

FOOD SECURITY, AGRICULTURAL INNOVATION, AND SMALLHOLDER LIVELIHOODS IN EAST AFRICA

Technology Adoption, Extension Services, and Value Chain Integration in Kenya, Ethiopia, and Tanzania

1. Wambui Njeri Kamau

Department of Agricultural Economics and Agribusiness Management, Egerton University, Njoro, Kenya

Email: wn.kamau@egerton.ac.ke | ORCID: 0000-0002-8819-4411

2. Tigist Hailu Bekele

Department of Rural Development and Agricultural Extension, Haramaya University, Haramaya, Ethiopia

Email: t.bekele@haramaya.edu.et | ORCID: 0000-0001-7230-5503

3. Zawadi Mwangi Kimaro

Department of Agricultural Economics and Agribusiness, Sokoine University of Agriculture, Morogoro, Tanzania

Email: z.kimaro@sua.ac.tz | ORCID: 0000-0003-5512-9901

ABSTRACT

Background: Smallholder farmers constitute the backbone of agricultural production in East Africa, providing food security for the majority of rural households and employing the largest share of the economically active population. Yet smallholder agricultural systems face compounding pressures from climate change-induced weather variability, land fragmentation, limited access to improved inputs, inadequate extension services, and constrained market integration that collectively limit productivity, income, and food security outcomes.

Aim: This study examined how agricultural innovation adoption, access to extension services, and value chain integration influence food security and livelihood outcomes among smallholder farmers in Kenya, Ethiopia, and Tanzania, with social capital and market access as moderating variables.

Methodology: Panel data from 1,260 smallholder households across nine districts in the three countries, collected in 2022 and 2025, were analysed using fixed effects regression, endogenous switching regression for innovation adoption, and structural equation modelling for livelihood outcomes. Food security was measured using the Food Insecurity Experience Scale. Moderation analysis employed the Hayes PROCESS framework.

Findings: Agricultural innovation adoption, specifically improved seed varieties, digital extension services, and mobile market platforms, significantly improved household food security and income outcomes across all three countries. Extension service access moderated innovation adoption effects positively, while value chain integration showed the strongest standalone effect on income outcomes. Social capital significantly moderated the value chain integration-income relationship.

Contributions: The study contributes to agricultural economics, food security, and rural development literature by providing longitudinal panel evidence of innovation-livelihood pathways among East African smallholders and identifying social capital and extension access as critical moderating conditions for sustainable agricultural transformation.

Keywords: Food security, Smallholder farmers, Agricultural innovation, Extension services, Value chain integration, East Africa.

Cite as: Kamau, W. N., Bekele, T. H., & Kimaro, Z. M. (2026). Food security, agricultural innovation, and smallholder livelihoods in East Africa: Technology adoption, extension services, and value chain integration in Kenya, Ethiopia, and Tanzania. *International Journal of Contemporary Issues Research*, 1(1), 79–104. <https://doi.org/10.69480/IJCIR.1.1.2026.04>

1.0 INTRODUCTION

Achieving food security for the approximately 350 million people in East Africa remains one of the most urgent contemporary policy challenges in the region. Despite significant agricultural potential, East African food systems are characterised by persistent yield gaps between actual and technically achievable smallholder production, high post-harvest losses attributable to inadequate storage and market infrastructure, and growing climate-induced production risk that threatens the viability of rain-fed smallholder agriculture (Khanal et al., 2023). The intersection of these challenges with rapid population growth, urbanisation, and shifting dietary patterns creates compounding food system stresses that require integrated policy responses.

Agricultural innovation, encompassing improved seed varieties, precision irrigation technologies, digital extension services, and mobile market platforms, represents a critical lever for smallholder productivity improvement. However, innovation adoption rates among East African smallholders remain substantially below potential, constrained by financial barriers, risk aversion, inadequate extension support, and limited market access that reduces the expected returns to investment in new technologies (Abate et al., 2022). Understanding which innovations generate the most significant livelihood improvements, and under what institutional conditions their benefits are most broadly distributed, is essential for evidence-based agricultural policy.

2.0 THEORETICAL AND CONCEPTUAL FRAMEWORK

Agricultural Innovation Adoption and Diffusion

Rogers' diffusion of innovations framework, adapted to East African smallholder contexts by Khanal et al. (2023), identifies relative advantage, compatibility with existing practices, complexity, trialability, and observability as the primary determinants of innovation adoption decisions. In smallholder contexts, financial risk aversion adds a critical adoption constraint not fully captured in Rogers' original formulation: innovations whose benefits are uncertain or delayed relative to their upfront costs face systematic adoption barriers even when their expected value is positive (Abate et al., 2022).

Sustainable Livelihoods Framework

The sustainable livelihoods framework, developed by the UK Department for International Development and extensively applied in African rural development research, conceptualises livelihood outcomes as functions of five capital types: human capital (skills and health), social capital (networks and norms), natural capital (land and water), physical capital (infrastructure and tools), and financial capital (savings and credit). Moderating conditions including institutions, policies, and market structures condition the conversion of capital assets into livelihood outcomes. This framework guides the moderation analysis of the present study.

3.0 METHODOLOGY

Panel data from 1,260 smallholder households (Kenya: 440, Ethiopia: 420, Tanzania: 400) across nine districts were collected in 2022 and 2025, yielding 2,520 household-year observations. Household selection used stratified random sampling with district as the primary stratification unit. Food security was measured using the eight-item Food Insecurity Experience Scale validated for African contexts. Livelihood outcomes were assessed through per-capita household income, dietary diversity score, and asset accumulation index. Innovation adoption was recorded for improved seed varieties, digital extension app usage, drip irrigation adoption, and mobile market platform membership. Fixed effects regression was the primary estimator. Endogenous switching regression addressed selection bias in innovation adoption. Moderation analysis employed the Hayes PROCESS macro.

4.0 FINDINGS AND DISCUSSION

Innovation Adoption and Food Security

Fixed effects regression results confirm that agricultural innovation adoption significantly improves household food security across all three countries. Improved seed variety adoption shows the strongest food

security effect ($\beta = 0.341$, $p < 0.001$), consistent with Abate et al.'s (2022) meta-analytic evidence. Digital extension app usage shows significant positive effects on both food security ($\beta = 0.218$, $p < 0.01$) and income ($\beta = 0.267$, $p < 0.01$), with effect magnitudes comparable to traditional face-to-face extension services. Mobile market platform membership shows the strongest income effect ($\beta = 0.312$, $p < 0.001$), reflecting improved price discovery and reduced transaction costs in agricultural commodity markets. Drip irrigation adoption shows smaller but statistically significant food security effects ($\beta = 0.149$, $p < 0.05$), with effects concentrated in the dry-season cropping calendar.

Extension Services as a Moderating Condition

Moderation analysis confirms that extension service access significantly moderates the effect of improved seed adoption on food security ($\beta_{\text{interaction}} = 0.193$, $p < 0.01$), such that the food security benefits of improved seeds are significantly larger among households with regular extension contact. This finding has important policy implications, suggesting that extension investment and seed system improvement are complements rather than substitutes in smallholder food security interventions, consistent with the integrated systems approach advocated by Khanal et al. (2023). Social capital significantly moderates the value chain integration-income relationship ($\beta_{\text{interaction}} = 0.224$, $p < 0.01$), with highly socially connected households capturing 34 percent larger income gains from market platform membership than socially isolated households.

Country Heterogeneity

Cross-country heterogeneity in innovation effects reflects institutional context differences. Ethiopian smallholders show the strongest seed adoption effects, attributable to the Farmer Training Centre extension system that provides systematic innovation exposure at kebele level. Kenyan smallholders show the strongest mobile market platform effects, reflecting M-Pesa integration in agricultural commodity trading that reduces payment transaction costs. Tanzanian smallholders show the highest value chain integration income effects, partly reflecting the Sokoine University agricultural marketing programme that supports cooperative market access. These country-level differences underscore the importance of institutional context in determining innovation effectiveness.

5.0 CONCLUSION AND RECOMMENDATIONS

Agricultural innovation adoption significantly improves smallholder food security and livelihood outcomes in East Africa, with extension service access and social capital serving as critical moderating conditions for innovation effectiveness. Extension services and technological innovation are complements: investment in one without the other yields substantially smaller benefits than integrated investment in both. Policymakers should prioritise integrated rural development programmes that simultaneously expand innovation access and strengthen extension infrastructure. Mobile market platform development should be combined with financial literacy and cooperative formation support to enable socially isolated farmers to capture value chain integration benefits. Longitudinal research should examine the sustainability and intergenerational transmission of innovation-driven livelihood improvements.

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