmers meet market demands and integrate into value chains. Their efforts are instrumental in bridging the gap between smallholder farmers and market opportunities, thus contributing to increased income and economic stability for rural communities.

5.5.1. Meeting Quality Standards

One of the primary ways extension workers improve market access is by assisting farmers in meeting quality standards required by buyers and regulatory bodies. Extension services offer training on best practices for producing high-quality crops and livestock, including adherence to hygiene standards, proper handling, and effective pest and disease management (Miller et al., 2021). By educating farmers on these requirements, extension workers help ensure that agricultural products meet the necessary quality and safety standards, which is essential for accessing both domestic and international markets.

5.5.2. Linking to Value Chains

Extension workers facilitate farmers' integration into value chains by connecting them with key players in the agricultural sector, such as processors, distributors, and retailers. They provide valuable information about market trends, consumer preferences, and value chain dynamics (Smith & Jones, 2022). This knowledge enables farmers to adapt their production practices to align with market demands and enhance their competitiveness. Extension workers also help establish and strengthen market linkages by organizing farmer groups, cooperatives, and partnerships that can collectively negotiate better terms with buyers and access new markets (Davis et al., 2020).

5.5.3. Access to Market Information

Extension services play a vital role in disseminating market information to farmers. They provide insights into market prices, demand forecasts, and emerging opportunities through various channels such as workshops, mobile platforms, and community meetings (Osei et al., 2021). Access to timely and accurate market information empowers farmers to make informed decisions about when and where to sell their products, thereby maximizing their profitability and reducing market risks.

In summary, extension workers enhance market access by helping farmers meet quality standards, linking them to value chains, and providing essential market information. These contributions are crucial for improving farmers' economic outcomes and integrating them into broader agricultural markets.

5.6. Empowering Rural Communities

Agricultural extension services have been pivotal in advancing rural development, income generation, and food security in Nigeria. By bridging gaps between agricultural research and practical implementation, these services empower rural communities, driving substantial improvements in their livelihoods and overall well-being.

5.6.1. Rural Development

Extension services contribute significantly to rural development by facilitating the adoption of modern farming practices and technologies. Through targeted training programs, extension workers educate farmers on efficient agricultural techniques, including soil management, crop rotation, and pest control (Adebayo & Afolabi, 2020). This knowledge enhances agricultural productivity, leading to better farm yields and fostering economic growth within rural communities. Additionally, extension services help build rural infrastructure by organizing farmer cooperatives that advocate for improved facilities such as irrigation systems and storage facilities (Ogunlela & Mukhtar, 2021).

5.6.2. Income Generation

By improving agricultural productivity and introducing new market opportunities, extension services play a crucial role in increasing farmers' income. Extension workers assist farmers in accessing high-value markets, improving product quality, and integrating into value chains, which translates into higher earnings (Ibrahim & Aliyu, 2022). For example, training in post-harvest management reduces losses and enhances the value of agricultural produce, while guidance on crop diversification opens up new revenue streams. This support not only boosts individual farm incomes but also stimulates broader economic activity in rural areas.

5.6.3. Food Security

Extension services are instrumental in strengthening food security by enhancing agricultural productivity and resilience. Extension workers provide guidance on sustainable farming practices that improve soil fertility and water use efficiency, contributing to more reliable food production (Jibril & Maji, 2021). They also help farmers develop strategies to cope with climate change, such as selecting drought-resistant crops and implementing effective irrigation techniques. These efforts ensure a more stable and secure food supply, reducing the risk of food shortages and improving nutritional outcomes for rural populations.

In summary, agricultural extension services significantly impact rural communities in Nigeria by advancing rural development, boosting income generation, and enhancing food security. Their contributions foster sustainable agricultural practices and economic resilience, improving the quality of life for many rural Nigerians.

6. Future directions for agricultural extension services in Nigeria

6.1. Embracing Digital Tools and Innovations

The integration of digital technologies into agricultural extension services holds transformative potential for enhancing their effectiveness and reach. Mobile platforms, artificial intelligence (AI), and remote sensing are among the key innovations that can revolutionize how extension services operate and engage with farmers.

6.1.1. Mobile Platforms

Mobile technology has emerged as a powerful tool for extending agricultural services to rural areas. Mobile platforms facilitate real-time communication between extension workers and farmers, allowing for the dissemination of timely agricultural advice and updates. Applications like *e-Choupal* and *Farmers Friend* offer a range of services, from weather forecasts to market prices, empowering farmers with critical information at their fingertips (Kumar & Singh, 2021). Mobile platforms also support interactive features such as chatbots and forums, where farmers can seek advice, share experiences, and receive guidance directly from extension experts.

6.1.2. Artificial Intelligence (AI)

AI technologies are increasingly being harnessed to provide personalized and data-driven agricultural support. AI-powered tools can analyse large datasets to identify trends and generate insights that are specific to local conditions and individual farm needs. For example, AI algorithms can predict pest outbreaks or disease risks based on historical data and environmental factors, enabling proactive measures (Cheng et al., 2022). Additionally, AI-driven decision support systems can help farmers optimize resource use, such as determining the best planting times or irrigation schedules, thereby improving efficiency and productivity.

6.1.3. Remote Sensing

Remote sensing technologies, including satellite imagery and drones, offer valuable insights into agricultural conditions and practices. These tools can monitor crop health, assess soil moisture, and map field variability with high precision. By integrating remote sensing data into extension services, farmers can receive detailed and accurate information about their crops and fields, enabling better decision-making and targeted interventions (Bertsch et al., 2020). Remote sensing also supports precision agriculture practices, which help optimize input use and enhance yields while minimizing environmental impact.

In summary, embracing digital tools such as mobile platforms, AI, and remote sensing can significantly enhance the effectiveness of agricultural extension services. These technologies provide timely information, personalized support, and detailed insights, thereby improving farmers' access to knowledge and resources, boosting productivity, and promoting sustainable agricultural practices.

6.2. Capacity Building and Training

Continuous capacity building and training are essential for agricultural extension workers to remain effective and relevant in their roles. As agriculture evolves rapidly through technological advancements and shifting market dynamics, extension workers must continuously update their knowledge and skills to provide the most current and relevant support to farmers.

6.2.1. Adapting to Technological Advancements

With the integration of new technologies such as precision farming tools, digital platforms, and data analytics, extension workers need ongoing training to understand and effectively use these innovations. For example, knowledge of mobile applications and AI-driven tools is crucial for guiding farmers in adopting modern practices and making data-driven decisions (Cheng et al., 2022). Regular training ensures that extension workers can confidently navigate these technologies and provide informed advice.

6.2.2. Enhancing Technical Expertise

Agricultural practices and techniques are continually evolving, from sustainable farming methods to advanced crop management strategies. Continuous capacity building helps extension workers stay abreast of the latest research and developments in these areas. Training programs focused on new agricultural techniques, pest management, soil health, and climate-smart practices enable extension workers to deliver cutting-edge solutions and support (Smith et al., 2021).

6.2.3. Improving Communication and Interpersonal Skills

Effective extension work goes beyond technical knowledge; it also requires strong communication and interpersonal skills. Capacity building programs often include training on how to effectively communicate complex information, engage with diverse farmer populations, and address varying needs and concerns. Enhancing these skills ensures that extension workers can build trust, facilitate learning, and foster positive relationships with farmers (Jones et al., 2020).

6.2.4. Addressing Emerging Challenges

Agricultural extension services must also respond to emerging challenges such as climate change, market fluctuations, and policy changes. Ongoing capacity building equips extension workers with the tools and strategies needed to tackle these issues effectively. Training programs that address these areas prepare extension workers to offer relevant advice and solutions that help farmers adapt and thrive (Brown et al., 2019).

In conclusion, continuous capacity building and training are vital for agricultural extension workers to maintain their effectiveness. By staying updated on technological advancements, enhancing technical and communication skills, and addressing emerging challenges, extension workers can provide valuable support to farmers, thereby improving agricultural productivity and sustainability.

6.3. Policy Reforms and Institutional Strengthening

To enhance the efficacy and coverage of agricultural extension services in Nigeria, several policy reforms and institutional strengthening measures are essential. These recommendations aim to address existing challenges and optimize the performance of extension services.

6.3.1. Establishing a Unified National Extension Policy

A cohesive and comprehensive national extension policy is crucial for standardizing practices, setting clear objectives, and ensuring coordinated efforts across various levels of government and institutions. This policy should outline the roles and responsibilities of extension services, provide guidelines for service delivery, and allocate resources efficiently. A unified policy can also facilitate better alignment with national agricultural goals and ensure consistency in service provision across regions (Eze et al., 2021).

6.3.2. Increasing Funding and Resource Allocation

Adequate funding is essential for the effective functioning of extension services. Policymakers should prioritize increasing financial resources for agricultural extension programs, including funds for training, technology acquisition, and operational costs. Additionally, establishing partnerships with private sector organizations and international donors can help leverage additional resources and support (Olayemi, 2022).

6.3.3. Strengthening Institutional Coordination and Collaboration

Improving coordination among agricultural institutions, research organizations, and extension agencies is vital for the effective dissemination of knowledge and resources. Policymakers should promote collaborative efforts between these entities to ensure that extension workers have access to the latest research, technologies, and best practices. Regular meetings, joint projects, and information-sharing platforms can enhance institutional synergy and streamline service delivery (Afolabi et al., 2020).

6.3.4. Expanding Extension Service Coverage

To reach more farmers, especially in remote and underserved areas, extending the coverage of extension services is necessary. This includes recruiting additional extension workers, establishing regional and local extension centres, and utilizing innovative delivery methods such as digital platforms and mobile services. Expanding coverage ensures that more farmers benefit from extension services and can improve their agricultural practices (Usman et al., 2021).

6.3.5. Promoting Capacity Building and Professional Development

Continual professional development for extension workers is essential for maintaining high service quality. Policymakers should support regular training programs, workshops, and seminars to keep extension workers updated on new technologies, practices, and regulatory changes. Strengthening the capacity of extension workers ensures they can effectively address the needs of farmers and implement best practices (Ibrahim et al., 2022).

In conclusion, implementing these policy reforms and institutional strengthening measures will significantly enhance the effectiveness and reach of agricultural extension services in Nigeria. By establishing a unified policy framework, increasing funding, improving institutional collaboration, expanding coverage, and promoting capacity building, the agricultural sector can achieve greater productivity, sustainability, and resilience.

7. Conclusion and policy implications

7.1. Recap of Key Findings

Agricultural extension workers play a pivotal role in transforming Nigeria's agricultural supply chains, significantly impacting productivity, sustainability, and ethical practices. Through their efforts, they bridge the gap between research institutions and farmers, facilitating the adoption of modern technologies and innovative farming techniques. Firstly, extension workers are instrumental in disseminating crucial knowledge and training farmers on advanced agricultural practices. Their role in promoting the use of modern technologies, such as precision farming and mobile-based information systems, has led to substantial improvements in farming productivity and efficiency. By introducing innovations like remote sensing and data analytics, extension workers help farmers optimize crop management and enhance yields, contributing to a more robust and resilient agricultural sector.

Moreover, extension workers advocate for ethical farming practices, including organic farming, water conservation, and responsible pesticide use. Their guidance ensures that farming practices not only boost productivity but also align with sustainability goals and environmental stewardship. This advocacy is crucial in promoting fair labour practices and reducing the ecological footprint of agriculture in Nigeria. In addition to technological and ethical advancements, extension services enhance market access for farmers. By facilitating connections between farmers and value chains, extension workers help farmers meet quality standards and access broader markets, thereby improving their economic stability and income. Despite these contributions, extension workers face challenges such as resource constraints, technological barriers, and policy limitations. Addressing these issues through policy reforms and institutional strengthening is essential for maximizing the impact of extension services. In summary, agricultural extension workers are key drivers of transformation in Nigeria's agricultural supply chains. Their work in promoting innovation, ethical practices, and market access supports the sector's growth and sustainability, ultimately contributing to improved food security and economic development.

7.2. Policy Recommendations

To enhance agricultural extension services and their impact on productivity and sustainability in Nigeria, policymakers should consider the following actionable recommendations:

7.2.1. Increase Funding and Resources

Allocate Adequate Budget: Governments should increase budgetary allocations for extension services to ensure they have the necessary resources for effective operation. This includes funding for training programs, infrastructure development, and provision of essential materials.

Improve Resource Distribution: Efficient distribution of resources, such as vehicles and technological tools, is essential to reach remote areas and facilitate timely support to farmers.

7.2.2. Enhance Training and Capacity Building

Continuous Professional Development: Implement regular training programs for extension workers to keep them updated on the latest agricultural practices, technologies, and ethical standards. This should include both technical skills and soft skills such as communication and leadership.

Certification and Accreditation: Establish certification and accreditation programs to ensure that extension workers meet high standards of competence and professionalism.

7.2.3. Strengthen Technological Integration

Promote Digital Tools: Encourage the use of digital platforms, mobile applications, and remote sensing technologies in extension services. This can enhance information dissemination, data collection, and farmer engagement.

Support Infrastructure Development: Invest in infrastructure that supports technology use, such as internet connectivity in rural areas, to overcome technological barriers.

7.2.4. Reform and Streamline Policies

Develop Comprehensive Policies: Create cohesive agricultural policies that integrate extension services into broader agricultural and rural development strategies. This includes clear guidelines for policy implementation and coordination among relevant institutions.

Enhance Policy Coordination: Improve collaboration between government agencies, research institutions, and extension services to ensure alignment of objectives and effective policy execution.

7.2.5. Foster Public-Private Partnerships

Engage Private Sector: Encourage partnerships with private organizations and NGOs to leverage additional expertise, funding, and innovative solutions for extension services.

Support Farmer Organizations: Strengthen relationships with farmer cooperatives and organizations to facilitate better communication and collaboration.

By implementing these recommendations, policymakers can significantly enhance the effectiveness of agricultural extension services, leading to improved productivity, sustainability, and overall development of Nigeria's agricultural sector.

7.3. The Path Forward

The future of agriculture in Nigeria is poised for transformative change, driven by advancements in technology and evolving agricultural practices. Extension workers will play a pivotal role in navigating this transition and shaping the future of Nigerian agriculture in the digital age. As digital technologies continue to advance, the role of extension workers will increasingly centre around integrating these tools into agricultural practices. Mobile platforms, artificial intelligence (AI), and remote sensing technologies offer unprecedented opportunities for enhancing farm productivity and efficiency. Extension workers will be crucial in facilitating the adoption of these innovations, ensuring that farmers can leverage technology to improve crop yields, optimize resource use, and make informed decisions based on real-time data.

The expansion of digital connectivity will also enable extension workers to reach remote and underserved areas more effectively. With the proliferation of smartphones and internet access, extension services can provide farmers with instant access to information, market prices, weather forecasts, and best practices. This digital engagement will bridge the gap between research institutions and farmers, promoting the rapid diffusion of new technologies and techniques. Furthermore, as climate change and environmental concerns become increasingly pressing, extension workers will be instrumental in advocating for sustainable agricultural practices. They will support farmers in adopting climate-smart techniques, such as conservation tillage, efficient water management, and organic farming, to ensure long-term resilience and sustainability. To support these evolving roles, there must be a concerted effort to enhance training and capacity building for extension workers. Continuous professional development will be essential to equip them with the skills needed to effectively utilize digital tools and address emerging challenges in agriculture. In summary, the path forward for agriculture in Nigeria involves embracing digital transformation, fostering sustainable practices, and

empowering extension workers to drive innovation and efficiency. By aligning extension services with technological advancements and sustainability goals, Nigeria can achieve a more resilient and prosperous agricultural sector.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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