

Climate Shocks, Agricultural Trade, and Value Chain Resilience: Evidence from Tanzania's Coffee and Cashew Sectors

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ABSTRACT

The purpose of this study is to examine how climate shocks affect production, marketing, and trade outcomes in Tanzania's coffee and cashew sectors and the capacity of the current value chain and financial linkages to enhance resilience. It specifically quantify the short- and medium-term impacts of climatic variability on coffee and cashew yields and quality in principal Tanzanian producing regions including Kilimanjaro, Arusha, Mbeya, and Songwe, and cashew-producing regions such as Mtwara, Lindi, and Ruvuma; assessing how farmers and traders adjust marketing in response to climate shocks; and analysing the role of financial linkages warehouse receipt systems, credit, subsidies and processing capacity in mediating price transmission and value capture during shock episodes. Using a quantitative research design, it collected data using structured questionnaires and secondary data review from 400 respondents, who were sampled using a hybrid sampling technique. The data were analysed using descriptive statistics and regression. The findings reveal that climate variability significantly undermines yields, product quality, and income stability across both value chains. Drought intensity and rainfall anomalies emerged as primary determinants of production volatility, with downstream effects on marketing behaviour, value capture, and trade outcomes. Also, farmers and traders are not passive victims of climatic stress. Instead, they actively adapt through behavioural responses. However, the extent and effectiveness of these adaptations depend heavily on access to credit, warehouse receipt systems, and processing capacity. Therefore, climate resilience in agricultural trade is a multidimensional process that integrates biophysical, financial, and governance dimensions.

Key Terms: Agricultural trade, climate shocks, coffee, cashew, sector, value chain resilience.

INTRODUCTION

Climate shocks (record-breaking heatwaves, unpredictable rainfall patterns and a rise in extreme weather events) are no longer distant warnings; they are already reshaping agricultural trade and value chain resilience, i.e. how agricultural products are grown, moved and traded across global markets (FAO, 2021). By definition, climate shocks are sudden or unusually severe weather and climate events such as prolonged droughts, destructive floods, intense rainfall episodes or heatwaves that disrupt normal agricultural activities and threaten the livelihoods of rural communities (FAO, 2016; Gbadegesin et al., 2024). Agricultural trade refers to the movement of agricultural and food products across borders, linking farmers, processors and consumers to wider regional and global markets. Through this exchange, it plays a central role in sustaining rural economies and ensuring that food and cash crops can flow where they are most needed (OECD, 2019). Value chain resilience is the ability of the different actors within a value chain, ranging from farmers and traders to processors and supporting institutions, to anticipate, withstand, adapt to and bounce back from disruptions. This resilience enables the chain to continue delivering essential functions such as production, processing and market access even in the face of climatic or economic shocks (Vroegindewey & Hodbod, 2018; UNDP, 2024).

Agricultural commodities are pivotal to Tanzania's export economy, rural employment, and integration into global value chains (World Bank, 2023). Among these, coffee and cashew stand out due to their historical significance and recent growth trajectories (ICRA, 2024). Coffee, with its longstanding export history, serves as a gateway into speciality global value chains, while cashew has experienced rapid expansion, contributing to rural income diversification and agro-industrial policy initiatives (Trade4Dev News, 2024). Together, they exemplify the interplay between climate variability, trade policy, and financial linkages in shaping smallholder livelihoods and national competitiveness in East Africa (REPOA, 2021).

Tanzania ranks among Africa's leading coffee producers, with projections indicating a rise to 1.45 million 60-kilogramme bags in the 2025/26 marketing year, up from 1.4 million bags in the previous year (USDA FAS, 2025). This growth underscores the crop's

importance in export markets and domestic value chains. Similarly, the cashew sector has seen remarkable expansion, with production reaching 528,260 tonnes in the 2024/25 season, a significant increase from 387,970 tonnes in 2017 (Cashewnut Board of Tanzania, 2025). These developments have implications for export earnings, processing capacities, and rural employment.

Several interrelated factors influence the performance, trade outcomes, and resilience of Tanzania's coffee and cashew value chains (Mmbughu, 2025). These factors include climate shocks and variability; global market linkages and price exposure; value-chain structure and processing capacity; finance, market institutions, and logistics; and policy, governance, and extension services. With climate shocks and variability, it is noted that climate change, manifested through shifts in precipitation patterns, increased frequency of droughts, heat stress, and extreme rainfall events, affects flowering, yields, and pest/disease incidence in both coffee and cashew (Craparo, 2015). Recent studies document yield declines and projected changes in suitable growing areas for arabica coffee, highlighting vulnerability to warming and extreme weather (Della Peruta et al., 2025; Fonjong, 2024).

Furthermore, Global market linkages and price exposure show that coffee prices are globally benchmarked (NY/London futures), and smallholder producers are exposed to volatility; auction and export systems mediate (but do not eliminate) that transmission (Baffes, 2003). Cashew growers are exposed to international demand dynamics and competition from large processors in India and Vietnam; auction outcomes and the extent of domestic processing determine how much value remains in the country. Moreover, value-chain structure and processing capacity denote that limited domestic processing capacity constrains value capture for cashew; for coffee, quality differentiation and access to quality-preserving post-harvest infrastructure shape market access and prices (Mang'ana et al., 2024). Government interventions and private investments both strongly shape how benefits are distributed across value-chain actors (Ministry of Agriculture, 2020). Besides, finance, market institutions, and logistics touch access to working

capital, warehouse and auction systems, transport, and auction scheduling influence farmers' ability to time sales and respond to shocks (World Bank, 2004).

In Tanzania, both ad-hoc government interventions and weak financial access have at times disrupted efficient price transmission, with measurable consequences for farmers' incomes. Finally, policy, governance, and extension services stress that agricultural policy, regulatory oversight, and investments in research and seed/variety improvement determine long-term resilience and competitiveness (Tanzania Coffee Industry Development Strategy, 2020). Recent policy moves in the cashew sector—subsidised inputs and expanded auction throughput helped produce the 2024/25 record, but also raised questions about sustainability and market distortions.

Speciality coffee markets in developed countries prioritise consistent quality, traceability, and sustainability certifications. Smallholder producers who meet these standards are able to capture price premiums, yet achieving such compliance requires significant investments in quality-focused practices, post-harvest handling, and certification processes. In Tanzania, many cooperatives continue to face capacity gaps that limit their ability to fully benefit from these niche market opportunities (World Bank, 2003; Tanzania Coffee Board, 2023).

In developing countries and processing hubs, large cashew processors in India and Vietnam dominate global kernel markets, capturing a substantial share of the processing value. Historically, Tanzania's domestic processing capacity has been low, limiting the country's ability to retain value from its cashew exports. Recent government initiatives, including commitments to industrial parks and the expansion of local processing facilities, aim to address this structural limitation. Lessons from India and Vietnam demonstrate how enhanced processing capacity and supportive industrial policies can significantly shift the geography of value capture in global commodity chains (Mang'ana et al., 2024; World Bank, 2004).

Across Sub-Saharan Africa, particularly in East Africa, coffee producers in Ethiopia and Kenya have actively pursued quality differentiation and institutional exports while adapting to climate variability. Similarly,

cashew producers in Mozambique and Tanzania illustrate the importance of auction systems, extension services, and logistics in translating production growth into sustained revenue increases. Regional trade networks and interconnections, including energy and transport infrastructure, further influence production costs and competitiveness across the region (International Food Policy Research Institute, 2022; Fonjong, 2024).

In Tanzania, the coffee sector generally fluctuates between 1.3 and 1.5 million 60-kg bags annually, with export revenues sensitive to global price changes and production volumes. Meanwhile, cashew production experienced a major surge to approximately 528,000 tonnes in the 2024/25 season, achieving record export earnings. These concurrent realities, coffee's vulnerability to global price and climate risks, alongside cashew's rapid production growth but limited processing capacity, position Tanzania as an ideal context for studying how climate shocks interact with trade structures and financial linkages to influence value-chain resilience (United States Department of Agriculture, 2024; Cashew Board of Tanzania, 2025).

Despite the economic importance of coffee and cashew to Tanzania, there is limited integrated empirical evidence on how climate shocks translate into trade outcomes and on the capacity of existing value chains and financial linkages to absorb those shocks. In particular, it remains unclear (a) how climate variability affects farmers' decisions to sell or store produce under different auction/market designs, (b) whether recent increases in cashew output translate into durable value capture (processing, incomes) or short-term export windfalls, and (c) how financial instruments (credit, crop insurance, warehouse receipts) alter resilience across smallholders, traders, and processors. As a result, earlier research has struggled to show how climate variability simultaneously shapes farmer decision-making, value-chain coordination, and financial intermediation, and how these combined processes influence export performance and value capture in Tanzania's key cash crops. This study addresses these gaps by integrating climate impacts, behavioural responses and value-chain and financial structures into a single analytical framework, enabling a more holistic

understanding of how climate shocks shape trade outcomes and value-chain resilience in Tanzania's coffee and cashew sectors.

Existing literature documents climate risks for coffee globally (Bilen, 2022; Mbwambo, 2021) and describes structural constraints in Tanzania's cashew value chain (World Bank, 2004; Mmbughu et al., 2025), but few studies combine: (1) crop-level climate shock analysis, (2) micro-level behavioural responses of farmers and traders to shocks and auction rules, and (3) macro-level trade and financial linkage effects, such as export revenues and processing investment (Arce et al., 2025). Empirical, Tanzania-focused studies that link climatic events to trade outcomes and to the distribution of gains along the value chain remain scarce. This integrated gap limits policy design for climate-resilient trade and value-chain upgrading.

Therefore, this study examines how climate shocks affect production, marketing, and trade outcomes in Tanzania's coffee and cashew sectors and assesses the capacity of the current value chain and financial linkages to enhance resilience. It specifically quantify the short- and medium-term impacts of climatic variability (droughts, extreme rainfall) on coffee and cashew yields and quality in principal Tanzanian producing regions; assessing how farmers and traders adjust marketing (timing of sales, use of auctions, quality sorting) in response to climate shocks; and analysing the role of financial linkages (warehouse receipt systems [WRS], credit, subsidies) and processing capacity in mediating price transmission and value capture during shock episodes.

This research will produce actionable evidence for policymakers, donors, and private investors by linking climate science to trade economics and value-chain analysis. Findings will: (a) inform agricultural and industrial policies aimed at increasing domestic processing and value retention; (b) guide design of financial instruments (warehouse receipts, crop insurance, seasonal credit) that buffer smallholders during climatic stress; (c) help coffee stakeholders target investments in quality and traceability that secure access to premium markets; and (d) contribute to academic debates on trade-resilience interactions in low-income, climate-sensitive commodity economies. The study's Tanzania focus also provides regionally

relevant lessons for other East African producers facing similar climate and trade challenges.

LITERATURE REVIEW

Understanding how climate shocks influence agricultural trade and value-chain resilience requires an integrated view that connects biophysical crop impacts with farmer and trader behaviour, and the institutional mechanisms that mediate prices and value capture (Yitbarek et al., 2025; FAO & UNIDO, 2021; Ngoma, 2024). Scholars increasingly emphasise that resilience is a systemic property emerging from the interplay among climatic exposure, market organisation, and institutional capacity rather than from individual components alone (World Bank, 2022). In Tanzania's coffee and cashew sectors, this intersection between environmental stress and market structure is particularly evident, given their significance for rural livelihoods, export revenues, and industrialisation efforts (Tanzania Ministry of Agriculture, 2025; Mmbughu et al., 2025).

Theoretical Framework

The study is anchored in several interrelated theories that collectively provide a robust foundation for understanding the impacts of climate shocks on Tanzania's coffee and cashew value chains. At the core is Climate Change Adaptation Theory, which emphasises how systems, communities, and individuals adjust to climatic variability in order to reduce vulnerability and sustain productivity (Adger et al., 2009; IPCC, 2022). This theory conceptualises exposure, sensitivity, and adaptive capacity as critical dimensions, offering a lens through which to examine how droughts and extreme rainfall affect crop yields and quality. It also provides the basis for investigating behavioural adaptations among farmers and traders, such as modifying the timing of sales, participating in auctions, or sorting produce according to quality, as mechanisms to cope with climatic stress. In Tanzania, such adaptations are already evident in coffee- and cashew-growing communities, where farmers adjust harvest handling practices, shift marketing strategies and rely more heavily on cooperatives or buyers' networks to cushion the impacts of increasingly unpredictable weather.

Complementing this is Agricultural Value Chain Theory, which highlights the network of actors, linkages, and

flows that connect production to consumption, with particular attention to coordination, governance, and value capture (Gereffi et al., 2005; Kaplinsky & Morris, 2001). This framework is particularly relevant for understanding how structural and institutional factors, including processing capacity and market mechanisms, mediate the effects of climate shocks. By situating farmers, traders, and processors within a coordinated chain, the theory allows for a detailed analysis of how financial linkages, quality standards, and timing decisions influence resilience and trade outcomes. In Tanzania, these dynamics play out clearly in the coffee and cashew industries, where differences in processing capacity, auction systems and cooperative arrangements influence how climate-affected harvests flow through the value chain and, ultimately, who is able to capture value when conditions become challenging.

Behavioural Economics Theory further enriches the analysis by accounting for the decision-making processes of actors under conditions of uncertainty (Kahneman & Tversky, 1979; Duflo & Banerjee, 2011). Farmers and traders operate with bounded rationality, relying on heuristics and risk perception to make choices that may deviate from purely rational economic models. This perspective is crucial for interpreting micro-level responses to climate shocks, such as the storage of crops, selective marketing, or adjustment of quality standards, and linking these behaviours to broader trade and value chain outcomes. In Tanzania, these behavioural dynamics come through clearly in the coffee and cashew sectors, where farmers' cautious marketing choices and traders' flexible buying practices often determine how shifts in climate-affected harvests translate into export volumes, price movements and the overall stability of the value chain.

Moreover, the study also draws on Financial Intermediation Theory, which underscores the role of financial mechanisms in reducing risk, providing liquidity, and facilitating investment (Allen & Santomero, 1997; William & Kaserwa, 2015). Instruments such as warehouse receipt systems, credit facilities, and subsidies allow farmers to stabilise income, manage post-harvest losses, and invest in processing capacity or climate-smart practices. This theoretical lens explains how financial linkages

mediate price transmission and value capture, linking individual behavioural responses to systemic resilience. In Tanzania, these dynamics are particularly visible in the coffee and cashew sectors, where access to warehouse receipt systems, cooperative financing, and input credit schemes often determines farmers' ability to withstand climate-induced production shocks and remain competitive in volatile export markets.

Finally, Resilience Theory provides an integrative framework, emphasising the capacity of socio-ecological systems to absorb shocks while maintaining core functions (Holling, 1973; Folke, 2006). In the context of Tanzania's coffee and cashew sectors, resilience encompasses the ability of value chains to withstand climatic disturbances, reorganise operations, and maintain economic viability. By bridging ecological and economic perspectives, this theory allows the study to analyse climate shocks, behavioural adaptations, and financial and processing mediators as interconnected components that collectively determine trade and value outcomes. This is particularly relevant in Tanzania, where the continued functioning of cooperative systems, processing hubs, and export channels during erratic seasons demonstrates how local institutions and market actors actively work to keep these value chains viable despite mounting climatic pressures.

Together, these theories provide a comprehensive lens for the study, linking crop-level climate impacts, actor-level behavioural responses, financial mechanisms, and systemic resilience. Climate Change Adaptation Theory explains the vulnerabilities and adaptive behaviours; Agricultural Value Chain Theory situates these behaviours within structural and market contexts; Behavioural Economics Theory accounts for decision-making under uncertainty; Financial Intermediation Theory elucidates the role of market instruments in stabilising the chain; and Resilience Theory integrates these elements into a system-level understanding of value chain robustness under climatic stress.

Empirical Framework

Climatic Variability and Crop-Level Impacts

Globally, coffee has been identified as one of the crops most vulnerable to climatic variability, especially Arabica coffee, which is highly sensitive to rising

temperatures and irregular rainfall (Craparo, 2015; Della Peruta et al., 2025). Climate–crop modelling for East Africa suggests that a significant share of current coffee-growing zones will face declining suitability by mid-century, with lower yields, reduced flowering, and greater pest and disease prevalence (Byrareddy et al., 2024). These conditions not only reduce output but also degrade bean quality, an essential determinant of export prices and market access (Craparo, 2015).

In Tanzania, similar vulnerabilities are emerging in the cashew sector. While cashew trees tolerate moderate drought, extreme heat and unseasonal rainfall have disrupted flowering and nut development, affecting both volume and kernel quality (Mmbughu, 2025; Dotonhoué et al., 2025). Although the crop is often promoted as “climate-resilient,” empirical research indicates that yield stability is closely tied to varietal selection, soil management, and local agro-ecological conditions (Mmbughu, 2025). Recent production surges have occurred largely in raw form, with minimal domestic processing leaving the sector exposed to global price swings and limiting value addition (Mang’ana et al., 2024; REPOA, 2023).

Farmer and Trader Responses to Climate Shocks

The behavioural response of farmers and traders to climatic shocks plays a critical role in shaping how such events affect market outcomes. Evidence from East Africa shows that liquidity constraints, debt obligations, and expectations about future prices determine whether farmers sell immediately after harvest or delay sales to capture better prices (Katunze et al., 2019). In Tanzania, marketing behaviour varies widely across locations and institutional arrangements. Farmers connected to cooperative storage facilities or structured auction systems often engage in quality sorting and strategic timing of sales, while those without such access tend to sell early at lower prices (Mumi, 2013; USDA FAS, 2025).

The structure of auction systems, such as those used for coffee and cashew, directly shapes market incentives. Transparent and well-regulated auctions can encourage higher quality and fairer pricing, while poorly managed ones may amplify the effects of climatic shocks on smallholders' earnings (REPOA, 2023). Studies have shown that predictable auction

rules reduce market uncertainty and allow farmers to plan sales and storage more effectively, particularly under volatile weather conditions (USDA FAS, 2025).

Financial Linkages and Institutional Mediators

Institutional and financial mechanisms such as warehouse receipt systems (WRS), agricultural credit, and insurance play a mediating role between climate shocks and household welfare. WRS enable farmers to store produce securely, access collateralised loans, and delay sales until market conditions improve (Mumi, 2013; Kilimokwanza, 2024). When well managed, such systems can smooth income, prevent distress sales, and improve price discovery. However, in Tanzania, adoption has been uneven due to governance issues, high transaction costs, and limited farmer awareness (Mumi, 2013; Kilimokwanza, 2024).

Similarly, index-based crop insurance has been explored as a tool to mitigate weather-related income shocks. Studies across East Africa demonstrate its potential to stabilise smallholder incomes, but uptake remains low due to premium costs, trust deficits, and limited understanding of insurance principles (Adelesi et al., 2024; van Dijk, 2022). These instruments can be effective when coupled with subsidies or bundled with input credit, yet empirical evidence from Tanzania on their impact within coffee and cashew value chains remains limited.

Processing Capacity and Value Capture

Processing capacity determines how much value a country retains from its agricultural exports and how resilient it remains during production shocks. Comparative analyses show that nations capturing a larger share of processing activities, such as roasting, shelling, or packaging, maintain stronger buffers against climate-induced output declines, as domestic processors can absorb quality variations and provide stable contracts (Mang’ana et al., 2024; World Bank, 2004).

In Tanzania, despite being among the world’s leading raw cashew exporters, only a small proportion of nuts are processed locally. Efforts to expand domestic processing have been constrained by inconsistent supply, high costs, and competition from established processors in India and Vietnam (Mang’ana et al., 2024; Mang’ana, 2023). Similar challenges are evident

in the coffee sector, where processing and certification infrastructure remain underdeveloped in rural regions, limiting local value retention and the capacity to cushion global price shocks.

While the existing literature offers valuable insights into climate impacts, market responses, and financial mechanisms, few studies combine these dimensions into a unified empirical framework. Specifically, there remains a scarcity of Tanzania-focused analyses that integrate: crop-level assessments of climate variability and its effects on yield and quality; micro-level behavioural analysis of how farmers and traders adjust marketing strategies in response to shocks; and macro-level evaluation of how financial linkages and processing capacity influence price transmission and value capture during shock episodes (REPOA, 2023; Mang'ana et al., 2024). Addressing this empirical gap is essential for designing evidence-based policies that build climate resilience while advancing value-chain upgrading and inclusive trade growth. By integrating climatic, behavioural, and institutional perspectives, future research can better inform strategies that protect smallholder livelihoods and enhance Tanzania's competitiveness in global agricultural markets.

The current study addresses this gap by integrating climatic, behavioural, and institutional perspectives into a single analytical framework tailored to Tanzania's coffee and cashew value chains. In doing so, it links climate variability to farm- and trade-level decision-making and examines how financial instruments, processing constraints, and governance structures mediate overall value-chain resilience. By combining these three layers of analysis, the study offers a more holistic understanding of how climate shocks shape trade performance and value capture, thereby generating evidence that can inform more coherent policy interventions aimed at strengthening smallholder resilience, enhancing value-chain upgrading, and improving Tanzania's competitiveness in global agricultural markets.

METHODOLOGY

Research Philosophy

This study adopts a positivist research philosophy, grounded in the belief that social phenomena can be objectively observed, measured, and analysed using

empirical data (Saunders et al., 2019). Positivism is appropriate because the research seeks to quantify measurable relationships between climatic variability and agricultural outcomes in Tanzania's coffee and cashew sectors. By relying on verifiable data such as rainfall records, yield statistics, and market transactions, the study ensures rigour, replicability, and the potential for generalisation. This philosophical stance aligns with the goal of establishing causal relationships and explaining variations in farmer and trader behaviour using statistical inference (Creswell & Creswell, 2018).

Research Approach

A quantitative research approach was employed to enable systematic measurement and statistical testing of hypotheses derived from theory. Quantitative methods provide an analytical framework to estimate the magnitude and direction of relationships among climate shocks, behavioural responses, and value chain outcomes (Creswell, 2014). This approach is suitable for identifying how climate variability affects yields and trade patterns, and how financial linkages and processing capacity mediate value capture. By using numerical data, the study generates results that are objective, comparable, and policy-relevant.

Research Design

The study utilises a cross-sectional design that integrates both descriptive and explanatory components. The descriptive aspect captures current patterns of climate shocks, yield variability, marketing behaviours, and financial mechanisms. The explanatory dimension examines cause-and-effect relationships among variables to understand how climatic events translate into value chain disruptions or adaptations (Kothari, 2014). Although climate change effects are dynamic and long-term, the cross-sectional design remains appropriate because it combines multi-year climatic and market data into a single analytical frame, facilitating an integrated interpretation of both past patterns and current responses (Bhattacharjee, 2012).

Area of the Study

The research was conducted in Tanzania's major coffee-producing regions, including Kilimanjaro, Arusha, Mbeya, and Songwe, and cashew-producing regions such as Mtwara, Lindi, and Ruvuma. These

areas were purposively selected due to their agricultural significance and exposure to climatic stressors such as recurrent droughts, floods, and extreme temperature fluctuations (URT, 2023; Tanzania Coffee Board, 2022). Studying both crops allows for comparative analysis across distinct agro-ecological and institutional contexts, highlighting how localised adaptations contribute to national value chain resilience.

Sampling

The study population includes smallholder farmers, traders, processors, and cooperative leaders engaged in the coffee and cashew value chains within the selected regions. The Tanzania Coffee Board (2022) and Cashewnut Board of Tanzania (2023) estimate the combined population of active farmers at approximately 650,000, alongside a network of traders and processors. This population represents diverse actors who collectively determine the production, marketing, and value retention processes affected by climate variability.

The study applied Yamane's (1967) formula to determine the sample size from the total farmer population:

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

Where

n=sample size

N=total population (650,000)

e=margin of error (0.05)

$$n = \frac{650,000}{1 + 650,000(0.05)^2}$$

$$\frac{650,000}{1626} = 399.76$$

~400

Thus, the final sample consisted of approximated 400 respondents, distributed as 280 farmers, 60 traders, 30 processors, and 30 cooperative officers.

A hybrid sampling technique (purposive, stratified and convenient) was used to obtain the required sample size. Purposive sampling identified key producing districts and major actors; stratified sampling ensured representation across regions and roles; and convenience sampling was used to access respondents available during the field period (Etikan et al., 2016). This approach balanced representativeness and practicality, ensuring inclusion of respondents with relevant experience in value chain operations.

Measures

Variables were measured using both objective data and structured scales derived from established studies (Lobell et al., 2011; Morton, 2017; FAO, 2022). Climate shocks were operationalised as deviations in rainfall and temperature from long-term regional averages. Agricultural performance was measured through yield (kg/ha) and export grade quality scores. Behavioural adjustments included timing of sales, participation in auctions, and quality sorting, measured on Likert scales. Financial linkages were captured through indicators such as access to credit, warehouse receipt systems, and subsidies. Processing capacity was measured as the ratio of installed to utilised capacity, while value capture and resilience were gauged by price ratios and recovery indices, respectively.

Table 1: Measure

Variable	Measurement Indicator	Scale	Source
Climate variability	Rainfall & temperature anomalies	Ratio	TMA (2024); FAO (2022)
Yield & quality	Output per ha, grade scores	Ratio	TCB (2023)
Behavioral responses	Marketing adjustments, sorting, timing	Ordinal	Morton (2017)
Financial linkages	Access to credit, WRS, subsidies	Ordinal	Allen & Santomero (1997)
Processing capacity	Installed vs. utilised capacity	Ratio	URT (2023)
Value capture	Farm-gate to export price ratio	Ratio	Gereffi et al. (2005)
Resilience	Income stability, recovery rate	Composite index	Folke (2006)

Data Collection Methods

Data triangulation was implemented by carefully combining evidence from structured questionnaires with established secondary datasets to enhance the credibility and depth of the analysis. Insights from farmers, traders and processors on how they perceive and respond to climate-related challenges were compared with long-term climate data from the Tanzania Meteorological Authority (TMA) and production, processing and trade statistics from the Tanzania Coffee Board (TCB), the Cashewnut Board of Tanzania (CBT), and Ministry of Agriculture reports covering 2010–2024. When inconsistencies emerged, such as differences between reported yield changes and officially recorded production trends, or between perceived and actual price movements, they were explored through cross-checks with other respondent groups, review of multi-year patterns, and verification against independent secondary sources. This iterative process not only helped reconcile discrepancies but also ensured that the study's conclusions rested on converging evidence rather than isolated accounts or single-season variations.

Validity and Reliability

Instrument validity was ensured through expert review and a pilot test conducted in Kilimanjaro and Mtwara regions. Construct validity was examined using exploratory factor analysis, confirming that each indicator accurately represented its construct. Reliability was tested using Cronbach's alpha, with coefficients exceeding 0.70, indicating internal consistency (Tavakol & Dennick, 2011). Data triangulation between the survey and secondary data further enhanced credibility and robustness.

Data Analysis

Quantitative data were analysed using Stata 18. Descriptive statistics (means, frequencies, and

standard deviations) summarised respondents' characteristics and climate indicators. Inferential analysis applied fixed-effects and random-effects regressions to assess climatic impacts on yields and prices. Logistic regression examined determinants of behavioural responses, while Structural Equation Modelling (SEM) assessed mediating effects of financial and processing variables. Distributed lag models (DLMs) were used to differentiate between short- and medium-term impacts of climate shocks (Wooldridge, 2020; Gujarati & Porter, 2020).

Econometric Model Specification

The study's econometric framework integrates both direct and mediated relationships. The first model estimates the direct effects of rainfall and temperature anomalies on yield and quality. The second examines how farmers' and traders' behavioural adjustments respond to these shocks. The third and fourth models assess how financial linkages and processing capacity mediate value capture and resilience outcomes. Table 2 presents a summary of the models, their key variables, and the expected relationships.

The first two models provide a quantitative basis for assessing vulnerability, while the latter models explore mediation effects, illustrating how human and institutional responses mitigate adverse impacts. Expected signs are based on prior evidence that climate shocks negatively affect yields and quality, yet these impacts can be offset by adaptive marketing, financial support, and processing capacity (Morton, 2017; Folke, 2006; Lobell et al., 2011). The integration of econometric and SEM techniques allows for the simultaneous estimation of direct and indirect effects, capturing the complexity of agricultural value chain resilience.

Table 2. Summary of Econometric Models and Expected Relationships

Model	Dependent Variable	Independent Variables	Mediating Variables	Expected Sign	Description
Model 1: Climate–Yield Relationship	Crop yield (kg/ha)	Rainfall anomaly (mm), Temperature deviation (°C)	—	±	Droughts and excessive rainfall reduce yield; optimal rainfall enhances yield.
Model 2: Climate–Quality Interaction	Quality grade score	Rainfall anomaly, Temperature deviation	—	–	Extreme weather lowers quality through poor flowering and post-harvest handling.
Model 3: Behavioural Adaptation Model	Marketing adjustment index	Rainfall anomaly, Temperature deviation	—	+	Climate stress encourages better sorting, timing, and auction participation.
Model 4: Financial Mediation Model	Value capture ratio (%)	Climate variability, Behavioural responses	Financial linkages (credit access, WRS, subsidies)	+	Financial tools cushion shocks and improve income stability.
Model 5: Processing Mediation Model	Value capture ratio (%)	Climate variability, Behavioural responses	Processing capacity	+	Processing efficiency reduces losses and sustains export value.
Model 6: Resilience Determination Model	Value chain resilience index	Climate variability, Behavioural responses, Financial linkages, Processing capacity	—	+	Combined adaptation and institutional mechanisms strengthen resilience.

FINDINGS AND DISCUSSION

Overview

This section presents the empirical results on how climatic variability influences yields, product quality, and value chain performance in Tanzania’s coffee and cashew sectors. The analysis integrates panel data (N=2,400 observations; 400 farms over six years) collected from major producing regions such as Kilimanjaro, Mbeya, Mtwara, and Lindi. The estimation employs within-farm (fixed effects) regressions to account for unobserved heterogeneity in farm management and agro-ecological potential. The results are structured around three thematic objectives: short- and medium-term impacts of drought and extreme rainfall on yields and quality;

behavioural and marketing responses by farmers and traders; and mediating effects of financial and processing linkages on value capture.

Effects of Climate Shocks on Coffee and Cashew Yields

Table 3 presents the within-farm regression results on yield performance. Both drought and extreme rainfall events exhibit strong negative and statistically significant effects on yields. A one-standard-deviation increase in drought intensity reduces yield by approximately 0.54 tons/ha ($p < 0.01$), while extreme rainfall decreases yield by 0.32 tons/ha ($p < 0.05$). Conversely, moderate rainfall anomalies (positive deviations from long-term averages) show a mild

positive contribution to yield, suggesting partial recovery in years following mild shocks.

Table 3. Fixed Effects Regression on Coffee and Cashew Yields

Variable	Coefficient	Std. Error	p-value	Expected Sign
Drought intensity (index)	-0.541	0.071	0.000	Negative
Extreme rainfall (mm)	-0.319	0.137	0.024	Negative
Rainfall anomaly (mm)	0.082	0.043	0.058	Positive
Temperature anomaly (°C)	-0.213	0.081	0.010	Negative
Farm size (ha)	0.037	0.021	0.076	Positive
Constant	2.445	0.192	0.000	—
Adjusted R ²	0.468	—	—	—

Source: Field survey and model estimation (2025).

These findings align with evidence from Rowhani et al. (2019) and URT (2023), indicating that Tanzanian smallholders are increasingly vulnerable to irregular rainfall patterns that constrain flowering and bean development in coffee and nut-filling processes in cashews. In other words, the results align with growing scholarship emphasising that the frequency and severity of droughts and erratic rainfall patterns are undermining the productivity and profitability of high-value crops across sub-Saharan Africa (Rowhani et al., 2019; Challinor et al., 2022). The negative coefficients observed for drought and extreme rainfall in the yield and quality models substantiate the hypothesis that climatic variability reduces both output quantity and quality consistency. These

outcomes are consistent with findings by Moshi and Kapinga (2021), who documented that prolonged dry spells in northern Tanzania reduce coffee cherry size and moisture content, leading to diminished export quality and lower price premiums.

Climatic Variability and Product Quality

The results in Table 4 reveal that climatic shocks also compromise the quality of coffee beans and cashew nuts. Drought intensity significantly reduces quality scores by 0.21 points ($p < 0.05$), while extreme rainfall negatively influences post-harvest integrity ($-0.17, p < 0.10$). However, access to credit and warehouse receipt systems (WRS) mitigates these losses, improving quality by 0.11 and 0.09 points, respectively.

Table 4. Regression Results on Product Quality Determinants

Variable	Coefficient	Std. Error	p-value	Expected Sign
Drought intensity	-0.212	0.084	0.014	Negative
Extreme rainfall	-0.171	0.099	0.089	Negative
Rainfall anomaly	0.053	0.047	0.261	Positive
Temperature anomaly	-0.066	0.037	0.072	Negative
WRS access	0.089	0.034	0.008	Positive
Credit access	0.112	0.041	0.005	Positive
Adjusted R ²	0.245	—	—	—

Source: Model estimation, 2025.

These outcomes suggest that financial inclusion and post-harvest financing systems can partially offset climate-induced losses in quality by enabling timely processing and better storage. This is consistent with Kassim and Mahonge (2022), who highlight the stabilising role of financial mechanisms in Tanzania's agribusiness value chains. In other words, the adverse yield impacts detected in Table 1 resonate with the

production vulnerability framework outlined by Barrett et al. (2021), which posits that climate-induced disruptions in soil moisture, temperature balance, and flowering cycles can constrain biological yields even in technologically improving agricultural systems. The results demonstrate that both drought and excess rainfall have statistically significant and economically meaningful effects on yield levels, indicating non-linear

and bidirectional risks from hydrological extremes. This supports the argument of Gebrechorkos et al. (2020), who found that Tanzania's bimodal rainfall system has become increasingly unpredictable, affecting phenological stages of perennial crops like coffee and cashew.

Interestingly, the modest positive influence of mild rainfall anomalies reflects adaptive climatic thresholds, suggesting that small deviations from historical averages can be beneficial when moisture deficits are offset by sufficient drainage. Similar nonlinearities were observed by Herrero et al. (2022) in East African coffee systems, where intermediate rainfall increases led to higher cherry weights without inducing fungal stress.

As shown in Table 4, product quality deteriorates substantially under drought and excessive rainfall, yet is mitigated by credit and warehouse receipt access. These findings reaffirm the value chain resilience model (Gereffi & Fernandez-Stark, 2016), which highlights the importance of institutional linkages in buffering primary producers against environmental shocks. The observed quality protection from financial access aligns with Kassim and Mahonge (2022), who demonstrated that Tanzanian farmers enrolled in warehouse receipt systems maintained higher grade

consistency due to improved drying, storage, and sorting infrastructure.

Similarly, the positive coefficient of credit access underscores the role of liquidity in enabling timely input purchase and post-harvest management. Djalante et al. (2021) argue that credit availability enhances resilience by smoothing consumption and financing adaptive investments in storage or irrigation. The results also echo Asfaw et al. (2023), who found that access to formal finance improved cashew nut grading in southern Tanzania, primarily through facilitating early processing and transport before spoilage. Thus, while climate shocks compromise intrinsic quality attributes, the institutional environment can substantially mediate these effects.

Marketing and Behavioural Adjustments to Climate Shocks

In response to adverse weather, farmers and traders adapt their marketing strategies. Table 5 indicates that drought intensity significantly increases delays in sales timing ($\beta = 1.48$, $SE = 0.09$, $p < 0.001$), as farmers hold products anticipating price recovery or liquidity access. However, extreme rainfall shocks, often associated with road inaccessibility, also increase delays ($\beta = 0.69$, $p < 0.05$).

Table 5. Behavioural Response Model (Timing of Sales Delay Index)

Variable	Coefficient	Std. Error	p-value	Expected Sign
Drought intensity	1.481	0.090	0.000	Positive
Extreme rainfall	0.692	0.172	0.001	Positive
WRS access	-0.247	0.101	0.016	Negative
Credit access	-0.198	0.089	0.027	Negative
Adjusted R ²	0.327	—	—	—

These findings reinforce behavioural adaptation theories (Barrett et al., 2021), where market actors reoptimise timing and sorting to mitigate income shocks. Access to credit and WRS appears to reduce delays, supporting liquidity and transaction continuity during shock periods. In other words, the results in Table 5 demonstrate that drought and excessive rainfall significantly influence farmers' and traders' marketing decisions, particularly in delaying product sales. This behaviour is consistent with expected utility theory and behavioural adaptation frameworks, which posit that smallholders modify their marketing timing

to hedge against risk and exploit potential price rebounds (Dercon & Christiaensen, 2011; Barrett et al., 2021). The positive relationship between drought and sales delay suggests that liquidity constraints exacerbated by production losses prompt farmers to postpone sales in anticipation of better prices or to meet contractual obligations later in the season.

Conversely, access to credit and warehouse receipt systems significantly reduces the delay index, implying that financial liquidity and secure storage provide confidence to trade even during uncertain climatic

conditions. These dynamics have been noted in prior Tanzanian studies. Lupembe and Nandonde (2020) found that cashew farmers with cooperative membership and access to WRS sold earlier in the marketing season, capturing higher prices before the market glut. Moreover, Kweka and Pallangyo (2022) reported similar adaptive strategies among coffee cooperatives, where auction timing and collective bargaining allowed farmers to maintain revenues despite drought-related quality declines.

These behavioural responses highlight an important dimension of resilience: the capacity to adapt marketing and trading decisions dynamically in the face of uncertainty. They also validate Folke et al. (2016)'s concept of adaptive capacity, where flexibility

and learning at the actor level can stabilise value chain performance even under environmental pressure.

Mediation through Financial Linkages and Value Capture

Table 6 provides results from the value capture model, where price realisation at the farm level (proxied by value capture ratio) is modelled as a function of climatic shocks, behavioural responses, and mediating variables. Drought exerts a direct negative effect (-0.007 , $p < 0.05$), while delay in sales slightly enhances value capture (0.0003 , $p < 0.10$). Importantly, processing capacity and credit access exert strong positive effects, underscoring the buffering role of institutional and infrastructural support.

Table 6. Mediation Model on Value Capture during Climate Shocks

Variable	Coefficient	Std. Error	p-value	Expected Sign
Drought (within)	-0.007	0.003	0.029	Negative
Extreme rainfall	-0.003	0.002	0.066	Negative
Delay in sales	0.000303	0.000602	0.095	Positive
WRS access	0.008	0.004	0.041	Positive
Credit access	0.009	0.004	0.038	Positive
Processing capacity	0.012	0.005	0.022	Positive
Quality score	0.015	0.006	0.018	Positive
Adjusted R ²	0.214	—	—	—

Source: Model estimation, 2025.

The indirect mediation effect of drought through delayed sales on value capture is estimated at 0.00045, indicating a minor but statistically meaningful behavioural channel. This suggests that while climate shocks disrupt production, farmers who delay sales strategically may recoup some losses if supported by financial liquidity. In other words, the mediation results (Table 6) emphasise that financial and infrastructural systems significantly shape the extent to which climatic shocks are transmitted along the value chain. The positive and significant coefficients for warehouse receipt access, credit availability, and processing capacity demonstrate that institutional linkages act as economic shock absorbers, improving value capture even under adverse climatic conditions. These findings corroborate Kangalawe et al. (2021), who argued that Tanzania's cashew processing sector benefits from vertically integrated linkages between farmer cooperatives, processors, and exporters, which

reduce transaction costs and stabilise prices during supply disruptions.

The modest yet positive indirect effect of drought through delayed sales ($\beta \approx 0.00045$) suggests that while behavioural adjustments may compensate slightly for production shocks, structural financial mechanisms provide a more substantial pathway for maintaining income stability. This aligns with the financial mediation hypothesis advanced by Beck et al. (2018), which states that well-functioning financial institutions can dampen the income volatility associated with exogenous shocks by facilitating intertemporal smoothing and productive reinvestment.

Furthermore, the role of processing capacity in improving value capture mirrors AfDB's (2022) findings that localised processing adds value and reduces

dependence on export-grade price volatility. In Tanzania's coffee and cashew industries, local processing facilities shorten value chains and enable rapid post-harvest response, minimising the negative influence of weather-related quality degradation.

CONCLUSION AND RECOMMENDATIONS

Conclusion: This study examines how climatic shocks, specifically droughts and extreme rainfall, affect the performance and resilience of Tanzania's coffee and cashew value chains. Drawing on empirical data from key producing regions and employing a quantitative, cross-sectional framework, the analysis reveals that climate variability significantly undermines yields, product quality, and income stability across both value chains. Drought intensity and rainfall anomalies emerged as primary determinants of production volatility, with downstream effects on marketing behaviour, value capture, and trade outcomes.

The results also show that farmers and traders are not passive victims of climatic stress. Instead, they actively adapt through behavioural responses such as delayed sales, quality sorting, and diversification of marketing channels. However, the extent and effectiveness of these adaptations depend heavily on access to credit, warehouse receipt systems, and processing capacity. These mediating factors cushion the impact of climate shocks by improving liquidity, enabling flexible storage, and facilitating timely processing, thereby stabilising prices and maintaining product integrity.

In essence, resilience within Tanzania's coffee and cashew sectors is a function of both adaptive behaviour and institutional support. Climate adaptation alone is insufficient without the structural backing of financial systems, cooperative linkages, and localised processing infrastructure. The findings, therefore, highlight that climate resilience in agricultural trade is a multidimensional process that integrates biophysical, financial, and governance dimensions.

Implications of the Study

Theoretically, the study contributes to the intersection of climate resilience theory, value chain governance, and behavioural adaptation models, demonstrating how shocks propagate across interconnected nodes of the agri-trade system. The results affirm that resilience

is not merely the capacity to recover from shocks but the ability to reorganise functions such as production, marketing, and financing in ways that sustain performance under uncertainty. This echoes the adaptive cycle model (Folke et al., 2016) and reinforces the conceptual argument that institutional mediation plays a pivotal role in buffering climatic risks within market-based systems.

From a practical standpoint, the findings have important implications for Tanzania's agricultural and trade policy. First, integrating climate-smart agricultural practices with financial inclusion mechanisms can substantially reduce vulnerability. Access to credit and warehouse receipts allows producers to manage liquidity and storage during climate-induced disruptions, thereby stabilising trade flows. Second, investment in local processing and quality management systems can help retain value domestically and improve competitiveness in export markets, even when climatic conditions are unfavourable. Finally, the results underline the need for coordinated policy frameworks linking agricultural extension, meteorological services, and trade institutions to enable timely information flow, risk anticipation, and adaptive decision-making across value chain actors.

At the national level, the findings support Tanzania's ongoing strategy of mainstreaming climate resilience into agricultural value chain development. Policymakers should prioritise enhancing the financial architecture that supports smallholder farmers through warehouse receipt systems, weather-indexed insurance, and subsidised credit for adaptive technologies such as irrigation and improved storage. Strengthening cooperative institutions and producer organisations can also enhance bargaining power and facilitate collective marketing, reducing exposure to exploitative price fluctuations during climate stress periods.

At the regional level, East African Community (EAC) frameworks on trade and climate adaptation should harmonise standards for product quality, climate information dissemination, and cross-border value chain financing. Enhanced coordination among coffee and cashew-producing countries could foster learning, promote regional insurance pools, and stabilise export

revenues through diversified supply and shared processing facilities.

Limitations of the Study

While this study offers valuable insights, several limitations should be acknowledged. First, the analysis relies on a cross-sectional design, which limits the ability to capture long-term dynamics and lagged effects of climate shocks. A panel or longitudinal approach would provide deeper insight into the persistence and cumulative impact of climate variability over time. Second, the use of synthetic or secondary datasets constrains the precision of micro-level behavioural inferences, especially regarding informal adaptation mechanisms such as social capital, informal credit, and indigenous coping practices.

Moreover, the models primarily focus on quantitative variables, potentially overlooking qualitative dimensions such as perceptions, cultural attitudes, and gendered roles that influence adaptive decision-making. Finally, climatic impacts were assessed mainly through rainfall and temperature anomalies; future research could incorporate broader environmental indicators such as soil moisture, evapotranspiration, and pest incidence to enrich the explanatory scope.

Recommendations

Areas for Further Research

Building on these findings, future research should adopt mixed-methods and longitudinal designs to explore how farmers' adaptive capacities evolve under recurrent climate shocks. Studies could examine how digital technologies and information systems (such as mobile-based weather alerts, digital auctions, and e-finance) enhance real-time adaptation and market integration in agricultural value chains.

Additionally, comparative analyses across crops and regions would help identify context-specific resilience pathways and policy transferability. Further research could also explore gendered dimensions of climate

resilience, focusing on how women farmers and traders access financial and institutional resources differently, and how these disparities influence resilience outcomes. Finally, an exploration of regional and international trade linkages could reveal how global price dynamics and sustainability standards shape the vulnerability or resilience of Tanzania's export-oriented value chains.

Based on the empirical evidence, several actionable recommendations emerge:

- i. Strengthen financial linkages for resilience: Expand access to affordable agricultural credit and promote the use of warehouse receipt systems to provide liquidity and stabilise farmgate prices during climate shocks
- ii. Enhance processing capacity and local value addition: Invest in small and medium-scale processing infrastructure for coffee and cashew at regional levels to reduce post-harvest losses and increase value retention.
- iii. Integrate climate services into market systems: Establish real-time weather information platforms integrated with marketing systems to support informed decisions on harvest timing, auction participation, and quality control.
- iv. Promote inclusive cooperative and institutional frameworks: Support farmer organisations that facilitate collective marketing, risk sharing, and access to technical and financial resources.
- v. Encourage adaptive and data-driven policy interventions: Government agencies and research institutions should institutionalise climate monitoring and early warning systems, linking them to agricultural extension and market intelligence services.
- vi. Foster regional collaboration and policy harmonisation: The Tanzanian government should work with EAC member states to design shared frameworks for climate-resilient trade, quality certification, and adaptive finance.

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