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THE IMPACT OF TRANSPORTATION AND MARKET INFRASTRUCTURE ON FOOD LOSSES AMONG RURAL FARMERS IN DELTA STATE, NIGERIA

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ABSTRACT: *Food loss remains a critical challenge threatening food security and rural livelihoods in Sub-Saharan Africa, with Nigeria experiencing substantial post-harvest losses estimated at 30-50% annually. This study examined the impact of transportation and market infrastructure on food losses among rural farmers in Delta State, Nigeria. Using a cross-sectional research design, data were collected from 384 randomly selected farmers across three agricultural zones during January-June 2024. A structured questionnaire was used to gather information on transportation challenges, market infrastructure conditions, and food loss experiences. Data analysis utilized descriptive statistics, Pearson correlation, and multiple regression analysis. Results revealed that 78.4% of farmers experienced significant food losses, with inadequate transportation (mean = 4.23, SD = 0.87) and poor market infrastructure (mean = 4.15, SD = 0.92) identified as primary contributors. Regression analysis demonstrated that transportation accessibility ($\beta = -0.456$, $p < 0.001$) and market infrastructure quality ($\beta = -0.389$, $p < 0.001$) significantly predicted food loss levels, collectively explaining 67.3% of the variance ($R^2 = 0.673$, $F = 156.42$, $p < 0.001$). Road conditions, distance to markets, and storage facilities emerged as critical determinants. The study concludes that improving transportation networks and market infrastructure could reduce food losses by approximately 40-45%. Recommendations include government investment in rural road rehabilitation, establishment of modern storage facilities, and development of integrated market systems to enhance agricultural value chains and farmer incomes.*

KEYWORDS: *Food losses, transportation infrastructure, market systems, rural farmers, post-harvest management*

Introduction

Food loss refers to commodities as well as livestock and crop completely discarded, burnt, or spoilt and hence are not reused (Aburime, 2023). Nigeria, as Africa's most populous nation with over 200

million people, depends heavily on agriculture for food supply, employment, and economic development, with approximately 70% of the population engaged in agricultural activities (Ogundari & Awokuse, 2018). Despite this substantial agricultural engagement, the country faces persistent food insecurity challenges, partly attributed to significant food losses occurring along the agricultural value chain.

Food loss, defined as the decrease in edible food mass throughout the supply chain from harvest to retail, represents a critical constraint to achieving food security and sustainable agricultural development (FAO, 2019). In Nigeria, post-harvest food losses are estimated at between 30% and 50% annually, translating to economic losses exceeding $9 billion and affecting the livelihoods of millions of smallholder farmers (Adeoye et al., 2021). These losses occur at various stages including harvesting, handling, storage, processing, and transportation, with transportation and market infrastructure playing crucial roles in determining the magnitude of losses experienced by farmers.

Transportation infrastructure serves as the critical link connecting farm production to market consumption, facilitating the movement of agricultural produce from rural production areas to urban consumption centers (Gollin & Rogerson, 2014). Inadequate transportation systems, including poor road networks, limited vehicle availability, high transportation costs, and prolonged transit times, contribute substantially to physical damage, quality deterioration, and complete loss of agricultural produce (Kitinoja et al., 2018). Market infrastructure encompasses the physical facilities, organizational systems, and institutional arrangements that enable efficient agricultural exchange, including market buildings, storage facilities, processing equipment, information systems, and regulatory frameworks (Barrett et al., 2022).

The relationship between infrastructure deficits and food losses has attracted increasing attention from researchers, policymakers, and development practitioners. Omotilewa et al. (2021) in their study have demonstrated strong correlations between infrastructure quality and agricultural productivity outcomes, farmer incomes, and food security indicators. However, context-specific research examining the particular challenges faced by farmers in ecologically diverse and infrastructural disadvantaged regions like Delta State remains limited. Understanding these localized dynamics is essential for designing targeted interventions that address the specific constraints faced by rural farmers in different geographical contexts.

In Delta State, where agriculture employs over 60% of the rural population, farmers report losing between 25% and 45% of their harvested produce before reaching final consumers, with transportation challenges and inadequate market infrastructure cited as primary contributing factors (Osabohien et al., 2020).

The problem manifests in several interconnected dimensions. First, rural road networks in Delta State are predominantly unpaved, poorly maintained, and frequently impassable during rainy seasons, which coincide with major harvest periods for key crops. Second, the lack of adequate storage facilities at farm and market levels compels farmers to sell immediately after harvest, often flooding markets and depressing prices while simultaneously experiencing physical losses to spoilage, pests, and mechanical damage. Third, market infrastructure in rural areas remains severely underdeveloped, with most markets lacking basic amenities such as covered stalls, cold storage, processing equipment, and waste management systems. Fourth, the absence of organized market information systems leaves farmers vulnerable to information asymmetries, preventing them from making informed decisions about harvest timing, market selection, and price negotiation.

Despite recognition of these challenges, empirical research quantifying the specific relationships between transportation infrastructure, market systems, and food loss magnitudes in Delta State remains limited. This knowledge gap constrains evidence-based policy formulation and targeted intervention design. This study therefore addresses a critical research gap by systematically investigating how transportation and market infrastructure dimensions influence food loss experiences among rural farmers in Delta State, Nigeria.

The following specific objectives guided the study:

I. assess the extent and magnitude of food losses experienced by rural farmers in Delta State and identify the primary crops and value chain stages most affected by losses.
II. examine the relationship between transportation infrastructure characteristics (road quality, vehicle availability, transportation costs, market distance) and the levels of food losses experienced by farmers.
III. evaluate the influence of market infrastructure quality (storage facilities, market amenities, information systems, processing facilities) on food loss magnitudes among rural farmers.

Hypothesis

H_0: There is no significant relationship between transportation infrastructure quality and food loss levels among rural farmers in Delta State

Methodology

This study employed a cross-sectional survey research design to examine the impact of transportation and market infrastructure on food losses among rural farmers in Delta State, Nigeria. The cross-sectional approach was appropriate for capturing data at a specific point in time while allowing for the examination of relationships between variables across a diverse sample of farmers operating under varying infrastructural conditions (Creswell & Creswell, 2018).

The research was conducted in Delta State, located in the South-South geopolitical zone of Nigeria, lying approximately between latitudes 5°00' and 6°30' North and longitudes 5°00' and 6°45' East. Delta State covers a land area of approximately 17,698 square kilometers with a population estimated at 5.6 million people. The state is divided into three agricultural zones by the Delta State Agricultural Development Programme (ADP): Delta North, Delta Central, and Delta South zones, each characterized by distinct ecological features and agricultural practices. These ecological and infrastructural variations provided valuable diversity for examining how different infrastructure contexts influence food loss experiences.

The target population comprised all registered smallholder farmers in Delta State engaged in the production of major food crops including cassava, yam, rice, maize, vegetables, and plantain. According to the Delta State Agricultural Development Programme (ADP) records, approximately 487,000 smallholder farmers were registered across the three agricultural zones as of 2023.

The sample size was determined using Yamane's (1967) formula for finite populations:

$n = N / [1 + N(e)^2]$

Where: n = sample size; N = population size (487,000); e = margin of error (0.05)

$n = 487,000 / [1 + 487,000(0.05)^2] = 487,000 / 1,218.5 = 400$

To account for potential non-response and incomplete questionnaires, the sample size was adjusted to 384 respondents after pilot testing indicated a 96% response rate.

A multi-stage sampling technique was employed. First, the three agricultural zones (Delta North, Delta Central, Delta South) were purposively selected to ensure geographical representation. Second, four Local Government Areas (LGAs) were randomly selected from each zone, yielding 12 LGAs. Third, from each selected LGA, two farming communities were randomly chosen, producing 24 communities. Finally, proportionate random sampling was used to select farmers from each community based on ADP registration lists, with 16 farmers selected per community (384 total respondents).

The questionnaire utilized both closed-ended questions and 5-point Likert scales (1 = Strongly Disagree to 5 = Strongly Agree) to measure perceptions and experiences regarding infrastructure conditions and food losses. The instrument was validated by three experts in agricultural economics and extension education who assessed content validity, clarity, and appropriateness. Reliability testing using Cronbach's alpha coefficient yielded values of 0.87 for the transportation infrastructure scale and 0.84 for the market infrastructure scale, indicating high internal consistency.

Data Collection

Data collection was conducted over a six-month period from January to June 2024 by 12 trained research assistants through face-to-face interviews with farmers at their farms or homes, with each interview lasting approximately 35-45 minutes. The research team obtained informed consent from all participants, assured confidentiality, and explained the research purpose and voluntary nature of participation.

Data Analysis

Data were analyzed using the Statistical Package for Social Sciences (SPSS) version 26.0. The analytical approach included:

1. **Descriptive Statistics:** Frequencies, percentages, means, and standard deviations were computed to summarize socio-demographic characteristics, food loss experiences, and infrastructure conditions.
2. **Inferential Statistics:** Pearson Product-Moment Correlation analysis examined relationships between transportation infrastructure, market infrastructure, and food loss levels. Multiple Linear Regression analysis assessed the predictive influence of infrastructure variables on food loss magnitudes.

The multiple regression model was specified as:

$$\mathbf{Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \varepsilon}$$

Where:

- Y = Food loss level (percentage of harvest lost)
- X_1 = Road quality index
- X_2 = Vehicle availability score
- X_3 = Distance to nearest market (kilometers)

- X_4 = Storage facility availability index
- X_5 = Market infrastructure quality index
- β_0 = Constant term; β_1-β_5 = Regression coefficients; ε = Error term

Decision criteria for hypothesis testing utilized a significance level of $\alpha = 0.05$. Null hypotheses were rejected when p-values were less than 0.05, indicating statistically significant relationships.

Results

The results are presented according to the study objectives and research hypothesis.

Extent and Magnitude of Food Losses

Table 1 reveals the extensive nature of food losses experienced by rural farmers in Delta State across multiple crops and value chain stages.

Table 1: Extent and Magnitude of Food Losses by Crop Type and Value Chain Stage (N=384)

Variable	Category	N	Percentage (%)	Mean Loss (%)
Primary Crops Affected	Cassava	287	74.7	38.4
	Yam	246	64.1	32.6
	Vegetables	198	51.6	44.7
	Rice (paddy)	156	40.6	28.3
	Maize	142	37.0	25.4
	Plantain	134	34.9	36.8
Value Chain Stages	Harvesting	312	81.3	8.3
	On-farm handling	346	90.1	12.6
	Transportation	378	98.4	22.8
	Market storage	298	77.6	14.7
	Processing	186	48.4	9.2
Overall Loss Magnitude	<20%	54	14.1	
	20-30%	98	25.5	
	31-40%	132	34.4	35.2
	41-50%	76	19.8	
	>50%	24	6.2	

Note. N = Number of farmers reporting losses for each category; Multiple responses permitted for crop types and value chain stages. SD = Standard Deviation.

While cassava shows the highest extent of losses (74.7% of farmers reporting losses), vegetables shows the highest magnitude of losses (44.7% mean loss). Yam affected 64.1% of farmers with mean losses of 32.6%, while plantain showed 36.8% mean losses among 34.9% of affected farmers.

The value chain stage analysis revealed transportation as the most critical loss point, with 98.4% of farmers reporting transportation-related losses averaging 22.8% of produce (SD = 7.4). This finding underscores the central role of transportation infrastructure in determining food loss outcomes. On-

farm handling ranked second with 90.1% of farmers affected and mean losses of 12.6% (SD = 4.6), suggesting deficiencies in post-harvest handling knowledge and equipment. Market storage losses affected 77.6% of farmers at an average rate of 14.7% (SD = 5.8), indicating inadequate storage infrastructure at market locations. Harvesting and processing stages showed lower loss rates of 8.3% and 9.2% respectively.

The overall loss magnitude distribution showed that 60.4% of farmers (n=232) experienced losses exceeding 30% of their harvests, with a mean overall loss of 35.2% (SD = 13.6). Only 14.1% (n=54) reported losses below 20%, indicating that severe food losses represent a pervasive rather than isolated phenomenon in the study area.

Transportation Infrastructure and Food Losses

Table 2 demonstrates the critical relationship between transportation infrastructure characteristics and food loss experiences among rural farmers in Delta State.

Table 2: Transportation Infrastructure Characteristics and Their Relationship with Food Losses (N=384)

Transportation Variable	Categories/Scale	N	%	Mean	SD	Correlation with Food Loss*
Road Quality Assessment	Very Poor	142	37.0	2.14	0.98	r = 0.624**
	Poor	168	43.8			
	Fair	58	15.1			
	Good	16	4.1			
Distance to Nearest Market (km)	<5	48	12.5	11.8	6.4	r = 0.517**
	5-10	114	29.7			
	11-15	136	35.4			
	>15	86	22.4			
Vehicle Availability	Own vehicle	34	8.9	2.63	1.12	r = -0.482**
	Regular hired access	76	19.8			
	Occasional hired access	186	48.4			
	Rare/no access	88	22.9			
Transportation Cost (% of farm gate price)	<10%	28	7.3	24.6	8.7	r = 0.446**
	10-20%	102	26.6			
	21-30%	154	40.1			
	>30%	100	26.0			
Road Accessibility During Rainy Season	Fully accessible	22	5.7	1.92	0.84	r = 0.591**
	Mostly accessible	68	17.7			
	Occasionally accessible	186	48.4			

Note. **Correlation significant at $p < 0.01$ (2-tailed). SD = Standard Deviation.

Road quality assessment revealed that 80.8% (n=310) of respondents rated roads serving their farming areas as poor to very poor (mean = 2.14, SD = 0.98 on a 5-point scale), with a strong positive correlation with food losses ($r = 0.624$, $p < 0.01$). This correlation suggests that deteriorating road conditions significantly contribute to increased food losses through prolonged transportation times, mechanical damage from rough surfaces, and limited market access.

Distance to nearest markets averaged 11.8 kilometers (SD = 6.4), with 57.8% (n=222) of farmers traveling more than 10 kilometers to reach markets. This distance showed a significant moderate positive correlation with food losses ($r = 0.517$, $p < 0.01$), indicating that increased transportation distances elevate loss risks through extended exposure to damaging conditions and delayed marketing.

Vehicle availability was severely limited, with only 8.9% (n=34) of farmers owning transportation vehicles and 71.3% (n=274) relying on occasional or rare hired access (mean = 2.63, SD = 1.12). The negative correlation between vehicle availability and food losses ($r = -0.482$, $p < 0.01$) suggests that improved transportation access could substantially reduce loss magnitudes.

Transportation costs were prohibitively high, averaging 24.6% of farm gate prices (SD = 8.7), with 66.1% (n=254) of farmers spending more than 20% of their produce value on transportation. This significant cost burden showed a positive correlation with food losses ($r = 0.446$, $p < 0.01$), likely reflecting both the direct impact of delayed transportation due to cost constraints and the indirect effects of farmers' weakened negotiating positions.

Rainy season accessibility emerged as particularly problematic, with 76.5% (n=294) of farmers reporting that their roads were only occasionally or rarely accessible during rainy periods (mean = 1.92, SD = 0.84). This seasonal inaccessibility strongly correlated with food losses ($r = 0.591$, $p < 0.01$), as harvest periods often coincide with rainy seasons when transportation challenges peak.

Market Infrastructure and Food Losses

Table 3 illuminates the profound influence of market infrastructure quality on food loss magnitudes among rural farmers in Delta State.

Table 3: Market Infrastructure Quality and Its Influence on Food Losses (N=384)

Market Infrastructure Variable	Categories/Scale	N	%	Mean	SD	Correlation with Food Loss*
Storage Facility Availability	Modern cold storage	12	3.1	1.67	0.89	r = -0.534**
	Basic covered storage	86	22.4			
	Open-air only	286	74.5			
Market Physical Infrastructure	Very poor	156	40.6	2.08	0.95	r = 0.558**
	Poor	152	39.6			
	Fair	62	16.1			
	Good	14	3.6			
Processing Equipment Access	Regular access	46	12.0	1.84	0.92	r = -0.467**
	Occasional access	98	25.5			
	No access	240	62.5			
Market Information Systems	Digital platforms	34	8.9	1.96	1.04	r = -0.412**
	Radio/phone networks	142	37.0			
	Personal networks only	208	54.2			
Market-Farm Distance Impact on Infrastructure Use	<5 km	48	12.5	11.8	6.4	r = 0.489**
	5-10 km	114	29.7			
	11-15 km	136	35.4			
	>15 km	86	22.4			

Note. **Correlation significant at $p < 0.01$ (2-tailed). SD = Standard Deviation.

Storage facility availability was critically deficient, with 74.5% (n=286) of farmers having access only to open-air storage and a mere 3.1% (n=12) accessing modern cold storage facilities (mean = 1.67, SD = 0.89). The strong negative correlation between storage facility quality and food losses ($r = -0.534$, $p < 0.01$) demonstrates that improved storage infrastructure could substantially mitigate losses.

Market physical infrastructure received predominantly poor ratings, with 80.2% (n=308) of respondents rating their primary markets as poor to very poor (mean = 2.08, SD = 0.95). Poor infrastructure correlated significantly with increased food losses ($r = 0.558$, $p < 0.01$), suggesting that inadequate market facilities—including lack of covered selling areas, absence of drainage systems, inadequate waste management, and insufficient sorting and grading spaces—create conditions that accelerate produce deterioration and increase physical damage.

Processing equipment access was severely limited, with 62.5% (n=240) of farmers having no access to processing facilities (mean = 1.84, SD = 0.92). The negative correlation ($r = -0.467$, $p < 0.01$) indicates that processing capabilities could help farmers convert perishable produce into more stable forms, reducing time pressure for sales and minimizing losses.

Market information systems remained underdeveloped, with 54.2% (n=208) of farmers relying solely on personal networks for market intelligence and only 8.9% (n=34) accessing digital information platforms (mean = 1.96, SD = 1.04). Better information access correlated negatively with food losses

($r = -0.412$, $p < 0.01$), suggesting that improved market information enables farmers to make more informed decisions about harvest timing, market selection, and price negotiation.

Hypothesis Testing Results

Table 4: Hypothesis Testing - Relationship Between Transportation Infrastructure and Food Losses

Hypothesis	Statistical Test	Variables	Coefficient/Value	Std. Error	t/r-value	p-value
H_{01}: No significant relationship between transportation infrastructure and food losses	Pearson Correlation	Transportation Infrastructure Quality Index	r = -0.687	-	-18.24	<0.001
		Road Quality	r = -0.624	-	-15.87	<0.001
		Vehicle Availability	r = -0.482	-	-10.92	<0.001
		Market Distance	r = 0.517	-	12.04	<0.001
		Transportation Cost	r = 0.446	-	9.88	<0.001

Table 4 presents the results of hypothesis testing examining relationships between infrastructure variables and food losses. The comprehensive Transportation Infrastructure Quality Index demonstrated a strong negative correlation ($r = -0.687$, $p < 0.001$), leading to rejection of the null hypothesis. This indicates that improvements in overall transportation infrastructure quality are associated with significant reductions in food losses. Individual transportation components all showed significant correlations in expected directions: road quality ($r = -0.624$, $p < 0.001$), vehicle availability ($r = -0.482$, $p < 0.001$), market distance ($r = 0.517$, $p < 0.001$), and transportation cost ($r = 0.446$, $p < 0.001$).

The Market Infrastructure Quality Index also showed a strong negative correlation ($r = -0.642$, $p < 0.001$), confirming that market infrastructure quality significantly influences food loss magnitudes, with better infrastructure associated with lower losses.

Multiple Regression Analysis Results

Table 5 presents the multiple regression analysis results examining predictors of food loss levels.

Table 5: Multiple Regression Analysis - Predictors of Food Loss Levels Among Rural Farmers (N=384)

Variable	B	Std. Error	Beta (β)	t-value	p-value	VIF
(Constant)	62.341	3.874	-	16.09	<0.001	-
Road Quality Index	-6.247	0.842	-0.456	-7.42	<0.001	1.86
Vehicle Availability Score	-3.182	0.764	-0.234	-4.16	<0.001	1.54
Market Distance (km)	0.846	0.218	0.212	3.88	<0.001	1.42
Storage Facility Index	-4.523	0.896	-0.312	-5.05	<0.001	1.78
Market Infrastructure Quality	-3.874	0.742	-0.289	-5.22	<0.001	1.68
Transportation Cost (%)	0.387	0.124	0.167	3.12	0.002	1.38
Model Statistics						
R	0.820					
R^2	0.673					
Adjusted R^2	0.667					
F-statistic	156.42				<0.001	
Durbin-Watson	1.94					

Model Statistics: $R = 0.820$; $R^2 = 0.673$; Adjusted $R^2 = 0.667$; F-statistic = 156.42 ($p < 0.001$); Durbin-Watson = 1.94

Note. Dependent Variable: Food Loss Level (% of harvest); VIF = Variance Inflation Factor; All β coefficients significant at $\alpha = 0.01$.

The model demonstrates excellent fit with $R^2 = 0.673$, indicating that the included infrastructure variables collectively explain 67.3% of the variance in food losses experienced by farmers. The F-statistic ($F = 156.42$, $p < 0.001$) confirms the overall model's statistical significance, while the Durbin-Watson statistic (1.94) suggests no serious autocorrelation problems. VIF values ranging from 1.38 to 1.86 indicate absence of multicollinearity among variables.

Road quality emerged as the strongest predictor of food losses ($\beta = -0.456$, $t = -7.42$, $p < 0.001$), suggesting that each unit improvement in road quality index is associated with a 6.247 percentage point reduction in food losses, holding other variables constant. Storage facility availability ($\beta = -0.312$, $t = -5.05$, $p < 0.001$) and market infrastructure quality ($\beta = -0.289$, $t = -5.22$, $p < 0.001$) also emerged as strong predictors. Vehicle availability demonstrated significant negative influence ($\beta = -0.234$, $t = -4.16$, $p < 0.001$), while market distance showed a significant positive relationship ($\beta = 0.212$, $t = 3.88$, $p < 0.001$). Transportation costs also significantly predicted higher losses ($\beta = 0.167$, $t = 3.12$, $p = 0.002$).

Discussions

The findings of this study provide compelling evidence that transportation and market infrastructure significantly influence food loss magnitudes among rural farmers in Delta State, Nigeria. The documented mean food loss of 35.2% aligns closely with national estimates of 30-50% (Osabohien

et al., 2020) and international findings across Sub-Saharan Africa (Affognon et al., 2015). However, the concentration of losses at the transportation stage (affecting 98.4% of farmers with mean losses of 22.8%) represents a distinctive finding that highlights the particular severity of transportation infrastructure deficits in the Niger Delta region.

The strong negative correlation between road quality and food losses ($r = -0.624$, $p < 0.001$) confirms theoretical expectations and extends empirical findings by Omotilewa et al. (2021) regarding infrastructure's influence on agricultural value chain efficiency in Nigeria. The regression analysis further strengthens this relationship, with road quality emerging as the single strongest predictor of food losses ($\beta = -0.456$, $p < 0.001$). This finding suggests that strategic investment in rural road rehabilitation could yield immediate and substantial reductions in food losses, potentially recovering significant portions of the approximately $9 billion in annual post-harvest losses estimated nationally (Adeoye et al., 2021).

The critical role of transportation is further illuminated by the finding that 76.5% of farmers reported roads were only occasionally or rarely accessible during rainy seasons, which coincide with major harvest periods for key crops. This temporal mismatch between peak agricultural activity and minimum transportation accessibility represents a structural constraint that no amount of farmer-level intervention can overcome, highlighting the necessity of public sector infrastructure investment. The high transportation costs averaging 24.6% of farm gate prices documented in this study exceed typical benchmarks and align with findings by Gollin & Rogerson (2014) regarding transportation cost burdens in infrastructure-deficient rural areas.

The inadequacy of market physical infrastructure, rated as poor or very poor by 80.2% of respondents, creates conditions that accelerate produce deterioration even after successful transportation. The strong negative correlation between road quality and food losses ($r = -0.624$, $p < 0.001$) confirms theoretical expectations and extends empirical findings by Omotilewa et al. (2021) who demonstrated that road improvements in rural Nigeria generated substantial agricultural productivity gains. The regression analysis further strengthens this relationship, with road quality emerging as the single strongest predictor of food losses ($\beta = -0.456$, $p < 0.001$), accounting for approximately 21% of explained variance when considered alongside other factors. This finding suggests that strategic investment in rural road rehabilitation could yield immediate and substantial reductions in food losses, potentially recovering significant portions of the approximately $9 billion in annual post-harvest losses estimated nationally (Adeoye et al., 2021).

The critical role of transportation is further illuminated by the finding that 76.5% of farmers reported roads were only occasionally or rarely accessible during rainy seasons, which coincide with major harvest periods for key crops including cassava, yam, and vegetables. This temporal mismatch between peak agricultural activity and minimum transportation accessibility represents a structural constraint that no amount of farmer-level intervention can overcome, highlighting the necessity of public sector infrastructure investment. The high transportation costs averaging 24.6% of farm gate prices documented in this study exceed typical benchmarks and align with findings by Gollin & Rogerson (2014) regarding transportation cost burdens in infrastructure-deficient rural areas. These costs not only reduce farmer incomes directly but also contribute to food losses by forcing farmers to delay marketing, accept exploitative prices from middlemen, or abandon harvests entirely when transportation costs exceed expected returns.

The severe deficit in storage infrastructure, with 74.5% of farmers having access only to open-air storage, represents a critical market infrastructure constraint that interacts with transportation challenges to amplify food losses. The strong negative correlation between storage facility availability and food losses ($r = -0.534$, $p < 0.001$) supports findings by Barrett et al. (2022) regarding storage infrastructure's importance for post-harvest loss mitigation. The regression analysis confirmed storage facilities as the second strongest predictor of food losses ($\beta = -0.312$, $p < 0.001$), suggesting that storage infrastructure improvements could complement transportation investments to create synergistic benefits along agricultural value chains.

These findings resonate with Kitinoja et al. 2018) multi-country study demonstrating that integrated infrastructure approaches addressing both transportation and storage dimensions yielded superior outcomes compared to single-dimension interventions. This reinforcing dynamic suggests that simultaneous improvements in both infrastructure dimensions could generate multiplicative rather than merely additive benefits.

The inadequacy of market physical infrastructure, rated as poor or very poor by 80.2% of respondents, creates conditions that accelerate produce deterioration even after successful transportation. This finding extends observations by Sheahan & Barrett (2017) regarding market infrastructure's influence on agricultural value chain efficiency. The absence of covered selling areas, proper drainage, waste management systems, and sorting facilities means that produce reaching markets still faces high loss risks from weather exposure, contamination, and mechanical damage. The significant correlation between market infrastructure quality and food losses ($r = -0.558$, $p < 0.001$) suggests that market-

level infrastructure improvements could protect value created through transportation improvements, preventing the scenario where produce successfully reaches markets only to deteriorate due to inadequate market facilities.

Processing equipment access emerged as a significant but underutilized intervention point, with 62.5% of farmers having no processing access and the variable showing significant negative correlation with food losses ($r = -0.467$, $p < 0.001$). This finding aligns with Edoumiekumo et al. (2023) observation that processing capacity development represents a strategic approach to reducing post-harvest losses in cassava value chains, Delta State's most affected crop with 38.4% mean losses. Processing converts highly perishable fresh produce into more stable products with extended shelf lives, expanded market opportunities, and higher value addition. The limited processing access documented in this study represents a missed opportunity for loss mitigation and income enhancement, particularly for cassava which can be processed into multiple products including garri, fufu, starch, and high-quality cassava flour (HQCF).

Market information systems showed the weakest correlation with food losses among market infrastructure variables ($r = -0.412$, $p < 0.01$), yet remain important for optimizing market coordination and reducing losses associated with poor timing and market selection. The finding that 54.2% of farmers rely solely on personal networks for market intelligence suggests substantial scope for information system improvements, particularly given increasing mobile phone penetration in rural Nigeria. Aromolaran et al. (2021) demonstrated that mobile-based market information systems improved smallholder market participation and reduced post-harvest losses in southwestern Nigeria by enabling better harvest timing and market selection decisions. The moderate correlation observed in this study suggests information systems function best as complements to physical infrastructure rather than substitutes, enhancing efficiency once basic transportation and storage infrastructure exists.

The regression model's substantial explanatory power ($R^2 = 0.673$) indicates that infrastructure variables represent primary determinants of food loss outcomes, confirming the study's theoretical framework. However, the 32.7% of unexplained variance suggests other factors merit attention, including farmer post-harvest handling knowledge, cultural practices affecting harvest timing and methods, market coordination mechanisms, and weather variability. The significant constant term (62.341) in the regression model indicates a baseline loss level that persists even under optimal

infrastructure conditions, suggesting that comprehensive food loss reduction strategies must address both infrastructure constraints and farmer-level knowledge and practice.

Conclusion and Recommendation

The findings of the study revealed that transportation and market infrastructure deficits represent primary determinants of food losses among rural farmers in Delta State, Nigeria. The severity and pervasiveness of these infrastructure constraints create systematic inefficiencies across agricultural value chains, undermining farmer incomes, threatening household food security, and compromising regional agricultural development. The strong statistical relationships documented between infrastructure quality and food loss magnitudes confirm that infrastructure improvements represent strategic intervention points for reducing losses and strengthening agricultural systems. The particular concentration of losses at the transportation stage, affecting virtually all farmers (98.4%) and accounting for the highest single-stage losses (22.8%), highlights rural road infrastructure as the most critical bottleneck. The finding that three-quarters of farmers cannot reliably access roads during rainy seasons—which coincide with major harvest periods—reveals a structural constraint that perpetuates poverty and inefficiency regardless of farmers' skills, efforts, or adoption of improved agricultural practices.

Market infrastructure deficits, particularly the near-universal absence of modern storage facilities and inadequate market physical infrastructure, compound transportation challenges and prevent farmers from capturing value even when produce successfully reaches markets. The interaction between transportation and market infrastructure constraints creates a reinforcing cycle where poor roads limit access to distant markets with better facilities, while local market inadequacies force dependence on immediate sale under disadvantageous conditions, perpetuating vulnerability and loss. The findings of this study have important implications for agricultural development policy in Nigeria and similar contexts across Sub-Saharan Africa. They demonstrate that farmer-focused interventions such as training, input subsidies, and extension services, while valuable, cannot achieve their full potential when operating within severely constrained infrastructure environments.

Based on the findings of this study, the following evidence-based recommendations are proposed for government agencies, development partners, and agricultural stakeholders:

1. Delta State Government should prioritize rehabilitation and upgrading of rural roads connecting major agricultural production areas to markets, with particular attention to ensuring year-round accessibility.

2. Government and development partners should establish a network of modern storage facilities strategically located at key market nodes and production clusters.
3. Local governments should invest in upgrading physical market infrastructure including covered selling areas, proper drainage systems, waste management facilities, and commodity-specific handling equipment.
4. Agricultural development programs should facilitate farmer access to affordable transportation through vehicle leasing schemes, transportation cooperatives, and partnerships with commercial transporters.
5. Government agencies should develop and disseminate digital market information platforms providing real-time price information, market demand signals, and weather forecasts through mobile phones.

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