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Climate-Responsive Financing, Climate-Smart Agriculture, and Productivity and Income among Smallholder Rice Farmers: A Systematic Evidence Review with a Tanzania Core

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Abstract

Background: Climate variability constrains smallholder rice production through liquidity shortages, input-risk exposure, insurance gaps and delayed investment. Climate-responsive financing (CRF) is promoted as a bridge between financial access and climate-smart agriculture (CSA), yet empirical studies often combine climate-specific finance with ordinary agricultural credit. **Objective:** To determine what empirical evidence exists on the effects of CRF on rice productivity and net farm income among smallholder farmers in Tanzania, and whether CSA has been demonstrated, rather than assumed, to mediate those effects. **Methods:** The review follows PRISMA 2020, PRISMA-S and the Synthesis Without Meta-analysis (SWiM) guideline. Eligibility was defined with a PECO framework and explicit operational definitions of smallholder farmers, CRF, rice-specific outcomes and net farm income. Studies were classified as core CRF evidence, adjacent agricultural-finance evidence or comparative mechanism evidence using pre-specified decision rules. Risk of bias was assessed with RoB 2 and ROBINS-I, and certainty with GRADE. Mediation evidence was classified using a single three-category scheme. The original database exports could not be reconstructed; the earlier project search log is therefore disclosed as a limitation and is not reported as audited PRISMA flow statistics. **Results:** Nine empirical studies, each checked against its publisher record during manuscript preparation, were synthesised: six from Tanzania and three comparative studies from Kenya and Nigeria. None met the full core CRF definition for Tanzanian rice. A randomised Tanzanian microcredit study found no overall increase in paddy yield, rice profit or household income. Studies of village savings and lending associations and an agricultural credit guarantee scheme reported positive productivity and profitability effects, with moderate risk of residual selection. A national Tanzanian study found CSA adoption associated with crop yield and farm income. Tanzanian index-insurance evidence concerns demand rather than productivity. No study demonstrated CRF-to-CSA-to-income mediation; the evidence is classified as pathway-consistent. **Conclusion:** Financial instruments can affect rice productivity and profitability under particular institutional and agro-ecological conditions, but climate-labelled financing and formal mediation evidence remain underdeveloped in Tanzania. Multi-season designs that link climate-labelled financing to measured CSA adoption and net income are the clearest research priority.

Keywords: Climate-Responsive Financing; Climate-Smart Agriculture; Mediation; Net Farm Income; Productivity; Rice; Smallholder Farmers; Systematic Review; Tanzania

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INTRODUCTION

Rice holds a strategic position in Tanzania's food system and smallholder economy, and national policy has set targets for expanding its production and productivity (United Republic of Tanzania [URT], 2019). Production nevertheless remains exposed to rainfall variability, water constraints, input-market imperfections and limited access to productive finance (Hansen et al., 2019; URT, 2019). The financing problem is not simply an absence of loans. Experimental evidence shows that smallholder investment responds to uninsured risk as well as to liquidity, so relaxing credit constraints alone may not change production decisions (Karlan et al., 2014).

This distinction matters because ordinary agricultural credit and climate-responsive finance are analytically different. A conventional loan may provide liquidity but leaves repayment obligations unchanged when rainfall fails. A climate-responsive instrument, by contrast, may incorporate weather-linked insurance, concessional risk sharing, adaptation-linked grants, flexible repayment or digital finance tied to climate information (Carter et al., 2017; Tadesse et al., 2015). The review therefore defines CRF through identifiable climate-response mechanisms and excludes generic credit unless such a mechanism is demonstrated.

Climate-smart agriculture (CSA) is defined as agriculture that sustainably raises productivity, strengthens adaptation and resilience, and reduces emissions where possible (FAO, 2013; Lipper et al., 2014). The conceptual proposition of this review is that finance may affect productivity and income directly, through input purchases and investment, and indirectly, by enabling CSA adoption. Evidence that finance raises adoption, combined with separate evidence that CSA raises yield, does not establish statistical mediation. Formal mediation requires temporal ordering, an identified exposure-to-mediator path, a mediator-to-outcome path and a design that addresses confounding (Imai et al., 2010; VanderWeele, 2015).

The empirical record illustrates why these distinctions are needed. Across six randomised evaluations of microcredit in several countries, average effects on household income were modest (Banerjee et al., 2015). In Tanzania, a randomised study of agricultural microcredit found no overall increase in paddy yield, rice profit or household income, despite fertiliser-use responses among farmers with weaker irrigation access (Nakano & Magezi, 2020). In contrast, participation in bundled village savings and lending associations (VSLAs) was associated with higher rice productivity and profitability in Mvomero (Mtenga et al., 2024), and participation in an agricultural credit guarantee scheme was associated with approximately 25% higher rice productivity in Shinyanga and Iringa (Sanka & Makhura, 2025).

The climate-specific literature adds a further layer. Index insurance can crowd in investment where basis risk is managed, but uptake is often low and sensitive to trust, liquidity and understanding of the product (Carter et al., 2017; Cole et al., 2013). Its benefits may also be unevenly distributed across gender, wealth and social groups (Fisher et al., 2019). In Tanzania, a framed field experiment showed that learning, expectations, ambiguity and recent drought experience shape index-insurance demand (Dougherty et al., 2020).

Three gaps follow from this literature. First, Tanzanian rice studies rarely separate climate-labelled finance from general agricultural finance. Second, productivity and net income are often treated as interchangeable although they sit at different points in the livelihood chain. Third, CSA is frequently presented as a mediator without a design capable of testing mediation.

Against this background, the review asks: what empirical evidence demonstrates effects of CRF on productivity and net farm income among smallholder rice farmers in Tanzania, and to what extent is CSA demonstrated as the pathway through which such effects occur? The review also maps the socio-demographic and agro-ecological conditions that shape access to specialised financing. Tanzanian rice studies form the evidence core; Sub-Saharan African and other developing-country studies are used only to clarify mechanisms.

CONCEPTUAL AND ANALYTICAL FRAMEWORK

The review is organised around a parsimonious pathway model (Figure 1). CRF is the exposure, CSA adoption is the proposed mediator, and rice productivity and net farm income are the primary outcomes. The direct path (c′) is retained because finance can affect outcomes without passing through CSA, for example, by financing purchased inputs. Agro-ecology, irrigation, gender, farm size, tenure, extension, market access and climate information are treated as effect modifiers.

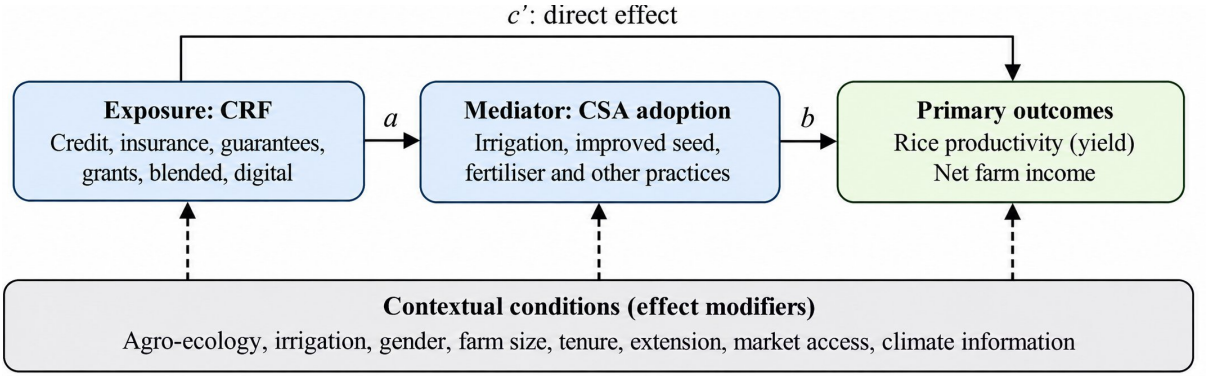


Figure 1: Conceptual framework linking climate-responsive financing, CSA adoption and rice outcomes

Source: Authors' construction, 2026, drawing on Imai et al. (2010) and Lipper et al. (2014). Paths a and b are each partly supported in the literature; the indirect effect a × b has not been estimated for Tanzanian rice farmers.

METHODS

Review Design and Reporting Standards

This study is a systematic evidence review reported in accordance with PRISMA 2020 (Page et al., 2021) and the PRISMA-S extension for literature searching (Rethlefsen et al., 2021). Because the included studies were too heterogeneous for pooling, the narrative synthesis follows the Synthesis Without Meta-analysis (SWiM) guideline (Campbell et al., 2020). Eligibility rules, classification rules, extraction fields, risk-of-bias procedures and synthesis rules were specified before the evidence was interpreted.

Review Question and PECO Framework

The review question was structured with the PECO framework summarised in Table 1.

Table 1: PECO framework

Element	Specification
Population	Smallholder rice farmers (Section 3.3); Tanzania is the core setting
Exposure	Financing with an identifiable climate-response mechanism (Table 2)
Comparator	No access, alternative or conventional finance, lower exposure, or a pre-intervention condition
Outcomes	Primary: rice productivity; net farm income from rice. Secondary: rice profit, household income, welfare, investment, CSA adoption
Mediator	CSA adoption, treated as a proposed rather than presumed pathway

Operational Definitions

Smallholder farmer: A household operating a farm that relies mainly on family labour and cultivates a small area. Because national and study definitions differ, a study qualified when it described its sample as smallholder or small-scale, or reported a mean cultivated area of 5 ha or less. Studies of commercial or estate farms were excluded.

Rice-specific outcome: An outcome measured for rice (paddy) alone, or reported as a separately identifiable rice subgroup. Whole-farm or multi-crop outcomes without a separable rice estimate were eligible only as comparative evidence.

Rice productivity: Paddy output per unit of cultivated land (e.g., kg/ha or t/ha) in a defined season.

Net farm income: The value of rice output (quantity × farm-gate price) minus variable production costs, including purchased inputs, hired labour, hired machinery and financing costs. Rice profit or gross margin computed on the same basis was treated as equivalent; gross revenue was not.

Climate-responsive financing: Financing that falls within one of the six domains in Table 2 and shows an explicit climate-risk, climate-adaptation or climate-information mechanism.

Table 2: Operational domains of climate-responsive financing

CRF domain	Eligibility signal	Example	Core exclusion
Climate-adaptive credit	Climate-linked repayment or adaptation design	Flexible repayment during climate shocks	Ordinary fixed agricultural loan
Climate-risk insurance	Weather, vegetation or index trigger	Weather-index crop insurance	Non-climate insurance
Risk-sharing finance	Guarantee or concessional structure linked to climate risk	Guarantee covering weather-related default	Unsubsidised market loan
Adaptation grants	Grant conditional on adaptation	Irrigation or resilient-seed grant	Unconditional cash transfer
Blended climate	Climate, public or	Climate facility on-	Ordinary private

CRF domain	Eligibility signal	Example	Core exclusion
finance	concessional capital combined with private capital	lent through banks	lending
Digital climate finance	Digital finance linked to climate information or adaptation	Mobile credit with weather alerts	Generic mobile transfer

Classification of Studies, Including Borderline Cases

Each study was assigned to one of three evidence tiers. **Core CRF evidence** comprises Tanzanian rice studies whose financing exposure meets Table 2. **Adjacent agricultural-finance evidence** comprises Tanzanian rice studies whose financing affects productivity or income but shows no demonstrated climate-response mechanism. **Comparative mechanism evidence** comprises Sub-Saharan African or other developing-country studies that inform financing, CSA or insurance pathways.

Borderline studies, in which the financing instrument was incompletely described, were classified with four rules applied in order:

The full text, supplementary files and cited programme documents were checked for the instrument's design.

If a climate-response mechanism was explicitly documented, the study was classified as core CRF evidence.

If the instrument was a risk-sharing or savings arrangement without documented climate conditionality, it was classified as adjacent evidence and labelled "climate-relevant" where its design plausibly reduces exposure to weather risk.

If the instrument could not be characterised at all, the study was excluded from the CRF synthesis and recorded with the reason "financing exposure insufficiently described."

No borderline study was promoted to the core tier on the basis that its borrowers were farmers or that agriculture is climate-sensitive. The same rules were applied at full-text screening and at data extraction, and every tier decision is recorded in the extraction workbook (Appendix C).

Handling of Non-Matching Outcome Measures

Outcomes that did not match the primary outcomes were retained but reported separately rather than substituted:

Rice profit or gross margin on a cost-deducted basis was synthesised with net farm income.

Gross revenue was reported as a production-value outcome, not as income, because it omits costs.

Household income, consumption or asset indices were reported as welfare outcomes, because they include non-rice sources.

General agricultural or crop productivity without a rice subgroup was reported as comparative evidence only.

Information Sources and Search Status

The search used four concept blocks: population, crop, financing and climate response. The full syntax for each source is given in Appendix B. Table 3 separates searches that were executed from searches that were planned, and states what records survive.

Table 3: Search status by information source

Source	Status	Search date	Fields	Filters and limits	Records retained
Scopus	Executed (project search log)	26 September 2026	TITLE-ABS-KEY	No date or language limit	Native export not retained
Web of Science Core Collection	Executed (project search log)	26 September 2026	Topic (TS)	No date or language limit	Native export not retained
Dimensions	Specified; execution not documented	—	Title and abstract	—	None
CAB Abstracts / AGRIS	Specified; execution not documented	—	Title, abstract, subject terms	—	None
Publisher and DOI verification	Executed during manuscript preparation	[authors to insert date]	Publisher and Crossref records	—	Verification notes for each included study
Backwards and forward citation chasing	Executed on verified studies	[authors to insert date]	Reference lists and citing records	—	Citation-chasing notes

The native Scopus and Web of Science export files were not preserved at the time of the original search. The search can be re-executed with the syntax in Appendix B, but a re-run would not reproduce the original record set exactly because both databases are continuously updated.

Study Flow and Audit Status

The earlier project search log reported 177 records, 58 duplicates, 119 records screened, 26 full-text reports assessed and five included studies. A second project document reported 193 records, and the two totals could not be reconciled. Because the supporting exports, deduplication file and screening log are unavailable, these figures are disclosed here as unaudited and are **not** reported as PRISMA flow results.

The five studies named in the earlier project extraction matrix (Anser, 2024; Ali, 2026; Caria, 2024; Carter, 2023; Erick, 2026) could not be traced to verifiable publisher records. They were therefore excluded from the synthesis and from the reference list.

The evidence synthesised in this review is the verified set: studies identified through the database and citation routes whose bibliographic details and reported findings were confirmed against publisher records. The resulting flow is reported in Appendix C and comprises nine empirical studies (six Tanzanian, three comparative), plus two review articles cited as background only.

Data Extraction

A structured matrix captured country and location, sample and size, financing instrument, climate-response mechanism, evidence tier, comparator, CSA measure, productivity outcome, income or profit outcome, design, identification strategy, effect estimate, uncertainty, subgroup findings, limitations, and funding or conflicts of interest. Different estimands and outcome definitions were retained rather than forced into a common metric.

Risk of Bias

Randomised studies were assessed with RoB 2 (Sterne et al., 2019) and non-randomised studies of interventions with ROBINS-I (Sterne et al., 2016). Matching and switching-regression methods were not treated as guarantees of causal validity; their ability to address observed and unobserved selection was judged in context. No summary quality score was calculated.

Certainty of Evidence

GRADE (Guyatt et al., 2008) was applied at outcome level, considering risk of bias, inconsistency, indirectness, imprecision and publication bias. Because the evidence base is sparse and heterogeneous, judgements are conservative and are not transferred across outcomes.

Synthesis Strategy

Evidence was grouped first by financing mechanism, then by outcome, then by causal pathway, and summarised by effect direction with the design of each study stated (Campbell et al., 2020). Vote counting was not used as a measure of effect. Random-effects meta-analysis was pre-specified only if at least three studies reported sufficiently comparable exposures, comparators, outcomes and estimands; this condition was not met.

Mediation Classification

A single three-category scheme is used throughout the manuscript (Table 4). It replaces the inconsistent four- and three-category schemes in the earlier version.

Table 4: Mediation evidence classification

Category	Criteria (all must hold)
Demonstrated mediation	(a) Financing measured before CSA adoption, and CSA before the outcome; (b) an estimated exposure-to-CSA effect; (c) an estimated CSA-to-outcome effect; (d) a formally estimated indirect effect with uncertainty; (e) a design addressing exposure–mediator and

Category	Criteria (all must hold)
	mediator–outcome confounding, with sensitivity analysis
Pathway-consistent evidence	At least one link (finance to CSA, or CSA to outcome) is empirically supported, but criteria (a), (d) or (e) are not met
Insufficient mediation evidence	Neither link is empirically supported for the population, or CSA was not measured

Reporting Bias

Selective outcome reporting and the greater visibility of positive findings were considered qualitatively. Funnel plots and small-study tests were not used because too few comparable studies were available.

RESULTS

Characteristics of the Included Evidence

Nine empirical studies were synthesised. No study met the core CRF definition for Tanzanian rice. Four Tanzanian studies are adjacent agricultural-finance evidence, one Tanzanian study informs the CSA-to-outcome link, one Tanzanian study concerns climate-risk insurance demand, and three studies from Kenya and Nigeria provide comparative mechanism evidence. Table 5 summarises each study.

Table 5: Characteristics and classification of included studies

Study	Setting	Design and identification	Financing instrument	Evidence tier	Outcome domain	Mediation category
Nakano & Magezi (2020)	Tanzania, rice	Randomised programme invitation; IV estimation	Agricultural microcredit with fertiliser voucher, cash and longer grace period	Adjacent	Paddy yield; rice profit; household income	Insufficient
Mtenga et al. (2024)	Tanzania (Mvomero), rice	PSM; ESR	Bundled VSLA participation	Adjacent (climate-relevant)	Rice productivity; rice profit	Insufficient
Sanka & Makhura (2025)	Tanzania (Shinyanga, Iringa), rice; n = 500	PSM; ESR	Agricultural credit guarantee scheme	Adjacent (climate-relevant	Rice productivity	Insufficient

Study	Setting	Design and identification	Financing instrument	Evidence tier	Outcome domain	Mediation category
				risk sharing)		
Sanka & Makhura (2026)	Tanzania (Shinyanga, Iringa), rice	Quasi-experimental impact evaluation	Agricultural credit guarantee scheme	Adjacent (climate-relevant risk sharing)	Welfare: consumption; asset index	Insufficient
Msuha et al. (2026)	Tanzania, national; multiple crops	Cross-sectional econometric analysis incl. OLS	Finance as one enabling factor	CSA link (comparative for rice)	Crop yield; farm income; CSA adoption	Pathway-consistent (CSA to outcome)
Doughert y et al. (2020)	Tanzania	Framed field experiment	Index insurance	Climate-specific (demand)	Insurance demand	Insufficient
Sibiko & Qaim (2020)	Kenya; multiple crops	IV methods	Weather-index insurance	Comparative	Input use; crop productivity	Pathway-consistent (insurance to inputs)
Amanya et al. (2025)	Kenya	Comparative analysis by shock exposure	Weather-index insurance	Comparative	Yield; resilience	Insufficient
Adeniyi et al. (2023)	Nigeria (Osun State), rice	Adoption-intensity analysis	Credit access	Comparative	CSA adoption	Pathway-consistent (finance to CSA)

Note: IV = instrumental variables; PSM = propensity score matching; ESR = endogenous switching regression; VSLA = village savings and lending association. Design details for Sanka & Makhura (2026) and Amanya et al. (2025) are to be confirmed against the full texts.

Finance and Rice Productivity

The evidence does not support the proposition that more agricultural finance automatically raises rice productivity. The randomised Tanzanian study found no overall increase in paddy yield, although fertiliser use rose among farmers with weaker irrigation access (Nakano & Magezi, 2020). By contrast, VSLA participation was associated with higher rice productivity (Mtenga et al., 2024), and credit-guarantee participants recorded approximately 25% higher productivity (Sanka & Makhura, 2025). The divergence suggests that financing design, borrower selection, complementary inputs and water conditions shape results.

Finance and Income

Income evidence is more heterogeneous than productivity evidence and is reported by outcome type (Section 3.5). For rice profit, the randomised study found no overall effect (Nakano & Magezi, 2020), whereas VSLA participation was associated with higher profitability (Mtenga et al., 2024). For household income and welfare, the randomised study found no overall effect on household income, and the credit-guarantee welfare study extended the evidence to consumption and assets (Sanka & Makhura, 2026). No Tanzanian study reported net farm income from rice exactly as defined in Section 3.3.

Finance and CSA Adoption

Evidence supports a plausible but not universal finance-to-CSA pathway. Among rice farmers in Nigeria, credit access was among the determinants of CSA adoption intensity (Adeniyi et al., 2023). In Tanzania, adoption of irrigation, improved seed and fertiliser practices was associated with higher crop yield and farm income, while adoption of several practices remained limited (Msuha et al., 2026). The Tanzanian randomised study shows why association should not be read as mechanism: improved credit access did not translate into broad productivity gains (Nakano & Magezi, 2020).

Climate-Risk Insurance

Index insurance falls clearly within the CRF definition, but Tanzanian evidence concerns demand rather than productivity. Learning, expectations, ambiguity and recent drought experience influenced demand in a framed field experiment (Dougherty et al., 2020). In Kenya, weather-index insurance was associated with greater input use and crop productivity (Sibiko & Qaim, 2020), with stronger yield effects under moderate than severe shocks (Amanya et al., 2025). Insurance is therefore analysed as a risk-management instrument rather than one expected to raise mean yield directly (Carter et al., 2017).

Mediation Assessment

Under Table 4, no study demonstrated mediation. Three studies provide pathway-consistent evidence for one link each: finance to CSA (Adeniyi et al., 2023), CSA to yield and income (Msuha et al., 2026) and insurance to input use (Sibiko & Qaim, 2020). No study measured financing before CSA adoption and CSA before rice outcomes, or estimated an indirect effect. The overall classification is pathway-consistent evidence.

Risk of Bias and Certainty of Evidence

The randomised study carries the lowest risk of bias. PSM and ESR studies address observed selection and model participation decisions but cannot remove unobserved confounding. The national CSA study is cross-sectional and does not claim causal effects (Msuha et al., 2026). Table 6 summarises outcome-level certainty.

Table 6: Risk of bias and GRADE certainty by outcome

Outcome and pathway	Studies	Risk of bias	Main downgrading reasons	Certainty
Agricultural finance → rice	Nakano & Magezi (2020); Mtenga et al. (2024); Sanka &	Low (RCT) to serious	Inconsistency in direction; indirectness (not	Low

Outcome and pathway	Studies	Risk of bias	Main downgrading reasons	Certainty
productivity	Makhura (2025)	(PSM/ESR)	climate-labelled)	
Agricultural finance → rice profit	Nakano & Magezi (2020); Mtenga et al. (2024)	Low to serious	Inconsistency; indirectness; few studies	Low
Agricultural finance → household income or welfare	Nakano & Magezi (2020); Sanka & Makhura (2026)	Low to serious	Indirectness (welfare ≠ net farm income)	Very low
CRF (climate-labelled) → rice productivity or net income	None in Tanzania	Not applicable	No eligible evidence	No evidence
CSA → yield and farm income	Msuha et al. (2026)	Serious (cross-sectional)	Confounding; single study; not rice-specific	Very low (causal)
Index insurance → demand (Tanzania)	Dougherty et al. (2020)	Low for the demand question	Indirectness to productivity	Moderate (for demand)
CRF → CSA → outcome (mediation)	None	Not applicable	No study meets Table 4 criteria	No evidence

Heterogeneity and Boundary Conditions

Irrigation altered the response to credit in the randomised study (Nakano & Magezi, 2020). Gender, land ownership, farm size, savings, improved seed and fertiliser were associated with productivity in the credit-guarantee study (Sanka & Makhura, 2025). CSA adoption and its returns differed across technologies and regions (Msuha et al., 2026), and insurance effects varied with shock severity (Amanya et al., 2025). These factors are treated as potential effect modifiers.

DISCUSSION

Principal Findings

The central finding is a boundary: agricultural finance and climate-responsive finance should not be treated as interchangeable. Tanzania has credible evidence that savings-and-lending arrangements and credit guarantees can be associated with higher rice productivity, profitability or household welfare. It does not yet have evidence that climate-labelled financing has a consistent causal effect on rice productivity and net farm income, nor that CSA mediates such an effect.

Interpretation of the Financing Evidence

The randomised study is the most instructive result. The programme was designed for

agriculture and bundled a fertiliser voucher, cash and a longer grace period, yet it did not raise paddy yield, rice profit or household income overall (Nakano & Magezi, 2020). This is consistent with multi-country microcredit evidence (Banerjee et al., 2015) and with evidence that uninsured risk, not only liquidity, limits smallholder investment (Karlan et al., 2014). Removing a liquidity constraint does not remove technology, water, agronomic or market constraints.

The positive VSLA and credit-guarantee results indicate that institutional design can change outcomes. VSLAs mobilise savings, extend credit and bundle collective services, while guarantees reduce lender risk and can expand access to loans. Both are closer to risk-sharing finance than ordinary unsecured lending. Their climate responsiveness, however, must be demonstrated through programme design rather than inferred from the climate sensitivity of agriculture. Because both rely on PSM and ESR, residual selection on unobserved characteristics such as managerial ability cannot be ruled out.

Climate-Risk Insurance

Insurance adds a risk-management dimension that credit alone does not provide. Tanzanian evidence shows that demand depends on beliefs, learning and ambiguity (Dougherty et al., 2020), consistent with wider evidence on low and fragile uptake (Cole et al., 2013). Kenyan evidence indicates that insurance can crowd in inputs and affect productivity under some shock conditions (Amanya et al., 2025; Sibiko & Qaim, 2020). Protection from loss should not be confused with an unconditional rise in mean yield, and attention to who benefits is needed because insurance gains can be unequally distributed (Fisher et al., 2019; Tadesse et al., 2015).

CSA as the Proposed Pathway

CSA remains the most promising bridge between finance and outcomes. The Tanzanian national study links CSA adoption to yield and farm income (Msuha et al., 2026), and the Nigerian rice study links credit access to adoption intensity (Adeniyi et al., 2023). Joining these two links across different populations, designs and time frames does not produce a mediation estimate (Imai et al., 2010; VanderWeele, 2015). The pathway is therefore an empirical hypothesis with partial support.

Why a Meta-Analysis was not Performed

The included studies differ in instrument (credit, VSLA, guarantee, insurance), outcome (yield, profit, household income, welfare, CSA adoption, insurance demand) and design (randomised, matching, switching regression, IV, cross-sectional). Pooling such estimates would produce a figure without a coherent interpretation. The structured synthesis is a deliberate choice to avoid false precision, consistent with SWiM guidance (Campbell et al., 2020).

Equity and External Validity

Irrigation changes the return to purchased inputs; tenure affects investment security; gender shapes control over land, collateral and financial decisions; farm size affects transaction costs; extension influences whether finance becomes adaptation; and market access determines whether more output becomes more income. Results from Mvomero, Iringa or Shinyanga cannot be generalised to all Tanzanian rice systems, and Kenyan and Nigerian evidence informs mechanisms but is not Tanzania-specific evidence.

Policy Context

Policy is moving toward integrated climate finance, including climate-smart financing pilots by agricultural lenders and parametric insurance under climate-adaptation programmes. These are policy developments rather than impact evidence and should be evaluated using the designs set out in Section 7.

Implications for Policy and Practice

The policy question is the design of financing, not its volume. Expanding agricultural credit without changing how products respond to climate risk may not be sufficient. A testable architecture would link finance with seasonal cash-flow design, credible climate information, insurance or guarantee mechanisms, adaptation-specific investment and extension support, and evaluate it against both productivity and net income, because higher output can coexist with higher costs or weak prices.

Financing institutions can make attribution possible by collecting baseline and follow-up data on financing terms, disbursement timing, climate exposure, CSA practices adopted, input use, yield, production costs, farm-gate prices and net income. Gender, farm size, irrigation status, tenure and market access should be recorded so that distributional effects can be tested. These are evidence-informed options rather than empirically established mandates.

Research Priorities

The most informative next study would evaluate a clearly climate-labelled financing package over several seasons, with a credible counterfactual and pre-specified outcomes (Table 7).

Table 7: Priority evidence gaps and required designs

Evidence Gap	Required Design	Primary Outcome	Priority
Climate-labelled finance in Tanzanian rice	Multi-season RCT or quasi-experiment	Rice yield and net farm income	Very high
CRF → CSA → outcome pathway	Repeated measures with temporal ordering; causal mediation analysis with sensitivity analysis	CSA adoption; indirect effect	Very high
Insurance → productivity	Index-insurance exposure combined with shock data	Yield; input investment	High
Gendered access	Gender-disaggregated estimates	Access, adoption, income	High
Distributional effects	Heterogeneity or quantile analysis	Income; assets	High

Strengths and Limitations

The review has four strengths. It separates financing with a climate-response mechanism from ordinary agricultural finance. It applies a geographic hierarchy in which Tanzanian rice

evidence is primary. It separates productivity, net income and welfare. It applies a stricter standard to mediation than to association, using a single, explicit classification.

The most consequential limitation is that the original Scopus and Web of Science exports, deduplication file and screening log were not preserved. The search flow therefore cannot be reconstructed; the earlier counts (177 or 193 records) are reported as unaudited, and the evidence base rests on a verified set that may omit eligible studies. A re-executed search with preserved exports would be required for a fully audited PRISMA flow.

Second, the financing instruments differ in the risks they transfer, the liquidity they provide and their eligibility conditions, so no single average effect is estimated. Third, outcomes sit at different points in the production and livelihood chain, and no Tanzanian study reported net farm income from rice as defined here. Fourth, no longitudinal study measured financing before CSA adoption and CSA before outcomes. Finally, Tanzanian rice systems vary widely, so evidence from one district or programme should not be assumed to represent all smallholder rice farmers.

CONCLUSION

Agricultural finance can matter for smallholder rice production, but its effects depend on institutional design, water security, input use, risk exposure and farmers' capacity to convert capital into adaptation. Tanzania has credible evidence on agricultural credit, VSLAs, credit guarantees, index-insurance demand and CSA outcomes, yet these strands do not establish a general causal effect of climate-responsive financing on rice productivity and net farm income.

The proposed CRF-to-CSA-to-outcome pathway is best treated as an empirical hypothesis with pathway-consistent support, not as an established causal fact. The review's contribution is to show where finance evidence ends, where climate-finance evidence begins, and what design is needed for a genuine mediation test.

Declarations

Author contributions (CRediT). [To be agreed by all three authors before resubmission.] Nyabundege Frank Mugeta: [e.g., conceptualisation, methodology, investigation, writing – original draft]. Ernest Kihanga: [e.g., supervision, writing – review and editing]. Joseph Kiria: [e.g., supervision, writing – review and editing]. All authors read and approved the final manuscript.

Data availability. The extraction workbook, risk-of-bias forms and search syntax are available from the corresponding author on reasonable request. The original database exports from the earlier project search were not preserved (Section 3.7).

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APPENDIX

Appendix A: PRISMA 2020 and PRISMA-S Reporting Map

Reporting item	Location in manuscript	Audit evidence retained
Title and abstract	Title page; Abstract	Final manuscript
Rationale and objectives	Section 1	—
Eligibility criteria and operational definitions	Sections 3.2–3.5; Tables 1, 2 and 4	Eligibility rules
Information sources and search status	Section 3.6; Table 3	Search syntax (Appendix B)
Search strategy (PRISMA-S)	Appendix B	Syntax; dates; fields; limits
Selection process and study flow	Section 3.7; Appendix C	Verification notes; exclusion reasons
Data collection	Section 3.8	Extraction workbook
Risk of bias	Sections 3.9 and 4.7; Table 6	RoB 2 and ROBINS-I forms
Synthesis methods (SWiM)	Sections 3.11 and 5.5	Grouping and effect-direction table
Reporting bias	Section 3.13	—
Certainty of evidence	Sections 3.10 and 4.7; Table 6	GRADE judgements
Results	Section 4; Table 5	—
Discussion and limitations	Sections 5 and 8	—
Declarations	Declarations	—

Appendix B: Database Search Syntax

The strings below are written from the Boolean logic recorded in the project search log. [Authors: confirm them verbatim against any retrievable search history before resubmission.]

Scopus (TITLE-ABS-KEY; executed 26 September 2026; no date, language or document-type limits)

TITLE-ABS-KEY (smallholder* OR "small-scale farm*" OR "farm household*")

AND TITLE-ABS-KEY (rice OR paddy OR "Oryza sativa")

AND TITLE-ABS-KEY (financ* OR credit OR loan* OR insurance OR guarantee*

OR grant* OR "blended finance" OR "digital finance")

AND TITLE-ABS-KEY ("climate-resilient" OR "climate-smart" OR "weather index"

OR "weather-index" OR "climate risk" OR adaptation OR drought OR flood*

OR "climate-responsive")

Web of Science Core Collection (Topic; executed 26 September 2026; no limits)

TS=(smallholder* OR "small-scale farm*" OR "farm household*")

AND TS=(rice OR paddy OR "Oryza sativa")

AND TS=(financ* OR credit OR loan* OR insurance OR guarantee* OR grant*

OR "blended finance" OR "digital finance")

AND TS=("climate-resilient" OR "climate-smart" OR "weather index"

OR "weather-index" OR "climate risk" OR adaptation OR drought OR flood*

OR "climate-responsive")

Dimensions and CAB Abstracts / AGRIS (specified; execution not documented). The same four blocks applied to title, abstract, keyword and subject fields.

Citation chasing. Reference lists (backward) and citing records (forward) of each verified study, screened against the same criteria.

Appendix C: Study Flow and Audit Status

Stage	Records	Status
Earlier project search log: records identified	177 (a second project document reports 193)	Unaudited; exports not retained; discrepancy unresolved
Earlier project log: duplicates, screened, full texts, included	58; 119; 26; 5	Unaudited; not reported as PRISMA results
Studies in earlier extraction matrix (Anser, 2024; Ali, 2026; Caria, 2024; Carter, 2023; Erick, 2026)	5	Excluded: no verifiable publisher record
Empirical studies verified and synthesised	9 (Tanzania 6; comparative 3)	Included (Table 5)
Review articles cited as background only	2 (Fisher et al., 2019; Tadesse et al., 2015)	Not part of the synthesis
Methodological and conceptual references	16	Cited for methods and context only

A fully audited PRISMA 2020 flow diagram requires re-executing the searches in Appendix B with preserved exports, deduplication and screening logs.