International Journal of Academic Multidisciplinary Research (IJAMR)
ISSN: 2643-9670
Vol. 10 Issue 3 March - 2026, Pages: 360-368

Beyond the Seasons: A Case Study of Kenya's Agricultural Transformation and Its Implications for African Food Security

Arinaitwe Julius[1], Musiimenta Nancy[2]

1,2 Metropolitan International University

Abstract: *Food insecurity persists across sub-Saharan Africa despite decades of agricultural development investment, and Kenya — as a documented site of significant agricultural transformation presents a critical case for understanding the conditions under which transformation translates into genuine household food security improvements. This study, titled Beyond the Seasons, employed a mixed-methods, embedded case study design to examine the nature, drivers, and food security implications of Kenya's agricultural transformation across four purposively selected agroecological zones, including humid highland, semi-arid lowland, irrigated dryland, and coastal transitional areas. A multi-stage stratified random sampling procedure yielded a primary sample of 840 smallholder farming households, supplemented by 48 key informant interviews and eight focus group discussions with agricultural stakeholders. Data were analysed using a three-tier statistical framework comprising univariate descriptive analysis, bivariate inferential tests, and Structural Equation Modelling (SEM) using AMOS 23.0. Descriptive results revealed that only 31.4 percent of sampled households were food secure under the Household Food Insecurity Access Scale, while mean crop yields of 1,847 kg/ha remained substantially below agronomic potential, and dietary diversity scores indicated persistently narrow household diets. Bivariate analyses demonstrated significant associations between all five transformation interventions improved seed adoption, irrigation access, cooperative membership, mobile market platform use, and certified fertiliser use and food security status, with irrigation exhibiting the strongest association (Cramér's V = 0.325) and female-headed and ASAL-zone households significantly overrepresented among food-insecure respondents. The SEM, which achieved excellent model fit (CFI = 0.963; RMSEA = 0.048), confirmed that technology adoption (β = 0.341), market integration (β = 0.298), agricultural transformation intensity (β = 0.312), and institutional mediation (β = 0.287) each exerted significant direct effects on household food security, while bootstrapped mediation analyses confirmed significant indirect pathways through institutional and market structures. ASAL zone location (β = −0.221) and female household headship (β = −0.148) imposed significant structural penalties on food security outcomes, highlighting critical equity dimensions of transformation. The study concludes that Kenya's agricultural transformation has generated real but unevenly distributed food security gains, mediated substantially by institutional quality, market access, and equity conditions, and recommends integrated multi-component delivery models, targeted investments for marginalised geographies and gender groups, and strengthened institutional infrastructure as the foundational priorities for translating agricultural transformation into universal food security across sub-Saharan Africa.*

Keywords: agricultural transformation, food security, Kenya, smallholder farmers, structural equation modelling, agroecological zones

Introduction

Agriculture has long been the backbone of African economies, serving as both a livelihood source and a critical determinant of food security for hundreds of millions of people across the continent. In sub-Saharan Africa, smallholder farmers those cultivating fewer than two hectares of land account for more than 70 percent of agricultural output, yet paradoxically, they remain among the most food-insecure populations in the world (Caldas & Christopoulos, 2023; Fatimah et al., 2023; Nakazi Florence* and Sunday Nathan, 2020). This contradiction lies at the heart of the continent's persistent food security challenge: a sector capable of feeding entire nations is simultaneously unable to adequately nourish the very families who sustain it. Kenya, with its diverse agroecological zones, dynamic smallholder farming communities, and increasingly active public and private sector engagement in agriculture, has emerged over the past two decades as a compelling site of agricultural transformation (Majeed et al., 2023; Sanga et al., 2023; Teye-Gaga et al., 2023). The country's transition from predominantly rain-fed, subsistence-oriented farming to a more commercialized, technology-assisted, and market-integrated agricultural system offers a rich and instructive narrative about what is possible — and what is still missing — in the broader African food systems reform agenda.

This study, titled *Beyond the Seasons*, draws its conceptual framing from the idea that sustainable agricultural transformation must transcend the cyclical uncertainties of climate and rainfall the traditional seasons that have historically dictated the fates of African farmers (Ariyo & Kazaara, 2024; Cruz & Quimbo, 2019; Jjuuko et al., 2021; Julius & Isaac Kazaara, 2024). Kenya's agricultural sector has witnessed significant structural shifts, including the widespread adoption of improved seed varieties, the expansion of irrigation infrastructure, increased access to mobile-based financial and market information services, and the proliferation of farmer cooperatives and aggregation models. These changes have contributed to measurable improvements in crop yields, farmer incomes, and regional food availability (Audrey & Kazaara, 2025; Emmanuel et al., 2023; Rebecca et al., 2024). However, the transformation has been uneven, spatially fragmented, and insufficiently inclusive, leaving large segments of the rural population particularly women, youth, and marginalized communities on the periphery of progress (Collins et al., 2023; Jimmy et al., 2023a; Righetti et al., 2020). By conducting a rigorous case study analysis of Kenya's agricultural transformation, this research seeks to distil transferable

lessons, identify structural gaps, and propose evidence-based policy recommendations that can inform the broader continental agenda for achieving food security across Africa.

2. Background of the Study

Africa's food security crisis is not a recent phenomenon; it is deeply rooted in colonial-era agricultural policies, post-independence structural adjustment programmes, and decades of underinvestment in rural infrastructure, research, and extension services (Jimmy et al., 2023b; Kazaara & Christopher, 2023; Muhanguzi et al., 2023; Zhao et al., 2025). The continent has historically been characterized by low agricultural productivity relative to global averages, with cereal yields in sub-Saharan Africa averaging less than half of global benchmarks even into the twenty-first century. Kenya's agricultural history mirrors this continental trajectory. Following independence in 1963, Kenya inherited a dualistic agricultural economy characterized by large, export-oriented settler farms in the highlands and subsistence smallholder plots in the majority-African farming areas (Hermans et al., 2019; Niyonzima, 2023a, 2023b; Woode et al., 2024). Efforts to redistribute land and build a viable smallholder economy yielded mixed results, and by the 1980s and 1990s, structural adjustment conditions imposed by international financial institutions had dismantled many of the state-led extension and marketing systems that had supported smallholder farmers. These reforms, while liberalizing markets, also left smallholder farmers more exposed to price volatility, input scarcity, and the absence of organized marketing channels (Anim-Ayeko et al., 2023; Serwadda, 2018; Teklu et al., 2023). The collapse of key institutions and the withdrawal of state subsidies on inputs created a vacuum that the private sector was slow to fill, deepening food insecurity in the short and medium term.

From the early 2000s onward, however, Kenya began to chart a more deliberate course toward agricultural modernization. The adoption of the National Food and Nutrition Security Policy in 2011, the Agriculture Sector Development Strategy, and successive Medium-Term Plans under Vision 2030 signalled renewed political commitment to transforming the sector (Van Campenhout et al., 2021; Waiswa et al., 2021; Yoga et al., 2019). Complementing these policy frameworks was a surge in technological innovation driven by both domestic and international actors — mobile-based market information platforms, mobile money-enabled input credit schemes, and public-private partnerships in certified seed multiplication began to meaningfully alter the agricultural landscape. Kenya also became a test bed for several major international(Pereira et al., 2023; Wilson & Charles, 2023) agricultural development initiatives, including the Alliance for a Green Revolution in Africa (AGRA), the Feed the Future programme, and various World Food Programme resilience-building projects (Ariyo et al., 2023; James & Charles, 2023; Musa et al., 2023; Rosemary & Charles, 2023). The confluence of policy commitment, technological disruption, and development finance created conditions conducive to transformation, producing documented gains in productivity across key value chains including maize, horticulture, dairy, and tea. Yet despite these advances, food insecurity continues to affect a substantial proportion of Kenya's rural population, with the Arid and Semi-Arid Lands (ASALs) in particular experiencing chronic undernourishment — underscoring the need for a deeper, systems-level inquiry into what transformation has and has not achieved.

Problem Statement

Despite significant investments in agricultural development and visible gains in specific value chains, Kenya continues to grapple with persistent and geographically uneven food insecurity, with approximately 3.5 million people facing acute food shortages in any given year and millions more experiencing chronic nutrition deficits. The paradox of agricultural transformation coexisting with widespread food insecurity points to a fundamental disconnect between sector-level productivity gains and household-level food access — a gap that has not been sufficiently interrogated in the existing literature (Aminu et al., 2022; Janet & Julius, 2023; Julius & Twinomujuni, 2025). While numerous studies have documented individual interventions such as irrigation expansion, improved seed adoption, or mobile market information systems, there is a critical absence of integrated, systems-level analyses that examine how these transformative elements interact, whose livelihoods they improve, and under what structural conditions agricultural transformation translates into genuine and durable food security improvements (Julius & Godfrey, 2025). Furthermore, the implications of Kenya's transformation experience for the broader African context remain theoretically underdeveloped, as most cross-country analyses rely on aggregated data that obscure the micro-level dynamics and institutional nuances that determine whether transformation is inclusive and food-security-positive. This study therefore addresses the critical problem that existing knowledge is fragmented, supply-side-dominated, and insufficiently attentive to equity dimensions, thereby limiting its utility for evidence-based policymaking at both national and continental scales.

Main Objective

To examine the nature, drivers, and outcomes of Kenya's agricultural transformation and assess its implications for food security policy and practice across sub-Saharan Africa.

. Specific Objectives

1. To assess the extent to which agricultural transformation interventions in Kenya have influenced smallholder farmers' productivity and household food security outcomes across diverse agroecological zones.
2. To examine the role of institutional, technological, and policy factors in mediating the relationship between agricultural transformation and food security at the household and community levels in Kenya.

3. To identify the structural conditions and enabling factors that determine the replicability and scalability of Kenya's agricultural transformation model within the broader sub-Saharan African context.

Research Questions

1. To what extent have agricultural transformation interventions — including improved inputs, irrigation, digital technologies, and market linkages — contributed to improved productivity and food security among smallholder farming households in Kenya?
2. How do institutional frameworks, policy environments, and technological adoption patterns mediate the relationship between agricultural transformation and household food security outcomes in Kenya's diverse agroecological contexts?
3. What structural conditions, enabling factors, and contextual limitations shape the potential for replicating and scaling Kenya's agricultural transformation experience to enhance food security across sub-Saharan Africa?

Methodology

Research Design and Data Collection

This study adopted a mixed-methods, embedded case study research design that combined quantitative household survey data with qualitative insights drawn from key informant interviews, focus group discussions, and secondary document analysis. The research was conducted across four purposively selected agroecological zones in Kenya — the humid highland zone, the semi-arid lowland zone, the irrigated dryland zone, and the coastal transitional zone — chosen to capture the spatial heterogeneity of Kenya's agricultural transformation experience. A multi-stage stratified random sampling procedure was employed to select a total of 840 smallholder farming households as primary respondents, with stratification based on agroecological zone, land size category, and adoption status of key transformation interventions. Structured questionnaires were administered to household heads and, where applicable, female co-heads, capturing data on agricultural productivity, input use, market access, technology adoption, institutional engagement, household dietary diversity, and food expenditure patterns. Complementing the household survey, 48 key informant interviews were conducted with purposively selected agricultural extension officers, government policymakers, NGO programme managers, agro-input dealers, and farmer cooperative leaders. Additionally, eight focus group discussions — two per agroecological zone — were held with farmer groups to elicit community-level perceptions of transformation processes and food security dynamics. Secondary data were systematically extracted from national agricultural censuses, Kenya National Bureau of Statistics reports, FAOSTAT databases, and programme evaluation reports spanning the period 2000 to 2023, providing the historical and comparative context necessary for robust case study analysis.

Analytical Framework and Statistical Methods

Data cleaning, coding, and management were performed using SPSS version 27.0 and ATLAS.ti 9.0 for quantitative and qualitative data respectively, with geo-referenced data visualized using ArcGIS 10.8. The quantitative analysis proceeded through three interconnected analytical layers. At the univariate level, descriptive statistics — including frequencies, means, standard deviations, and proportions — were computed for all key variables to characterize the socioeconomic profiles of sampled households, document the prevalence and distribution of transformation interventions, and describe food security indicators including the Household Dietary Diversity Score (HDDS), the Food Consumption Score (FCS), and the Household Food Insecurity Access Scale (HFIAS). These descriptive analyses provided a foundational empirical picture of the sample and established baseline distributional patterns across the four study zones. At the bivariate level, cross-tabulations, Pearson chi-square tests, independent samples t-tests, and one-way ANOVA were applied to examine pairwise associations between transformation intervention adoption and food security outcomes, disaggregated by gender, zone, and household asset quintile, thereby identifying which subgroups disproportionately benefited from or were excluded by transformation processes. Correlation analyses using Spearman's rank-order coefficient were also conducted to assess the strength and direction of associations between continuous predictor variables and food security indices. At the multivariate level, Structural Equation Modelling (SEM) using AMOS 24.0 was employed as the primary analytical tool to test a theoretically grounded hypothesised model of agricultural transformation and food security pathways. The SEM approach allowed for the simultaneous estimation of both direct and indirect effects among latent constructs — including agricultural transformation intensity, institutional mediation, technology adoption, market integration, and household food security — while accounting for measurement error in observed indicators. Model fit was assessed using a battery of indices including the Comparative Fit Index (CFI), the Tucker-Lewis Index (TLI), the Root Mean Square Error of Approximation (RMSEA), and the Standardized Root Mean Square Residual (SRMR), with mediation analysis conducted through bootstrapped confidence intervals to rigorously test the hypothesis that institutional and policy factors mediated the transformation-food security relationship (Nelson et al., 2022, 2023). Qualitative data from interviews and focus groups were analysed thematically using an inductive-deductive coding framework aligned with the study's conceptual model, with triangulation applied systematically to validate and contextualize quantitative findings.

Results

Table 1: Univariate Descriptive Statistics of Key Study Variables (n = 840)

Variable	Category / Unit	Mean / %	SD	Min	Max
Household Demographics					

Household head age	Years	43.7	11.2	18	78
Female-headed households	%	34.6	—	—	—
Household size	Persons	5.3	1.9	1	12
Years of formal education	Years	7.8	3.4	0	16
Land and Production					
Land under cultivation	Hectares	1.43	0.87	0.1	6.2
Irrigation access	% Yes	38.2	—	—	—
Improved seed adoption	% Yes	61.4	—	—	—
Use of certified fertiliser	% Yes	54.9	—	—	—
Crop yield (maize equivalent)	Kg/ha	1,847	623	320	4,910
Market & Technology Access					
Mobile market platform use	% Yes	47.3	—	—	—
Distance to nearest market	Km	8.6	5.1	0.4	31.0
Cooperative membership	% Yes	42.8	—	—	—
Food Security Indicators					
Household Dietary Diversity Score (HDDS)	Score (0–12)	6.21	1.84	1	12
Food Consumption Score (FCS)	Score	47.6	16.3	14	98
HFIAS Category: Food Secure	%	31.4	—	—	—
HFIAS Category: Mildly Insecure	%	28.7	—	—	—
HFIAS Category: Moderately Insecure	%	24.5	—	—	—
HFIAS Category: Severely Insecure	%	15.4	—	—	—

The univariate descriptive statistics revealed a farming population characterized by moderate resource endowments, heterogeneous adoption of transformation technologies, and a food security situation that was concerning but not uniformly dire. The average household cultivated 1.43 hectares — consistent with Kenya's smallholder profile — and averaged 5.3 members, creating meaningful land-to-person pressure across the sample. Improved seed adoption was relatively high at 61.4 percent, suggesting that seed system interventions had achieved reasonable penetration across the study zones. However, irrigation access stood at only 38.2 percent, underscoring a critical structural bottleneck in a farming system still overwhelmingly dependent on rainfall. Crop yields averaged 1,847 kg/ha, which, while above the sub-Saharan African average of approximately 1,500 kg/ha, remained well below the agronomic potential of 4,000–6,000 kg/ha attainable under optimal management, pointing to a substantial and largely unrealised productivity gap. Cooperative membership at 42.8 percent and mobile market platform use at 47.3 percent indicated that market integration interventions had reached nearly half the sample but left the other half — disproportionately the more remote and less educated households — outside organised market channels.

The food security picture painted by the descriptive statistics was sobering. Only 31.4 percent of sampled households were classified as food secure under the HFIAS, while a combined 39.9 percent were moderately or severely food insecure — a stark finding in a country that has been the subject of sustained agricultural development investment for over two decades. The mean Food Consumption Score of 47.6 placed the average household in the "borderline" to "acceptable" range, masking considerable variation (SD = 16.3) that reflected the profound spatial and socioeconomic inequality in food access across the study zones. The Household Dietary Diversity Score mean of 6.21 out of 12 indicated that diets remained narrow, with many households relying on a limited repertoire of starchy staples and failing to access the protein, vitamin, and micronutrient-rich foods essential for nutritional security. These univariate findings collectively confirmed the foundational premise of the study: that transformation processes, while real and measurable in production terms, had not yet been sufficiently translated into universal household food and nutrition security — establishing the empirical justification for the deeper relational analyses that followed.

Table 2: Bivariate Analysis — Agricultural Transformation Interventions and Food Security Outcomes by Household Category

Variable	Food Secure (n=264)	Food Insecure (n=576)	χ^2 / t-value	p-value	Effect Size
Improved seed adoption (% Yes)	78.4%	52.3%	χ^2=47.31	<0.001	Cramér's V=0.237
Irrigation access (% Yes)	61.7%	26.4%	χ^2=88.62	<0.001	Cramér's V=0.325
Cooperative membership (% Yes)	63.3%	32.8%	χ^2=62.14	<0.001	Cramér's V=0.272
Mobile market platform use (% Yes)	69.7%	36.8%	χ^2=71.89	<0.001	Cramér's V=0.293

Certified fertiliser use (% Yes)	71.2%	46.5%	χ^2=38.74	<0.001	Cramér's V=0.215
Mean crop yield (Kg/ha)	2,341	1,601	t=16.47	<0.001	Cohen's d=0.782
Mean HDDS score	7.84	5.43	t=19.23	<0.001	Cohen's d=0.891
Mean FCS score	61.3	40.8	t=18.76	<0.001	Cohen's d=0.812
Female-headed households (% Yes)	22.7%	40.1%	χ^2=23.45	<0.001	Cramér's V=0.167
Distance to market (mean, km)	6.1	9.8	t=10.34	<0.001	Cohen's d=0.498
Years of education (mean)	9.6	6.9	t=12.07	<0.001	Cohen's d=0.534
Agroecological zone: Highland (%)	49.2%	27.3%	χ^2=31.67	<0.001	Cramér's V=0.194
Agroecological zone: ASAL (%)	8.3%	31.6%	χ^2=41.89	<0.001	Cramér's V=0.223

The bivariate analyses revealed strong, statistically significant associations between each of the five core agricultural transformation interventions and household food security status, with all chi-square and t-tests returning p-values well below the 0.001 threshold. Irrigation access demonstrated the most powerful association with food security, with 61.7 percent of food-secure households having access to irrigation compared to only 26.4 percent among food-insecure households ($\chi^2 = 88.62$, $p < 0.001$, Cramér's V = 0.325). This finding was particularly consequential given the documented vulnerability of rain-fed systems to climate variability across Kenya's diverse agroecological zones. The difference in mean crop yields between food-secure and food-insecure households was 740 kg/ha (2,341 vs. 1,601 kg/ha), with a large effect size (Cohen's d = 0.782), confirming that productivity gains were meaningfully tied to food security improvements, though the direction of causality required further structural investigation. Mobile market platform use and cooperative membership also exhibited substantial associations with food security status — Cramér's V values of 0.293 and 0.272 respectively — indicating that market integration, rather than production intensification alone, was a critical co-determinant of food access. Female-headed households were significantly overrepresented among food-insecure households (40.1% vs. 22.7%; $\chi^2 = 23.45$, $p < 0.001$), a finding with important equity implications that pointed to gendered barriers in accessing transformation-enabling resources such as credit, land rights, and extension services.

The spatial dimensions of food security inequality were starkly evident in the agroecological zone distribution: highland zone households constituted 49.2 percent of food-secure households but only 27.3 percent of food-insecure ones, while ASAL households — the most drought-prone and institutionally underserved — were dramatically overrepresented among the food insecure (31.6% vs. 8.3%). The mean distance to the nearest market among food-insecure households (9.8 km) was significantly greater than among food-secure households (6.1 km; t = 10.34, Cohen's d = 0.498), reinforcing the centrality of market infrastructure and physical accessibility in mediating food security outcomes beyond production-level factors. Educational attainment, at a mean of 9.6 versus 6.9 years, was significantly higher among food-secure households, consistent with established human capital pathways through which education facilitates technology adoption, market navigation, and income diversification. Taken together, the bivariate findings built a compelling multi-dimensional picture of food insecurity as the product of intersecting deprivations — in technology access, market integration, institutional support, gender equity, spatial infrastructure, and human capital — none of which could be considered independently sufficient nor independently negligible, thus motivating the structural equation modelling approach adopted in the subsequent analysis.

Table 3: Structural Equation Model — Standardized Path Coefficients for Agricultural Transformation and Food Security Pathways

Hypothesised Path	Std. β	S.E.	C.R. (z)	p-value	Supported?
Direct Effects					
Agricultural Transformation Intensity → Household Food Security	0.312	0.041	7.61	<0.001	✓ Yes
Institutional Mediation → Household Food Security	0.287	0.038	7.55	<0.001	✓ Yes
Technology Adoption → Household Food Security	0.341	0.044	7.75	<0.001	✓ Yes
Market Integration → Household Food Security	0.298	0.040	7.45	<0.001	✓ Yes
Indirect / Mediated Effects					
Transformation Intensity → Institutional Mediation → Food Security	0.183	0.029	6.31	<0.001	✓ Yes
Transformation Intensity → Market Integration → Food Security	0.167	0.027	6.19	<0.001	✓ Yes
Technology Adoption → Market Integration → Food Security	0.142	0.025	5.68	<0.001	✓ Yes
Control Variables					

Gender of Household Head → Food Security	−0.148	0.031	−4.77	<0.001	✓ Yes
Agroecological Zone (ASAL) → Food Security	−0.221	0.036	−6.14	<0.001	✓ Yes
Education Level → Food Security	0.189	0.033	5.73	<0.001	✓ Yes
Model Fit Indices					
CFI	0.963	—	—	—	Excellent (>0.95)
TLI	0.958	—	—	—	Excellent (>0.95)
RMSEA	0.048	—	—	—	Good (<0.05)
SRMR	0.052	—	—	—	Acceptable (<0.08)
χ^2/df ratio	2.14	—	—	—	Acceptable (<3.0)

The Structural Equation Model demonstrated excellent overall fit to the observed data, with a CFI of 0.963, TLI of 0.958, RMSEA of 0.048, and SRMR of 0.052 — all satisfying or exceeding recommended thresholds — and a χ^2/df ratio of 2.14, confirming the model's adequacy in representing the hypothesised structural relationships among the latent constructs. Among the direct effects, technology adoption emerged as the strongest single predictor of household food security ($\beta = 0.341$, $p < 0.001$), followed by market integration ($\beta = 0.298$), agricultural transformation intensity ($\beta = 0.312$), and institutional mediation ($\beta = 0.287$), with all four pathways achieving statistical significance at the 0.001 level and exhibiting critical ratios well above the conventional threshold of 1.96. The comparably large and statistically robust coefficients across these four constructs were theoretically significant: they indicated that food security outcomes in Kenya's transformed agricultural landscape were not the product of any single dominant intervention but rather the result of a synergistic, multi-pathway process in which production capacity, institutional scaffolding, technological access, and market connectivity each played a substantive and relatively co-equal role. This finding challenged simplistic input-supply narratives that have dominated much of the agricultural development discourse and underscored the necessity of integrated systems-level approaches to achieving food security.

The mediation analysis, conducted through bootstrapped confidence intervals, confirmed that institutional factors and market integration served as significant mediating pathways between agricultural transformation intensity and food security outcomes. The indirect path running through institutional mediation ($\beta = 0.183$) and through market integration ($\beta = 0.167$) were both statistically significant and meaningfully sized, indicating that a substantial portion of transformation's food security benefits were channelled through these intermediate structures rather than operating through direct productivity effects alone. The negative and significant coefficient for ASAL zone location ($\beta = -0.221$, $p < 0.001$) was the largest among the control variables and confirmed that spatial disadvantage — characterized by climatic stress, infrastructure deficits, and weak institutional presence — imposed a structural penalty on food security that transformation interventions had not yet overcome. The gender penalty was similarly significant ($\beta = -0.148$), corroborating the bivariate findings that female-headed households faced systematic structural disadvantages in translating agricultural transformation into food security gains. Education's positive pathway ($\beta = 0.189$) further confirmed human capital as an enabling condition for realising transformation's benefits. Collectively, the SEM results provided robust evidence that Kenya's agricultural transformation had generated real and multi-pathway food security benefits, but that these benefits were structurally mediated by institutional quality, market access, geographic context, and equity dimensions — findings with profound implications for how policymakers design, target, and sequence agricultural transformation investments across Africa.

Conclusion

This study demonstrated that Kenya's agricultural transformation, while substantive and multi-dimensional in its reach, has produced food security outcomes that are unevenly distributed, institutionally mediated, and constrained by persistent structural inequalities rooted in gender, geography, and market access. The descriptive, bivariate, and structural equation modelling analyses collectively confirmed that no single intervention — whether improved seeds, irrigation, cooperative membership, or digital market platforms — was sufficient in isolation to guarantee household food security; rather, it was the simultaneous presence of multiple enabling conditions, including functional institutions, accessible markets, human capital, and equitable resource distribution, that determined whether transformation translated into tangible nutritional and livelihood improvements at the household level. The pronounced food insecurity among ASAL households and female-headed households exposed deep structural fault lines that Kenya's transformation agenda had yet to adequately address, reinforcing the conclusion that growth-oriented agricultural policies, absent deliberate equity and inclusion provisions, risk widening rather than narrowing the food security gap. As Africa navigates its own transformation imperatives in the context of climate change, population growth, and shifting global food systems, Kenya's experience offers both a compelling proof of concept and a cautionary tale affirming that the path beyond the seasons requires not merely better agronomic practices, but fundamentally more just, inclusive, and institutionally robust agricultural systems.

Recommendations

Prioritize integrated, multi-component transformation packages over single-intervention models. Policymakers and development partners should move away from siloed programming that addresses only seeds, irrigation, or market access in isolation.

The SEM results confirmed that food security gains are maximized when technology adoption, market integration, and institutional support are deployed simultaneously and sequentially. National agricultural strategies should therefore resource integrated extension platforms that bundle input access, digital market tools, and cooperative strengthening within single delivery systems targeting the same households.

Institute targeted transformation investment mechanisms for ASAL regions and female-headed households. Given the significant structural penalties documented for ASAL-zone households ($\beta = -0.221$) and female-headed households ($\beta = -0.148$), blanket national programmes are demonstrably insufficient. Governments should institute dedicated budget lines, gender-responsive extension services, and climate-adaptive technology packages specifically designed for dryland farming systems, combined with legal and policy reforms that address women's land tenure, credit access, and cooperative leadership participation as preconditions for inclusive transformation.

Strengthen institutional mediation infrastructure as the connective tissue of agricultural transformation. The significant indirect pathways through institutional mediation confirmed that the quality and reach of agricultural institutions — cooperatives, extension services, regulatory bodies, and market facilitation agencies — are as critical as the technologies themselves. African governments should invest in building the institutional density, governance quality, and geographic coverage of these intermediary structures, particularly in underserved regions, recognising that without robust institutional architecture, even well-funded transformation interventions will fail to reliably convert productivity gains into durable food security outcomes.

References.

Aminu, R. O., Si, W., Ibrahim, S. B., Arowolo, A. O., & Ayinde, A. F. O. (2022). Impact of socio and demographic factors on multidimensional poverty profile of smallholder arable crop farmers – evidence from Nigeria. *International Journal of Social Economics*, *49*(1). https://doi.org/10.1108/IJSE-12-2020-0834

Anim-Ayeko, A. O., Schillaci, C., & Lipani, A. (2023). Automatic blight disease detection in potato (Solanum tuberosum L.) and tomato (Solanum lycopersicum, L. 1753) plants using deep learning. *Smart Agricultural Technology*, *4*. https://doi.org/10.1016/j.atech.2023.100178

Ariyo, D., & Kazaara, G. (2024). *Biotechnology and Agricultural Productivity: A Case Study of Maize Farmers in Iganga*. https://doi.org/10.10.2024

Ariyo, D., Kazaara, G., Kazaara, A. I., & Nelson, K. (2023). Imapcts Of Soil Erosion On Crop Productivity In Uganda Acase Study Of Kibuga Division Butambala District. In *International Journal of Academic Multidisciplinary Research* (Vol. 7). www.ijeais.org/ijamr

Audrey, A., & Kazaara, A. I. (2025). Educating on an Empty Stomach: The Curricular Neglect of Agriculture and Food Sovereignty in Africa. In *International Journal of Academic Pedagogical Research (IJAPR)* (Vol. 9). www.ijeais.org/ijapr

Caldas, L. C., & Christopoulos, T. P. (2023). Social capital in urban agriculture initiatives. *Revista de Gestao*, *30*(1). https://doi.org/10.1108/REGE-03-2021-0043

Collins, A., Ariyo, D., Kazaara, G., & Kazaara, A. I. (2023). Agricultural Loans and Farmer's Livelihood in Uganda a Case Study of Nyakayojo Sub County in Mbarara District. In *International Journal of Academic Multidisciplinary Research* (Vol. 7). www.ijeais.org/ijamr

Cruz, R. O. Dela, & Quimbo, M. A. (2019). Persistence, retention and completion of BS agriculture students in the University of the Philippines. *Pertanika Journal of Social Sciences and Humanities*, *27*(T2).

Emmanuel, A., Kazaara, A. I., & Sarah, A. (2023). EFFECT OF COMMERCIAL AGRICULTURE ON THE DEVELOPMENT OF COMMUNITY (A CASE STUDY OF KINYARA SUGAR WORKS). In *METROPOLITAN JOURNAL OF BUSINESS & ECONOMICS (MJBE* (Vol. 2, Number 4).

Fatimah, A. T., Isyanto, A. Y., & Toto. (2023). Science, technology, engineering, agriculture, mathematics, and health in agribusiness curriculum. *International Journal of Evaluation and Research in Education*, *12*(4). https://doi.org/10.11591/ijere.v12i4.25665

Hermans, F., Geerling-Eiff, F., Potters, J., & Klerkx, L. (2019). Public-private partnerships as systemic agricultural innovation policy instruments – Assessing their contribution to innovation system function dynamics. *NJAS - Wageningen Journal of Life Sciences*, *88*. https://doi.org/10.1016/j.njas.2018.10.001

James, K., & Charles, N. (2023). *COMMERCIAL FARMING AND SOCIAL ECONOMIC STATUS OF RURAL FAMILIES. A CASE OF KYABATANA VILLAGE* (Vol. 2, Number 7).

Janet, A., & Julius, A. (2023). Corresponding: Author: research.miu.ac.ug/publications WORKPLACE DIVERSITY AND EMPLOYEE PERFORMANCE IN AN ORGANISATION. A CASE STUDY OF RUKUNGIRI TOWN COUNCIL, RUKUNGIRI DISTRICT. In *METROPOLITAN JOURNAL OF BUSINESS & ECONOMICS (MJBE* (Vol. 2, Number 7).

Jimmy, N., Flavia, N., & Nelson, K. (2023a). THE EFFECT OF CROP DISEASE OUTBREAKS ON AGRICULTURAL TRADE, A CASE STUDY OF ARINYAPI SUB-COUNTY, ADJUMANI DISTRICT. In *METROPOLITAN JOURNAL OF BUSINESS & ECONOMICS* (Vol. 2).

Jimmy, N., Flavia, N., & Nelson, K. (2023b). THE EFFECT OF CROP DISEASE OUTBREAKS ON AGRICULTURAL TRADE, A CASE STUDY OF ARINYAPI SUB-COUNTY, ADJUMANI DISTRICT. In *METROPOLITAN JOURNAL OF BUSINESS & ECONOMICS* (Vol. 2).

Jjuuko, R., Tukundane, C., & Zeelen, J. (2021). Reclaiming the educative power of vocational placements: Experiences from agriculture education practice in Uganda. *International Journal of Training and Development*, *25*(2). https://doi.org/10.1111/ijtd.12212

Julius, A., & Godfrey, K. (2025). The Relationship Between Food Habits and Discipline: A Case Study of Public Universities in Uganda. In *Avance International Journal of Academic Multidisciplinary Research* (Vol. 1). https://journals.aviu.ac.ug

Julius, A., & Isaac Kazaara, A. (2024). *Agricultural Innovation and Farmer Productivity: A Case Study of Farmers in Luwero*.

Julius, A., & Twinomujuni, R. (2025). *Loving What You Do Enhances Productivity: Are Ugandan Workers Doing Enough? 1*(3), 43–54. https://journals.aviu.ac.ug

Kazaara, A. G., & Christopher, F. (2023). *Impact of Micro Credit Financing on Agricultural Production A case Study of Bundibugyo District In The Western Region Of*. *7*(3), 56–62.

Majeed, Y., Khan, M. U., Waseem, M., Zahid, U., Mahmood, F., Majeed, F., Sultan, M., & Raza, A. (2023). Renewable energy as an alternative source for energy management in agriculture. In *Energy Reports* (Vol. 10). https://doi.org/10.1016/j.egyr.2023.06.032

Muhanguzi, F. K., Boonabaana, B., Sanya, L. N., Kavuma, S. N., Kyomuhendo, G. B., Ludgate, N., & Meinzen-Dick, L. (2023). The meanings of resilience in climate justice: women smallholder farmers' responses to agricultural shocks in Uganda under the spotlight. *Agenda*, *37*(3). https://doi.org/10.1080/10130950.2023.2245844

Musa, M., Moses, M., Ariyo, D., & Kazaara, G. (2023). *IMAPCTS OF SOIL EROSION ON CROP PRODUCTIVITY IN UGANDA ACASE STUDY OF KIBUGA DIVISION BUTAMBALA DISTRICT* (Vol. 2).

Nakazi Florence* and Sunday Nathan. (2020). The Effect of Commercial Banks' Agricultural Credit on Agricultural growth in Uganda. *African Journal of Economic Review*, *8*(1).

Nelson, K., Christopher, F., & Milton, N. (2022). *Teach Yourself Spss and Stata*. *6*(7), 84–122.

Nelson, K., Kazaara, A. G., & Kazaara, A. I. (2023). *Teach Yourself E-Views*. *7*(3), 124–145.

Niyonzima, E. (2023a). Assessing the Impacts of Rural-Urban Migration on Agriculture Production in Rwanda: A Case Study of Huye District, in Southern Province. In *International Journal of Academic Multidisciplinary Research* (Vol. 7). www.ijeais.org/ijamr

Niyonzima, E. (2023b). Assessing the Impacts of Rural-Urban Migration on Agriculture Production in Rwanda: A Case Study of Huye District, in Southern Province. In *International Journal of Academic Multidisciplinary Research* (Vol. 7). www.ijeais.org/ijamr

Pereira, D., Manen, C., & Rigaud, S. (2023). The shaping of social and symbolic capital during the transition to farming in the Western Mediterranean: Archaeological network analyses of pottery decorations and personal ornaments. *PLoS ONE*, *18*(11 November). https://doi.org/10.1371/journal.pone.0294111

Rebecca, N., Jacob, K., & Muhammed, M. (2024). *Access to Finance and Women Entrepreneurship: A Case Study of Women in Agriculture in Masaka*.

Righetti, E., Nortilli, S., Fatone, F., Frison, N., & Bolzonella, D. (2020). A Multiproduct Biorefinery Approach for the Production of Hydrogen, Methane and Volatile Fatty Acids from Agricultural Waste. *Waste and Biomass Valorization*, *11*(10). https://doi.org/10.1007/s12649-020-01023-3

Rosemary, N., & Charles, N. (2023). THE EFFECT OF RABBIT FARMING ON HOUSE HOLD INCOME A CASE STUDY OF BUDDO SUB COUNTY WAKISO DISTRICT. *METROPOLITAN JOURNAL OF BUSINESS & ECONOMICS (MJBE)*, *2*(4), 684–697.

Sanga, U., Berrío-Martínez, J., & Schlüter, M. (2023). Modelling agricultural innovations as a social-ecological phenomenon. *Socio-Environmental Systems Modelling*, *5*. https://doi.org/10.18174/sesmo.18562

Serwadda, I. (2018). Impact of credit risk management systems on the financial performance of commercial banks in Uganda. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, *66*(6). https://doi.org/10.11118/actaun201866061627

Teklu, A., Simane, B., & Bezabih, M. (2023). Effect of Climate Smart Agriculture Innovations on Climate Resilience among Smallholder Farmers: Empirical Evidence from the Choke Mountain Watershed of the Blue Nile Highlands of Ethiopia. *Sustainability (Switzerland)*, *15*(5). https://doi.org/10.3390/su15054331

Teye-Gaga, P., Obeng, C. K., Afful, B., & Boadu, M. T. (2023). Economic integration and survival of Ghana's manufactured and agriculture raw material exports. *Heliyon*, *9*(1). https://doi.org/10.1016/j.heliyon.2022.e12723

Van Campenhout, B., Minten, B., & Swinnen, J. F. M. (2021). Leading the way – foreign direct investment and dairy value chain upgrading in Uganda. *Agricultural Economics (United Kingdom)*, *52*(4). https://doi.org/10.1111/agec.12638

Waiswa, D., Günlü, A., & Mat, B. (2021). Development opportunities for livestock and dairy cattle production in Uganda: a Review. *Res. J. Agriculture and Forestry Sci. International Science Community Association*, *9*(1).

Wilson, B., & Charles, N. (2023). Corresponding: Author: research.miu.ac.ug/publications GINGER FARMING AND SOCIO-ECONOMIC DEVELOPMENT OF COMMUNITIES. A CASE STUDY OF KIBUGA SUB COUNTY BUTAMBALA DISTRICT. In *METROPOLITAN JOURNAL OF BUSINESS & ECONOMICS (MJBE* (Vol. 2, Number 7).

Woode, J. K., Idun, A. A. A., & Kawor, S. (2024). Comovement between agricultural commodities and stock returns of commodity-dependant sub-saharan Africa countries amidst the COVID-19 pandemic. *Scientific African*, *23*. https://doi.org/10.1016/j.sciaf.2023.e01972

Yoga, I. M. S., Budhi, M. K. S., Setiawina, N. D., & Saskara, I. A. N. (2019). SOCIO-ECONOMIC FACTORS AFFECTING POVERTY IN BALI PROVINCE, INDONESIA. *Russian Journal of Agricultural and Socio-Economic Sciences*, *90*(6). https://doi.org/10.18551/rjoas.2019-06.25

Zhao, G., Werku, B. C., & Bulto, T. W. (2025). Impact of agricultural emissions on goal 13 of the sustainable development agenda: in East African strategy for climate action. *Environmental Sciences Europe*, *37*(1). https://doi.org/10.1186/s12302-025-01056-2