Optimizing Agricultural Products Transportation for Food Security and Rural Growth in Southern Kaduna

[1]Masugari, Danjuma Yakubu, [2]Madaki, Albert & [3]Patience Peter
[1,2&3]*Department of Geography*
Kaduna State College of Education, Gidan Waya

Abstract

This study investigates the transportation of agricultural products in Southern Kaduna, Nigeria, focusing on infrastructure, logistics, and ways to reduce postharvest losses. Using a mixed-methods approach, 379 farmers, transporters, and traders were surveyed, and government officials were interviewed, complemented by focus group discussions. Quantitative data were analyzed with descriptive statistics and regression, while qualitative data were coded thematically. Results show that poor rural roads (65.4%), high transport costs (29.0%), long market trips (50.6% over 2 hours), and limited storage (55.7%) lead to product losses of 10–30%, with ginger most affected. Regression analysis ($R^2 = 0.510$, $F(5,376) = 28.78$, $p < 0.001$) indicates that better road conditions ($\beta = 0.310$) and access to new transport solutions ($\beta = 0.205$) improve productivity, while longer travel time ($\beta = -0.280$), higher costs ($\beta = -0.210$), and spoilage ($\beta = -0.175$) reduce it. Although only 20.1% use digital platforms, 75.2% are willing to share transport costs through cooperative systems and logistics hubs. The study recommends road improvements, better storage, cooperative transport, farmer training on digital tools, and public–private partnerships to reduce losses, increase incomes, and improve food security in the region.

Keywords: *Transportation, Postharvest Loss, Agricultural Products, Southern Kaduna, Logistics*

Corresponding Author: **Masugari, Danjuma Yakubu**

Background to the Study

Agriculture is one of the most influential drivers that produce world food security, economic development, and rural poverty elimination. Agriculture, according to the Food and Agriculture Organization (FAO, 2022), gives employment to nearly 27% of all active workers in the world and is a major driver in hunger and poverty alleviation. Postharvest losses remain a critical problem globally with nearly 14% of the produce lost in transit between sale and harvest as a result of poor handling, storage, and transportation. Efficient transport and logistic networks are therefore the key to making low loss, on-time agro-product delivery a reality in addition to driving the United Nations Sustainable Development Goals (SDGs), SDG 2: Zero Hunger.

Agriculture in Africa employs over 60% of the continent's labor force and accounts for about 23% of the continent's GDP (AfDB, 2022). However, they are being prevented from making their own input in a sustainable manner to feed the growing population due to poor infrastructures, poorer road conditions, and inefficient logistics. World Bank (2021) also revealed that food prices on African markets are inflated by up to 40% by transport bottlenecks, making the markets less competitive and exacerbating food insecurity. The most disproportionately affected are rural farmers with them shouldering a heavier burden of getting the products to city and export markets, which at huge postharvest losses and income declines.

The largest country in the African continent, Nigeria relies heavily on agriculture since it contributes nearly 24% of its GDP and livelihood support to more than 70% of rural dwellers (NBS, 2023). The country continues to lose trillions of dollars' worth of postharvest value annually due to poor transport, rural road infrastructure limitation, and logistics cost (Adebayo *et al.*, 2022). These are Nigeria food security policy risks and render farming unprofitable, particularly for rural farmers. Investment in the transport infrastructure and logistics is therefore necessary to ensure agricultural productivity and farmers' access to markets in the country.

The Southern Kaduna Senatorial Zone of Northwestern Nigeria is a good representation of such risks. The area is one of the major agricultural production belts whose top products include maize, rice, ginger, yam, cassava, and beans (KSADP, 2022). Poor road transport operations, distribution expenses, and rural road infrastructure limit the transport of produce from farms to regional and local level markets significantly (Olukayode, 2023). The farmers consequently experience high postharvest losses, low income, and uncompetitiveness of larger markets (Aina and Usman, 2023). These challenges need to be resolved by a permanent, local fix with infrastructural development, effective transport systems, technologically oriented logistics, and multi-stakeholder coordination for the overall agricultural potential of the area to be increased.

Statement of Research Problem

Despite the rightful contribution of agriculture in Southern Kaduna, inefficiencies in transport continue to disassemble its contribution to food security and rural economic

development. Previous efforts by the development agencies and governments have been in the direction of general improvement in the infrastructure without or with little attempt at master plans for overall co-ordination of transport and logistic problems of the region's crop produce. The consequence is that excessive postharvest losses, cost of transportation prohibitive, and access to remunerative markets poor is the rule. Lack of a master and sustainable transport plan in Southern Kaduna is a humongous research gap that this study is meant to fill.

Research Objectives
The primary objective of this study is to develop a strategic framework for optimizing the transportation of agricultural products from the Southern Kaduna Senatorial Zone to enhance food security and promote rural development. The specific objectives are to:

i. Assess the current state of transportation infrastructure and logistics for agricultural products in Southern Kaduna.
ii. Identify the major barriers contributing to postharvest losses and inefficiencies in agricultural transportation.
iii. Explore innovative transportation solutions and technologies that can improve the efficiency of agricultural product movement.

Literature Review
Transport and logistics are critical to the operation of farming economies across the world. Quite literally around the world, literature agrees that poor transport infrastructure is a primary source of food loss, especially in the developing world. FAO (2022) estimates that as much as 14% of farm production is lost between farm and retail due to inefficiencies in transport, logistics, and storage. For sub-Saharan Africa, the World Bank (2021) points out poor infrastructure, poor rural road quality, and high transportation cost as the most significant constraints for farmers to reach markets, thereby increasing the transaction cost and reducing competitiveness. The bottlenecks have a likelihood of leading to high urban food prices while rural farmers receive declining revenues.

Nigerian agriculture accounts for approximately 24% of GDP and employs more than 70% of the rural labor force (NBS, 2023). Yet, efficiency transport bottlenecks in the form of a low-quality rural road network, expensive logistics, and inadequate storage facilities weaken market integration and productivity. Inefficiency, according to Adebayo *et al.* (2022), is responsible for considerable postharvest losses that amount to billions of naira annually.

The Southern Kaduna Senatorial Zone is no reflection of these national issues. As one of Nigeria's foremost agric belts in ginger, yam, rice, and maize cultivation (KSADP, 2022), the zone is beset by seasonal road impassability, absence of logistics facilities, and exorbitant transportation charges. Olukayode (2023) expounds that during off-season harvest periods, rain water further exacerbates bad roads, rendering it extremely difficult for farmers to evacuate produce to market centers. Innovative options have been suggested, such as the use of digital platforms to connect farmers to transport services (WFP, 2020) and the creation of centralized logistics platforms (Adebayo *et al.*, 2022). Public–private partnerships (PPPs) have also been suggested as an option to bridge infrastructural and financial gaps (Akinwale, 2021; AfDB, 2022).
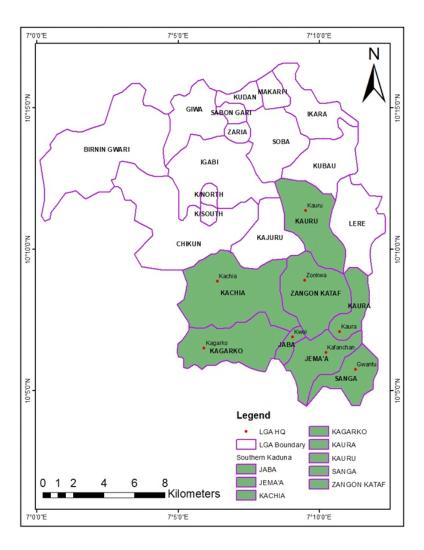
Identification of Research Gaps

While the literature strongly argues the contribution of efficient transport networks to agricultural productivity and food security, there are gaps. In the first place, most of the studies on Nigeria and Africa concentrate on the general nexus between infrastructure and agricultural performance, without coming up with a region-specific model, which is unique to areas like Southern Kaduna, where there are geographical and socio-economic uniqueness. Secondly, there is a narrow empirical focus on mainstreaming emerging transport solutions such as digital logistic platforms, cold chain transport, and collective transport systems into the Nigerian agricultural value chain. Filling the gaps is a prerequisite for reducing postharvest losses, increasing farmers' earnings, and stimulating rural development in Southern Kaduna.

Theoretical Framework

The study draws from the Sustainable Livelihoods Framework (SLF), which emphasizes the importance of assets, institutions, and processes in building rural livelihoods. The framework is suitable because transport facilities and logistics are part of the "physical capital" which enable farmers to access markets and maximum return on land and labor. Farmers' livelihoods are improved by higher income, reduced vulnerability, and better food security through enhanced transport systems. The SLF also focuses on the role played by external support systems such as government intervention, PPPs, and the adoption of technology in creating enabling environments for sustainable rural development.

Methodology

This study was conducted in the Southern Kaduna Senatorial Zone of northwestern Nigeria, located between latitudes 10°00′0″N and 13°00′0″N, and longitudes 6°00′0″E and 9°00′0″E (Chori, 2003). It is bordered by Kauru and Chikun LGAs to the north, the Federal Capital Territory (FCT) and Nasarawa State to the south, Niger State to the west, Lere and Kubau LGAs to the east, and Plateau State to the southeast. The zone is largely rural and depends on agriculture, producing crops such as maize, ginger, beans, cassava, and rice. It consists of eight Local Government Areas (LGAs): Jema'a, Jaba, Kaura, Kachia, Kagarko, Zangon Kataf, Sanga, and Kauru. Despite its rich agricultural potential, poor transport and logistics hinder market access and reduce productivity. The study population included farmers, transporters, traders, government officials, and development agencies, while a sample size of 382 respondents was determined using Krejcie and Morgan's (1970) table.

Figure 1: Kaduna State Map Showing Southern Kaduna
Source: Kaduna State Ministry of Land and Survey, 2025

The study used both quantitative and qualitative methods. Questionnaires were given to farmers, transporters, and traders to collect data on transport costs, road conditions, storage, and postharvest losses. Interviews were conducted with government officials and development agencies, while focus group discussions involved farmers and transporters. Field visits were made to observe road and transport conditions. Secondary data were collected from reports and past studies. Quantitative data were analyzed with descriptive statistics and regression analysis to examine how transport problems affect productivity. Qualitative data were analyzed through thematic coding to identify common issues and solutions. Both sets of findings were combined to create a framework for improving agricultural transportation in Southern Kaduna, focusing on infrastructure, logistics, and partnerships.

Results and Discussion
Socio-Economic Characteristics of Respondents
This section looks at personal data of respondents. Underneath here are tables showing detail of results.

Table 1: Socio-Economic Characteristics of Respondents

Variable	Frequency	Percentage (%)
Age Group		
Below 30	65	17.2
30–39	124	32.7
40–49	108	28.5
50 and above	82	21.6
Total	**379**	**100**
Education Level		
No formal	94	24.8
Primary	106	28.0
Secondary	121	31.9
Tertiary	58	15.3
Total	**379**	**100**
Household Size		
1–3 members	74	19.5
4–6 members	142	37.5
7–9 members	102	26.9
10 and above	61	16.1
Total	**379**	**100**
Primary Livelihood Source		
Farming only	187	49.3
Farming + trading	98	25.9
Farming + artisan	56	14.8
Other (civil service etc.)	38	10.0
Total	**379**	**100**

Source: Field Survey, 2025

Table 1 presents the socio-economic characteristics of respondents in Southern Kaduna. The findings show that farming is mainly practiced by middle-aged adults, with 32.7% aged 30–39 years and 28.5% aged 40–49 years, while only 17.2% were below 30 years. Education levels were modest: 31.9% attained secondary education, 28.0% primary education, and 24.8% had no formal schooling, while just 15.3% had tertiary education. This reflects the rural context where access to higher education is limited and farming is the dominant activity.

Household size was generally large, with 37.5% having 4–6 members and 26.9% having 7–9 members, which suggests access to family labor for farming. In terms of livelihoods, nearly half of the respondents (49.3%) relied solely on farming, while 25.9% combined farming with trading, and 14.8% with artisan work. Only 10% engaged in non-farming jobs such as civil service. These results confirm that agriculture is the mainstay of households in the area, though limited education and low diversification may affect the adoption of innovations and long-term economic resilience.

Assess the Current State of Transportation Infrastructure and Logistics
This section present information on the Current State of Transportation Infrastructure and Logistics in southern Kaduna senatorial zone

Table 2: Current State of Transportation Infrastructure and Logistics

Variable	Frequency	Percentage (%)
Condition of Rural Roads		
Good	77	20.3
Fair	115	30.3
Poor	131	34.6
Very poor	56	14.8
Total	**379**	**100**
Means of Transporting Farm Produce		
Motorcycle	156	41.2
Pick-up van	113	29.8
Truck/Lorry	77	20.3
Animal cart	33	8.7
Total	**379**	**100**
Time to Transport Produce to Market		
Less than 1 hr	94	24.8
1–2 hrs	137	36.1
3–4 hrs	93	24.5
More than 4 hrs	55	14.6
Total	**379**	**100**
Access to Storage Facilities		
Yes, adequate	59	15.6
Yes, but limited	133	35.1
No access	152	40.1
Not sure	35	9.2
Total	**379**	**100**

Source: Field Survey, 2025

Table 2 shows that most respondents rated rural roads as poor (34.6%) or fair (30.3%), with only 20.3% calling them good. This highlights poor road conditions as a major barrier, similar to Olukayode (2023), who found the same in Northern Nigeria. Motorcycles (41.2%) were the main means of transport, followed by pick-up vans (29.8%), showing limited access to larger vehicles. This agrees with Aina and Usman (2023), who noted that farmers often rely on motorcycles because of bad roads.

Market access was also difficult, with 36.1% spending 1–2 hours and almost 39% more than 2 hours to reach markets. Such delays expose crops to spoilage, confirming Adebayo *et al*. (2022), who linked long travel times to postharvest losses. Storage was another problem, as 40.1% had no access and 35.1% had only limited facilities, consistent with FAO (2022), which identified poor storage as a major weakness in Nigeria's food system. Overall, poor roads, weak transport, long travel times, and lack of storage reduce productivity in Southern Kaduna, reflecting similar challenges across sub-Saharan Africa.

Major Barriers Contributing to Postharvest Losses and Inefficiencies
This section present information on the major barriers contributing to postharvest losses and inefficiencies in southern Kaduna senatorial zone.

Table 3: Major Barriers Contributing to Postharvest Losses and Inefficiencies

Variable	Frequency	Percentage (%)
Biggest Challenge in Transporting Produce		
Poor road conditions	134	35.4
High cost of transport	110	29.0
Lack of vehicles	78	20.6
Seasonal inaccessibility	57	15.0
Total	**379**	**100.0**
Frequency of Produce Loss Due to Delays		
Very often	97	25.6
Sometimes	172	45.4
Rarely	76	20.0
Never	34	9.0
Total	**379**	**100.0**
Proportion of Produce Lost in Transport		
Less than 10%	115	30.3
10–20%	113	29.8
21–30%	95	25.1
Above 30%	56	14.8
Total	**379**	**100.0**
Crop Most Affected by Transport Spoilage		
Maize	97	25.6
Ginger	132	34.8
Rice	77	20.3
Yam	73	19.3
Total	**379**	**100.0**

Source: Field Survey, 2025

Table 3 shows that poor roads (35.4%) and high transport costs (29.0%) are the main problems farmers face, similar to Aina and Usman (2023), who also found that bad roads and costly logistics limit farmers' market access. Other challenges include lack of vehicles (20.6%) and seasonal inaccessibility (15.0%), which supports World Bank (2021) findings that poor transport services and flooding disrupt supply chains. Almost half of the farmers (45.4%) said they sometimes lose produce due to delays, while 25.6% lose very often, in line with Adebayo *et al*. (2022), who linked frequent delays to spoilage.

The scale of losses is also high. About 30.3% reported less than 10% loss, while nearly 40% lose between 10–30%, and 14.8% lose more than 30%. This agrees with FAO (2022), which reported that 20–40% of crops in Nigeria are lost before reaching markets. Ginger (34.8%) was the most affected crop, followed by maize (25.6%), rice (20.3%), and yam (19.3%), reflecting Olukayode (2023), who noted that ginger in Southern Kaduna spoils easily during transport.

These findings confirm that poor transport leads to high losses, lower farmer income, and food insecurity.

Innovative Transportation Solutions and Technologies
This section shows information on the innovative information solutions and technologies explore in southern Kaduna senatorial zone.

Table 4: Innovative Transportation Solutions and Technologies (n = 379)

Variable	Frequency	Percentage (%)
Awareness of Digital Platforms for Transport		
Yes, I use them	76	20.1
Yes, but I don't use	96	25.3
No, not aware	152	40.1
Not sure	55	14.5
Total	**379**	**100**
Willingness to Share Transport Costs		
Strongly willing	133	35.1
Willing	152	40.1
Unwilling	57	15.0
Strongly unwilling	37	9.8
Total	**379**	**100**
Most Useful Transport Solution		
Refrigerated vehicles	95	25.1
Logistics hubs	95	25.1
Cooperative transport	115	30.3
Mobile booking apps	74	19.5
Total	**379**	**100**
Agreement that Technology Reduces Losses		
Strongly agree	152	40.1
Agree	133	35.1
Disagree	57	15.0
Strongly disagree	37	9.8
Total	**379**	**100**

Source: Field Survey, 2025

Table 4 shows that most farmers are not using digital platforms, with 40.1% unaware of them and only 20.1% using them. These points to a digital gap, similar to Akinwale (2021), who found low use of logistics technologies among rural farmers in Nigeria. However, many respondents showed readiness to work together, with 40.1% willing and 35.1% strongly willing to share transport costs. This supports WFP (2020), which noted that shared transport reduces costs for smallholder farmers.

For preferred solutions, cooperative transport (30.3%) was chosen most, followed by refrigerated vehicles (25.1%) and logistics hubs (25.1%), while mobile apps (19.5%) were least preferred. This suggests farmers favor practical, collective approaches over digital ones, which agrees with Adebayo *et al.* (2022) on the role of cooperatives in solving logistics issues. Most

respondents also believed technology can help, with 40.1% strongly agreeing and 35.1% agreeing that it reduces losses. This supports FAO (2022), which reported that technology-driven logistics and storage cut spoilage and improve efficiency. Overall, while digital use is low, farmers in Southern Kaduna are open to cooperative and technology-based solutions.

Regression Analysis on the Relationship between Transportation Inefficiencies and agricultural productivity

This section presents the Relationship between Transportation Inefficiencies and agricultural productivity.

Table 5: Regression Model Summary

Dependent Variable	R	R Square	Adjusted R Square	Std. Error of the Estimate
Agricultural Productivity (Y)	0.714	0.510	0.498	0.315

Source: Field Survey, 2025

The model summary indicates that transportation-related predictors jointly explain 51% of the variance in agricultural productivity ($R^2 = 0.510$). The adjusted R^2 (0.498) confirms the robustness of the model, meaning almost half of the variations in productivity among farmers are explained by road conditions, time to market, transport costs, postharvest losses, and access to innovations.

Table 6: ANOVA Results for Regression Model

Dependent Variable	Sum of Squares	df	Mean Square	F	Sig.
Agricultural Productivity (Y)	45.320	5	9.064	28.780	0.000
Residual	43.540	376	0.116		
Total	88.860	381			

Dependent Variable: Agricultural Productivity, Predictors: (Constant), Road Condition, Time to Market, Transport Cost, Postharvest Losses, Access to Innovations

Source: Field Survey, 2025

The ANOVA confirms that the regression model is statistically significant ($F(5,376) = 28.780$, $p < 0.001$), meaning the predictors jointly influence agricultural productivity in Southern Kaduna.

Table 7: Regression Coefficients for Agricultural Productivity Model

Predictor	B (SE)	Beta	T	Sig.
(Constant)	2.12 (0.245)	—	8.65	0.000
X_1: Road Condition	0.325 (0.071)	0.310	4.58	0.000
X_2: Time to Market	-0.290 (0.066)	-0.280	-4.39	0.000
X_3: Transport Cost	-0.215 (0.064)	-0.210	-3.36	0.001
X_4: Postharvest Losses	-0.178 (0.059)	-0.175	-3.01	0.003
X_5: Access to Innovations	0.210 (0.072)	0.205	2.92	0.004

Dependent Variable: Agricultural Productivity

Source: Field Survey, 2025

Table 7 shows the regression results for agricultural productivity. Road condition ($\beta = 0.310$, $p < 0.001$) and access to innovations ($\beta = 0.205$, $p = 0.004$) had positive effects, meaning good roads and new technologies improve productivity. On the other hand, time to market ($\beta = -0.280$, $p < 0.001$), transport cost ($\beta = -0.210$, $p = 0.001$), and postharvest losses ($\beta = -0.175$, $p = 0.003$) reduced productivity, showing that delays, high costs, and spoilage harm farmers' output. These findings support FAO (2022) and Adebayo *et al*. (2022), who also reported that poor transport systems lower farmers' income, and AfDB (2022), which stressed the role of innovations in improving food security. Overall, better roads and innovations are key to reducing losses and improving agricultural productivity in Southern Kaduna.

Table 8: Thematic Analysis of Stakeholder Interviews

Interview Question	Codes (Key Responses)	Theme	Interpretation
Major transportation challenges and their effects on productivity	Poor road conditions, high transport costs, seasonal inaccessibility, insecurity	Infrastructure deficits and cost barriers	Poor feeder roads, especially in rainy seasons, limit farmers' access to markets, increase postharvest losses, and reduce productivity and incomes.
Existing policies and interventions	Ad hoc government projects, donor-funded initiatives, lack of sustainability	Policy gaps and ineffective interventions	Government and donor interventions exist but are poorly coordinated, underfunded, and unsustained, leading to limited impact on agricultural logistics.
Role of Public–Private Partnerships (PPPs)	Shared investment, resource mobilization, collaborative maintenance	Potential of PPPs as a sustainable solution	PPPs can bridge financing gaps by mobilizing resources from government, private enterprises, and communities, offering a viable model for rural transport improvement.
Innovative or technology-driven solutions	Digital logistics platforms, cooperative transport, centralized hubs, refrigerated vehicles	Innovation as a catalyst for efficiency	Adoption of technology-based solutions and cooperative systems can reduce spoilage, improve logistics coordination, and expand farmers' access to profitable markets.
Recommendations for a sustainable framework	Integrated strategy, stakeholder collaboration, capacity building, security measures	Framework for sustainable rural transport	An integrated approach combining infrastructure investment, innovation, farmer training, and stakeholder partnerships is essential for long-term improvements.

Source: Field Survey, 2025

Table 8 presents the thematic analysis of stakeholder interviews. Respondents highlighted poor road conditions, high transport costs, and seasonal inaccessibility as key challenges, showing that weak infrastructure limits market access and lowers farm incomes. They noted that existing policies and donor projects are not well coordinated or sustained, creating gaps in support. Stakeholders also saw Public–Private Partnerships (PPPs) as a good way to share resources and improve rural transport. Innovative options such as digital platforms, cooperative transport, and refrigerated vehicles were suggested to cut losses and improve logistics. Overall, the findings point to the need for an integrated approach that combines better infrastructure, technology, training, and collaboration among stakeholders.

Discussion of Findings
This study shows that poor transport systems are a major challenge to farming in Southern Kaduna. Most farmers reported bad or fair roads, dependence on motorcycles, long trips to markets, and little or no storage, all of which reduce productivity. The main barriers were poor roads, high transport costs, and delays, causing many farmers to lose 10–30% of their crops, especially ginger. Although awareness of digital platforms was low, most farmers were willing to adopt cooperative and technology-based solutions. The regression results confirmed that good roads and innovations improve productivity, while delays, high costs, and spoilage reduce it. These findings agree with earlier studies such as Olukayode (2023), FAO (2022), and Adebayo *et al*. (2022), which also linked poor transport and weak storage to high postharvest losses. The results highlight the need for better roads, storage, cooperatives, and Public–Private Partnerships (PPPs) to reduce losses, improve farmer income, and strengthen food security in the region.

Conclusion
This study found that poor road conditions, high transport costs, long travel times, and limited storage facilities are the main barriers to agricultural productivity in Southern Kaduna. Farmers rely heavily on motorcycles to move produce, which slows access to markets and increases postharvest losses, especially for perishable crops like ginger. Although awareness of digital platforms was low, many farmers expressed willingness to adopt cooperative and technology-based solutions. Regression analysis confirmed that better roads and innovations improve productivity, while inefficiencies such as delays, costs, and spoilage reduce it. These findings highlight the urgent need for improved transport systems to boost farmer income and strengthen food security.

Recommendations
The study recommends investment in rural road rehabilitation, storage facilities, and affordable transport services to reduce delays and postharvest losses. Cooperative transport systems should be encouraged to lower costs and improve logistics, while farmer training can promote the use of digital platforms and innovative solutions. Policymakers and development partners should also support Public–Private Partnerships (PPPs) to mobilize resources and ensure sustainable improvements in rural transport. Together, these measures can help unlock Southern Kaduna's agricultural potential and contribute more effectively to rural development and national food security.

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