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[Research Article]

Influence of Institutional Factors on Agricultural Investments and Support Technologies in Enhancing Food Sufficiency in Tharaka-Nithi County, Kenya

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Abstract

Agricultural investments and support technologies play a vital role in improving agricultural productivity, profitability, and sustainability by allocating financial, physical, and human resources to farming activities. This study investigated how agricultural investments and the use of support technologies enhance household food sufficiency among smallholder farmers, with particular emphasis on the role of institutional factors. A descriptive research design was employed to collect quantitative and qualitative data from a sample of 398 respondents in Tharaka Nithi County, Kenya. Quantitative data were gathered using structured questionnaires administered to farming households, while qualitative data were obtained through key informant interviews with agricultural officers, cooperative leaders, and other relevant stakeholders. The study revealed that institutional factors significantly influenced both agricultural investments and the adoption of support technologies. High input costs were identified as the primary constraint to agricultural investment (M = 4.20), while corruption (M = 4.13) and political interference (M = 4.07) further hindered investment decisions and technology uptake. Conversely, key institutional drivers including market access, farmer organizations, research collaboration, subsidies, credit availability, extension services, cooperatives, and farmer training were perceived as essential enablers, with mean scores ranging from 3.80 to 3.98 on the Likert scale. Based on these findings, the study recommends that national and county governments strengthen institutional support by expanding access to affordable inputs and credit, enhancing extension services, promoting transparency in subsidy programs, and strengthening farmer cooperatives, research partnerships, and market linkages to improve household food sufficiency.

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Abstrak

Investasi pertanian dan teknologi pendukung memainkan peran krusial dalam meningkatkan produktivitas, profitabilitas, dan keberlanjutan pertanian melalui pengalokasian sumber daya keuangan, fisik, dan manusia untuk kegiatan pertanian. Penelitian ini mengkaji pengaruh investasi pertanian dan penggunaan teknologi pendukung terhadap peningkatan kecukupan pangan rumah tangga petani kecil, dengan penekanan khusus pada peran faktor-faktor institusional. Desain penelitian deskriptif digunakan untuk mengumpulkan data kuantitatif dan kualitatif dari sampel sebanyak 398 responden di Kabupaten Tharaka Nithi, Kenya. Data kuantitatif dikumpulkan menggunakan kuesioner terstruktur yang dibagikan kepada rumah tangga petani, sedangkan data kualitatif diperoleh melalui wawancara dengan informan kunci, yaitu petugas pertanian, pemimpin koperasi, dan pemangku kepentingan

Kata kunci:
Kabupaten Tharaka-Nithi;
investasi pertanian;
faktor institusional;
adopsi teknologi;
petani kecil;
kecukupan pangan.

terkait lainnya. Studi ini mengungkapkan bahwa faktor institusional berpengaruh signifikan terhadap investasi pertanian maupun adopsi teknologi pendukung. Tingginya biaya input diidentifikasi sebagai hambatan utama investasi pertanian (M = 4,20), sementara korupsi (M = 4,13) dan campur tangan politik (M = 4,07) semakin menghambat keputusan investasi serta penyerapan teknologi. Sebaliknya, pendorong institusional utama termasuk akses pasar, organisasi petani, kolaborasi penelitian, subsidi, ketersediaan kredit, layanan penyuluhan, koperasi, dan pelatihan petani dianggap sebagai pemampu penting, dengan nilai rata-rata pada skala Likert berkisar antara 3,80 dan 3,98. Berdasarkan temuan ini, penelitian merekomendasikan agar pemerintah nasional dan daerah memperkuat dukungan institusional dengan memperluas akses terhadap input dan kredit yang terjangkau, meningkatkan layanan penyuluhan, mendorong transparansi program subsidi, serta memperkuat koperasi petani, kemitraan penelitian, dan keterkaitan pasar guna meningkatkan kecukupan pangan rumah tangga.

INTRODUCTION

Adoption of agricultural technology is increasingly recognized as a vital strategy for enhancing household food sufficiency and global food security, particularly among smallholder farmers. Technologies such as improved seed varieties, synthetic fertilizers, irrigation infrastructure, mechanization, digital advisory tools, and post-harvest management systems significantly increase crop yields, reduce post-harvest losses, and stabilize food availability. However, the adoption and sustained use of these technologies are heavily mediated by institutional factors including regulatory frameworks, governance structures, market systems, and institutional support services that govern farmers' access to essential agricultural resources. This study investigates the influence of these institutional factors on agricultural investment and technology adoption among smallholder farmers.

Existing empirical literature has largely focused on individual, household, and farm-level determinants of adoption. For instance, in a systematic review of 128 studies across Africa, Fadeyi et al. (2022) identified financial capacity, gender, age, educational attainment, farm size, and extension access as the primary drivers of adoption. Similarly, empirical studies in Kenya emphasize individual and market-related factors such as socio-demographic characteristics, credit access, input market access, and production risks in shaping technology uptake (Manda et al., 2016). More recent evidence underscores the role of credit access, technical training, non-governmental organization (NGO) support, and farmer group membership in driving the adoption of climate-smart agricultural practices (Andati et al., 2023).

Despite these insights, critical knowledge gaps remain. First, existing research provides limited understanding of how diverse institutional factors such as credit facilities, market access, extension delivery, cooperatives, research institutions, and agricultural policies interact to influence long-term technology adoption and investment decisions. Second, prior studies predominantly focus on initial technology uptake rather than sustained adoption after external interventions (such as subsidies, temporary training, or donor funding) are withdrawn. Consequently, empirical evidence remains limited on the institutional configurations needed to sustain technology adoption and translate investments into long-term improvements in agricultural productivity and food security. This study addresses these gaps by evaluating the combined effect of institutional factors on agricultural investment, technology adoption, and the long-term sustainability of adopted practices.

Kenya's agricultural sector operates across diverse agro-ecological zones (AEZs) that influence local farming systems, technology adoption, productivity, and household food security. National agricultural policy frameworks increasingly emphasize tailoring support systems and technologies to specific agro-ecological conditions (Ministry of Agriculture and Livestock Development, 2024). Tharaka Nithi County presents a compelling case study because of marked variations in altitude, rainfall patterns, soil composition, and farming systems across different AEZs. The county's spatial profile spans Upper Midland, Lower Midland, and Intermediate Lowland zones, exhibiting sharp contrasts between the humid highlands and semi-arid lowlands (County Government of Tharaka Nithi, 2023). Despite this agricultural potential, smallholder farmers face systemic disparities in accessing extension services, credit, input-output markets, and institutional support. National policy frameworks also recognize that inadequate funding, infrastructure deficits, and low staff-to-farmer ratios continue to hinder effective extension delivery (Ministry of Agriculture and Livestock Development, 2023). These institutional constraints directly affect farmers' capacity to invest in and sustain agricultural technologies, making Tharaka Nithi an ideal location to examine these dynamics.

Concurrently, agricultural extension in Kenya is transitioning from conventional face-to-face models toward digital extension services, including mobile

applications, SMS-based advisories, and web-based agricultural platforms. Ministry of Agriculture and Livestock Development (2023) frames digital extension as a priority approach and calls for equipping extension personnel with ICT infrastructure and digital literacy skills. This national digital transformation is exemplified by initiatives such as the Kenya Integrated Agriculture Management Information System (KIAMIS), which registered over 6.5 million farmers by mid-2025 to streamline farmer registration, input distribution, market linkages, and advisory services (FAO, 2026). At the local level, Mutuma et al. (2023) reported that 51% of sampled smallholder dairy farmers in Tharaka Nithi used mobile applications to access agricultural information, though adoption was moderated by education level, credit availability, distance to markets, service costs, and perceived ease of use.

However, digital extension does not automatically guarantee sustained technology adoption. Persistent structural barriers such as limited digital literacy, high connectivity costs, inadequate network coverage, and broader dimensions of the digital divide continue to constrain smallholder participation (Yang et al., 2023). Limited empirical research exists on how digital platforms complement conventional institutional support mechanisms across agro-ecologically diverse settings. To address this gap, this study evaluates digital platforms alongside traditional institutional drivers, including field extension services, credit institutions, markets, government programs, and farmer organizations.

The overarching objective of this study is to analyze the role of institutional factors in driving agricultural investment, technology adoption, and household food security among smallholder farmers in Tharaka Nithi County, Kenya. Specifically, the study examines how access to credit, formal markets, extension advisory services, government support, farmer organizations, and digital platforms collectively influence farmers' investment choices and technology adoption. This inquiry aligns with recent empirical evidence demonstrating that technology adoption among smallholders depends not only on technology availability but also on supportive institutional, financial, and informational ecosystems (Kumar & Doan, 2025). Ultimately, this study offers actionable empirical insights for county and national policymakers to design integrated support interventions that extend beyond initial technology adoption to promote long-term, sustainable agricultural productivity and household food security.

METHOD

Study Area

This study was conducted in Tharaka Nithi County, Kenya, located on the eastern slopes of Mount Kenya, with a population of 393,177 according to the 2019 census. Geographically, Tharaka Nithi County lies between longitudes 37°18’37″ E and 37°28’33″ E, and latitudes 00°07’23″ S and 00°26’19″ S. The county borders Meru County to the east, Kitui County to the South, and Embu County to the west.

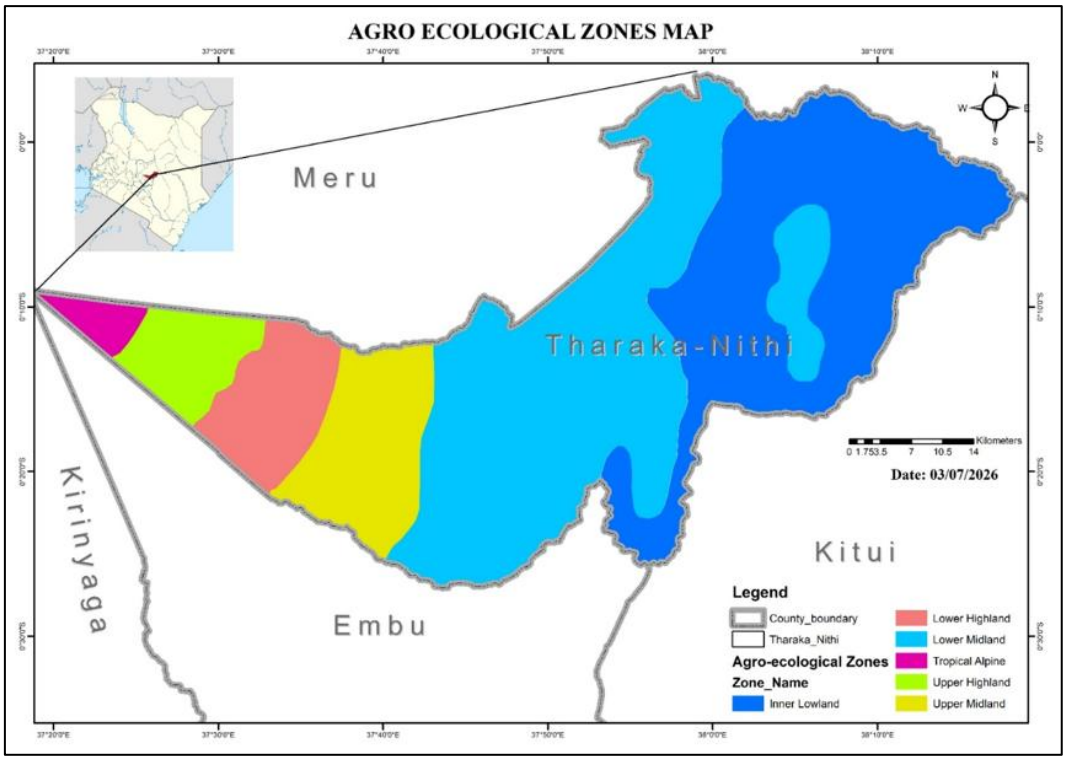

Figure 2. Map of Tharaka Nithi County Showing Agro-climatic Zones (Author, 2026)

The area experiences a bimodal rainfall pattern, with the long rain occurring between March and June and the short rains between October and December. Tharaka Nithi County exhibits diverse soil types influenced by its varied topography and agro-ecological zones. Tharaka-Nithi County spans an elevation gradient from approximately 600 m in the lowlands to nearly 5,200 m.a.s.l in the upper highlands, resulting in marked variations in ecological conditions, agricultural systems, and soil characteristics across the county (Kathambi et al., 2020; Wabocha et al., 2025).

In the high-altitude areas of Tharaka-Nithi, particularly along the eastern slopes of Mount Kenya, volcanic rocks and ash are the dominant geological materials, with humic Andosols being the dominant reference soil group. At lower elevations around 1,100–1,500 m, humic Nitisols are more prevalent and are characterized by deep, well-drained profiles and moderate to high inherent fertility (Rugendo et al., 2023; Rotich et al, 2025). The mid-altitude zones, ranging between 1,200 and 1,500 meters, fall within the Upper Midland 2 and 3 (UM2 and UM3) agro-ecological classifications, supporting a wide range of agricultural activities due to their moderate climatic conditions and relatively fertile soils. Conversely, in the lowland areas descending to approximately 600 meters above sea level, Cambisols and Regosols predominate. These soils occur across diverse agro-ecological settings, with the drier lowland zones supporting drought-tolerant crops such as millet and green grams. Understanding these soil and agro-ecological variations is important for agricultural planning and for selecting crop production strategies suited to local environmental conditions in Tharaka-Nithi County (Recha et al., 2017; Manzi & Gweyi-Onyango, 2021; Wawire et al., 2021).

Agriculture is the county's primary economic activity, engaging approximately 80% of the population. The highland areas are well-suited for cash crops such as tea and coffee due to their favorable climate and fertile soils. The midland zones support mixed farming systems, with crops including maize, beans, millet, sorghum, and other drought-tolerant crops, while coffee is cultivated mainly in the wetter, higher-elevation areas of the county (Manzi & Gweyi-Onyango, 2021). Vegetable farming is also widespread in these midland areas, contributing to both household consumption and income generation. In contrast, farmers in the lowland and semi-arid zones predominantly cultivate drought-resistant crops such as green grams, finger millet, and sorghum. Livestock production is another integral component of the agricultural system across the county, with households keeping cattle, goats, sheep, and poultry. In the semi-arid lowlands, indigenous livestock breeds adapted to harsh climatic conditions are commonly reared, providing meat and milk while serving as a vital financial safety net and source of livelihood resilience (County Government of Tharaka Nithi, 2023; KNBS, 2019; NDMA, 2024).

Study Design

This study adopted a mixed-methods research design, integrating both quantitative and qualitative approaches within a single framework to provide a comprehensive understanding of the research problem. This design enabled the researcher to combine numerical data on agricultural investments, support technologies, and household food sufficiency with qualitative insights from farmers and key informants. By integrating these approaches, the study captured not only measurable patterns and relationships but also the underlying perceptions, experiences, and contextual factors influencing agricultural practices and investment decisions (Kothari & Garg, 2017).

Population and Sample

The target population for this study comprised 98,050 farming households in Tharaka Nithi County, representing 92.5% of the county's total 106,000 households. To determine an adequate representation of this population, the sample size was calculated using Equation 1 by Yamane's (1967):

$$n = \frac{N}{1 + N(e)^2} \quad (1)$$

where N is the target population (98,050), e is the acceptable margin of error (0.05), and n is the required size. Substituting these values yielded a minimum sample size of 398 households.

A stratified random sampling technique was subsequently employed to select the 398 respondents across the county's three sub-counties. The sample allocated to each sub-county was determined filter-proportionately using the Equation 2:

$$n_i = \frac{n \times N_i}{N} \quad (2)$$

where n_i is the sample size for stratum i, n is the total sample size, N_i is the population of farming households in stratum i, and N is the total farming population. Table 4 summarises the detailed distribution of sample respondents across the sub-counties.

Research Instrument, Quality Assurance, and Ethical Considerations

The study employed both quantitative and qualitative data collection instruments to address the research questions. Quantitative data were collected from

Table 1. Number of Respondents in the Study Area

Sub-County	Farming Households	Proportionate Sample
Chuka/Igambang'ombe	38,950	158
Maara	30,200	123
Tharaka	28,900	117
Total	**98,050**	**398**

farmers using structured questionnaires containing closed-ended questions and five-point Likert-scale items, capturing information on agricultural investments, institutional factors, access to support technologies, and household food security. Qualitative data was gathered through structured and semi-structured Key Informant Interviews (KIIs) with extension officers, agricultural agency officials, and relevant stakeholders to gain deeper institutional context.

To ensure data quality and instrument validity, the questionnaire was peer-review and scrutinized by experts in geography and social sciences to evaluate its efficiency and adequacy. Modifications were made based on their feedback. Additionally, the instrument was pretested in Embu County because of its similar eco-climatic conditions, allowing identification and correction of ambiguities (Raykov et al., 2024). Internal consistency was tested using Cronbach's Alpha, yielding a reliability coefficient of 0.79, which exceeds the recommended threshold of 0.70 (Fraenkel & Wallen, 2003).

Ethical standards were strictly observed throughout the instrument administration process. The research protocol was reviewed and approved by the Chuka University Ethics Review Committee and licensed by NACOSTI under the Science, Technology and Innovation Act, 2013. Participation was voluntary, and informed consent was obtained from all respondents in accordance with the Declaration of Helsinki (World Medical Association, 2013). Respondents were informed of their right to withdraw at any time without penalty. To ensure confidentiality and privacy, no personal identifiers were recorded, and all research data were stored in password-protected digital files accessible exclusively to the research team.

Data Analysis

Data analysis used a combination of quantitative and qualitative techniques to address the research objectives. Before empirical evaluation, the raw quantitative data gathered through structured questionnaires underwent a systematic data-cleaning process to check for completeness, correct entry errors, and address missing values, ensuring overall dataset integrity and quality. The cleaned data were subsequently coded and entered into the Statistical Package for the Social Sciences (SPSS Version 28.0) for statistical computation. Quantitative data were analyzed using descriptive statistics including frequencies, percentages, means, and standard deviations to summarize the demographic profiles of respondents, patterns of agricultural investment, technology adoption rates, and perceived institutional barriers. To evaluate the five-point Likert-scale items assessing institutional drivers and constraints, a continuous mean score interpretation framework was applied, where mean values of 1.00 to 1.80 represented a very low level, 1.81 to 2.60 indicated a low level, 2.61 to 3.40 reflected a moderate level, 3.41 to 4.20 denoted a high level, and 4.21 to 5.00 represented a very high level.

Concurrently, qualitative data obtained from KIIs were transcribed verbatim, systematically organized, and analyzed using thematic analysis. Audio recordings and field notes were carefully reviewed to identify recurring patterns, concepts, and thematic categories corresponding to institutional support systems, regulatory policies, extension services, digital platform implementation, and the long-term sustainability of adopted technologies. The study then triangulated key qualitative findings and illustrative narrative excerpts from agricultural officers, cooperative leaders, and other institutional stakeholders with the quantitative survey results. This mixed-methods analytical approach provided a robust, contextualized interpretation of how institutional mechanisms collectively influence agricultural investment, technology adoption, and household food sufficiency among smallholder farmers in Tharaka Nithi County.

RESULT AND DISCUSSION

Smallholder farmers' evaluation of the institutional mechanisms influencing their investment decisions and support for technology uptake was captured using a 5-point Likert scale. Figure 2 depicts the resulting continuous mean values for each institutional driver and constraint.

All mean scores exceed the neutral threshold of 3.0, indicating widespread agreement that institutions play a pivotal role in shaping investment decisions and technology uptake. The most significant barrier identified was the high cost of agricultural inputs (M = 4.20), followed closely by governance challenges, including corruption (M = 4.13) and political interference (M = 4.07), which respondents perceived as discouraging investment and adoption. Conversely, respondents strongly acknowledged positive institutional drivers, including market access, farmer organizations, research collaboration, subsidies, credit access, extension services,

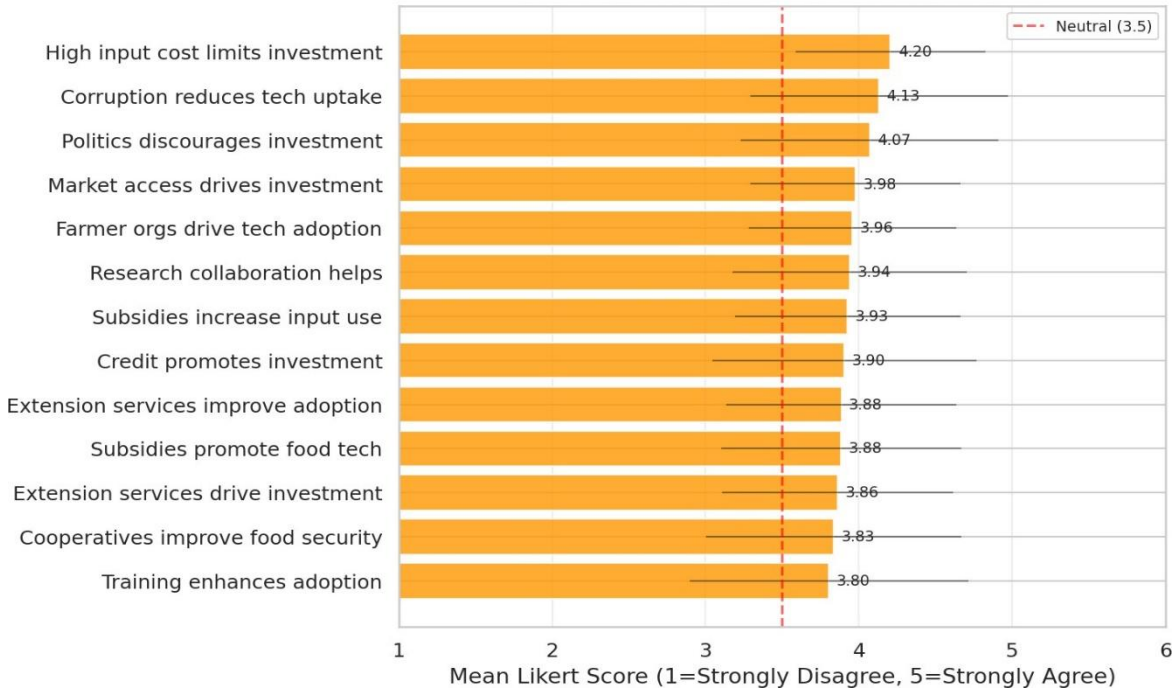

Figure 2. Mean Likert Scores for Institutional Drivers and Constraints Affecting Agricultural Investment and Technology Adoption

cooperatives, and farmer training. Overall, these findings imply that strengthening institutional support systems and governance will enhance technology adoption and improve food security among smallholder farmers.

The finding that high input costs severely limit agricultural investment (M = 4.20) highlights input affordability as a primary constraint for smallholders. Exorbitant prices for fertilizer, certified seeds, agrochemicals, and machinery diminish farmers' investment capacity, forcing many to rely on less productive practices. This result aligns with Branca et al. (2022), who identified input and output market constraints as major determinants of technology adoption. Similarly, FAO (2023) emphasized that high initial investment costs and limited financial resources can constrain smallholders' adoption of new agricultural technologies. However, Ooga & Gikunda (2021) noted that factors such as land tenure and farm income also moderate technology adoption, suggesting that high input costs may not impact all farmers uniformly. Nevertheless, these findings underscore the urgent need for affordable input distribution systems and financial support tailored to resource-constrained farmers in Tharaka Nithi County.

The high mean score for corruption hindering technology uptake (M = 4.13) indicates that weak governance and inequitable access to agricultural support pose substantial barriers to technological progress. Corruption distorts the fair distribution of subsidized inputs, credit, and state-supported technologies, thereby excluding deserving smallholders. This finding concurs with Dalaa et al. (2021), who observed that preferential treatment and corruption impede agricultural technology diffusion. Omulo & Kumeh (2020) likewise highlighted governance bottlenecks as key constraints to effective extension and service delivery. Conversely, Chowdhury et al. (2022) demonstrated that informal social networks can promote technology adoption even within flawed formal institutional environments, suggesting that farmer-to-farmer networks can partially buffer institutional weaknesses.

Political interference was also identified as a major deterrent to investment (M = 4.07), suggesting that political instability and politicized agricultural programs introduce uncertainty. When political patronage drives resource allocation or program implementation, farmers become hesitant to make long-term capital investments. This aligns with Dalaa et al. (2021), who demonstrated that political influences disrupt technology diffusion, and Branca et al. (2022), who stressed the role of stable policy environments in enabling technology uptake. However, Kirimi et al. (2021) found that participation in farmer testing groups positively influenced adoption, indicating that community-led and participatory initiatives can foster technology uptake even under challenging macro-political conditions.

Market access emerged as a crucial driver of investment (M = 3.98), indicating that reliable market outlets incentivize farmers to expand production and invest in technology. Secure market linkages improve expected returns, mitigate price risks, and enhance

farmers' liquidity to purchase inputs. This finding is consistent with FAO (2023), which emphasized that market conditions, expected profitability, and market access play important roles in shaping farmers' investment decisions. However, empirical findings by Ruzzante et al. (2021) in Kenya showed that commercial orientation alone does not automatically guarantee superior technology adoption, as subsistence farmers sometimes exhibited better post-harvest management than commercial producers. This highlights that market access must be complemented by targeted incentives and advisory services.

The positive role of farmer organizations (M = 3.96) demonstrates that collective action enhances access to market information, inputs, technical training, and capital. Group structures also facilitate peer learning, reducing the perceived risks of adopting novel technologies. This finding aligns with Njenga et al. (2021), who reported that farmer group membership significantly boosted the adoption of soil and water conservation practices in Tharaka Nithi County, and Chowdhury et al. (2022), who confirmed the positive impact of social connectivity on technology uptake among Kenyan farmers.

Research collaboration (M = 3.94) was recognized as another important catalyst for adoption. Multi-stakeholder collaboration among researchers, extension agents, and farmers ensures that technological innovations are tailored to local agro-ecological conditions. This finding concurs with Njenga et al. (2021), who identified communication gaps among researchers, extension personnel, and farmers as major adoption barriers, and Isgren et al. (2023), who emphasized interdisciplinary institutional support for scaling innovations in East Africa. In contrast, Kirimi et al. (2021) noted that participatory on-farm trials often exert a more immediate influence on adoption than formal research partnerships alone, implying that research collaborations are most effective when farmers actively participate in technology development.

Subsidies were found to significantly increase input utilization (M = 3.93), showing that reducing upfront financial burdens encourages the uptake of improved seeds, fertilizers, and equipment. This result is consistent with Nguyen et al. (2023), which found that agricultural input subsidies, particularly subsidized fertilizer and improved seeds, were associated with increased agricultural productivity and farm household incomes. Mohammed et al. (2023) similarly emphasized public-private partnerships and subsidy programs to expand agricultural mechanization. However, Branca et al. (2022) cautioned that adoption depends on interacting factors including land tenure, credit, and extension suggesting that subsidies alone cannot overcome all systemic barriers and must be integrated into broader institutional frameworks.

Access to credit (M = 3.90) was confirmed as a critical enabler of agricultural investment, allowing farmers to acquire capital-intensive technologies and inputs. This finding concurs with Kirimi et al. (2021), who identified financial access as a key determinant of adoption patterns. However, credit availability alone does not guarantee investment unless loan products are affordable, flexible, and tailored to agricultural production cycles and climate risks.

Agricultural extension services were shown to improve technology adoption (M = 3.88), underscoring the importance of technical guidance and information dissemination. Extension services bridge knowledge gaps, provide practical demonstrations, and assist farmers in contextualizing innovations. This concurs with Njenga et al. (2021), who found that extension contact significantly increased technology uptake in Tharaka Nithi County. Nevertheless, Omulo & Kumeh (2020) noted that traditional face-to-face extension services are often constrained by fiscal and logistical challenges, advocating for hybrid models that integrate digital farmer-to-farmer advisory platforms.

Financial support through subsidies was also recognized for driving the adoption of food-processing and storage technologies (M = 3.88). This finding is consistent with Ruzzante et al. (2021) and FAO (2023), who noted that targeted financial incentives help smallholders overcome cost barriers related to food safety and post-harvest management. However, Ruzzante et al. (2021) also observed that combining technical training with basic equipment provision was more cost-effective than relying solely on monetary subsidies, indicating that subsidies produce optimal outcomes when paired with capacity building.

Extension services further influenced broader investment decisions beyond initial technology adoption (M = 3.86). Access to reliable advisory services enables farmers to accurately assess the costs, benefits, and risks of diverse agricultural enterprises. This finding aligns with Njenga et al. (2021) and Ruzzante et al. (2021), who highlighted the central role of advisory support in scaling agricultural innovations. However, as Omulo & Kumeh (2020) observed, traditional extension coverage remains uneven due to institutional inefficiencies, leading to variable outcomes across different farmer segments.

Agricultural cooperatives were identified as vital mechanisms for enhancing food security (M = 3.83). By facilitating collective marketing, resource pooling, and shared access to services, cooperatives improve household incomes and food availability. This result concurs with Nyawo & Olorunfemi (2023), who demonstrated that cooperatives enhance access to inputs, training, and output markets, and Chowdhury et al. (2022), who highlighted the role of cooperative social capital in technology diffusion.

Finally, although farmer training received the lowest score among the thirteen indicators (M = 3.80), respondents still strongly agreed that capacity building promotes technology uptake. Training enhances technical competency and operational confidence. However, Mgendi et al. (2021) noted that training alone did not yield significant yield improvements in non-irrigated plots, demonstrating that training must be coupled with adequate water resources, input access, and supportive infrastructure to achieve sustained productivity gains.

These overall empirical outcomes are consistent with Waaswa et al. (2024), who reported that institutional factors such as credit access, training, institutional support, and group membership fundamentally dictate agricultural technology adoption among smallholders in Kenya. This reinforces the conclusion that adoption decisions are shaped not merely by individual knowledge, but by the enabling capacity of the surrounding institutional ecosystem. In summary, agricultural investment and technology adoption among smallholder farmers in Tharaka Nithi County are governed by three interconnected institutional pillars: financial services (credit and subsidies), knowledge transfer (extension services, training, research collaboration, and farmer organizations), and market and institutional infrastructure (market access, cooperatives, and governance). Addressing high input costs and governance barriers while expanding extension, credit, and cooperative networks will create a resilient environment for sustained technology adoption, ultimately improving farm productivity and household food security.

CONCLUSION

This study evaluated the influence of agricultural investments and support technologies on household food sufficiency among smallholder farmers in Tharaka Nithi County, Kenya, with a specific focus on the role of institutional factors. The findings demonstrate that institutional mechanisms play a pivotal role in shaping farmers' decisions to invest in agriculture and adopt productivity-enhancing technologies. High input costs (M = 4.20) emerged as the most formidable barrier to agricultural investment, accompanied by governance challenges such as corruption (M = 4.13) and political interference (M = 4.07), which create uncertainty and distort the equitable distribution of resources. Conversely, institutional enablers most notably market access, farmer organizations, research collaborations, subsidies, credit access, extension services, and cooperatives were identified as critical drivers that facilitate technology uptake and improve farm performance.

The results further indicate that sustainable technology adoption and agricultural investment depend on three integrated institutional pillars: financial support, knowledge transfer, and market infrastructure. While individual interventions such as subsidies or training provide immediate relief, long-term food sufficiency cannot be achieved through isolated measures. To translate agricultural investments into sustained improvements in food security, national and county governments, alongside development partners, must strengthen the institutional environment. Priority should be given to expanding access to affordable inputs and agricultural credit, improving transparency in subsidy distribution, scaling up conventional and digital extension services, and strengthening farmer cooperatives and market linkages. Addressing these institutional constraints will foster an enabling environment for smallholder farmers, drive technology adoption, increase agricultural productivity, and ultimately secure household food sufficiency.

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AUTHOR CONTRIBUTIONS

Medrine Cirindi Nkoroi: conceptualization, methodology, and writing—original draft preparation; **Moses Kathuri Njeru**: methodology, investigation, formal analysis, interpretation of findings, writing—original draft preparation, writing—review & editing; **James Muthomi Riungu**: methodology, investigation, formal analysis, writing—original draft preparation, writing—review & editing. All authors have read and agreed to the published version of the manuscript.

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DATA AVAILABILITY

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

All authors declare that they have no conflicts of interest.

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