AATCC Review

06 October 2025: Received
16 December 2025: Revised
10 January 2026: Accepted
12 February 2026: Available Online

https://aatcc.peerjournals.net/

Review Article Open Access

# Sustainable agricultural finance: Innovative models and instruments for smallholder farmers

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## ABSTRACT

*Smallholder farmers produce a substantial share of the world's food yet remain disproportionately excluded from formal financial systems, limiting their productivity, resilience, and capacity to adopt sustainable agricultural practices. Persistent challenges, including credit rationing, climate risk, high transaction costs, and weak institutional support, underscore the need for financing approaches that move beyond conventional agricultural lending. This review examines the evolving landscape of sustainable agricultural finance, with particular emphasis on innovative models and financial instruments designed to meet the unique needs of smallholder farmers. Value chain financing, cooperative-based lending, blended finance, and public-private partnerships that strategically match financial returns with social and environmental benefits are all covered in this paper's synthesis of recent research. Alongside new fintech solutions that use digital platforms, alternative data, and mobile technologies to lower risk and increase financial inclusion, it also examines the expanding role of customised financial instruments, such as climate-index insurance, digital credit, savings platforms, and sustainability-linked funds. The institutional and legislative frameworks that support these innovations are also discussed, emphasising the functions of non-state actors, governments, and development finance organizations in scaling sustainable finance solutions. By critically assessing empirical evidence from diverse geographic contexts, the review evaluates the impacts of these financing approaches on farm productivity, income stability, and climate resilience, while identifying persistent constraints related to scalability, equity, and digital exclusion. The paper concludes by outlining emerging pathways for integrating climate finance and data-driven innovations into smallholder agricultural systems. Overall, this review provides a comprehensive framework for understanding how sustainable agricultural finance can catalyse inclusive and resilient rural transformation.*

***Keywords:*** *Sustainable agricultural finance, Smallholder farmers, financial inclusion, Innovative financing models, Climate resilience and Digital finance.*

## Introduction

Smallholder farmers are pivotal to global food security and rural livelihoods but remain systematically underserved by formal financial systems, constraining their capacity to invest in productivity and resilience-enhancing innovations. Financial constraints are a persistent barrier, with much of the sector depending on informal credits, savings, and self-generated resources due to inadequate formal finance outreach [1].

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*DOI: https://doi.org/10.21276/AATCCReview.2026.14.01.85*


High perceived risk, a lack of collateral, and an uneven rural financial infrastructure are some of the factors that worsen the financing gap by preventing smallholders from accessing credit, insurance, and savings products that could increase their productivity and market participation [2]. These limitations are especially severe in portions of South Asia and sub-Saharan Africa, where agriculture continues to be a major employer but lags behind in measures of financial inclusion. Therefore, improving the financial architecture for smallholder farmers is crucial for more general development objectives, such as reducing poverty and ensuring the sustainability of the agrifood system.

The concept of sustainable agricultural finance has gained traction as an integrative response to these challenges, embedding principles of financial inclusion, risk mitigation, and environmental sustainability into agricultural investment

frameworks. Sustainable agricultural finance goes beyond simple credit provision to include diversified instruments that address risk, liquidity, and climate-related vulnerabilities [1]. Research suggests that expanding access to financing can help smallholders implement better inputs and climate-adapted practices, increasing resilience and productivity [3]. For example, integrated risk management and credit solutions, like combining credit with insurance or savings, have been associated with more consistent investment in sustainable practices, particularly when backed by institutional support and favorable regulatory frameworks. These methods are in line with international development agendas that advocate for integrated finance strategies to promote rural change that is sustainable.

Recent innovations in agricultural finance illustrate emerging pathways for expanding sustainable finance tailored to smallholder contexts. Digital financial services and fintech solutions, including mobile banking and digital credit applications, have improved accessibility and reduced barriers in rural settings, enabling wider outreach to underserved farming communities [4]. Complementary institutional innovations, such as blended finance and value chain financing, are being piloted to mobilise capital while sharing risks between private investors and public actors [5]. Research from Ghana demonstrates that participation in creative financing strategies, such as community savings groups and cooperative credit arrangements, is associated with increased economic efficiency among smallholders of maize, indicating that a variety of funding sources can supplement both formal and informal mechanisms [6]. These advancements show that a mix of distribution methods and financial tools can better address the various demands of smallholder farmers, promoting resilience and inclusivity.

Despite these advances, scaling sustainable agricultural finance remains uneven and fraught with challenges. Persistent barriers such as limited financial literacy, gender and age disparities in access to finance, and regulatory constraints continue to constrain the depth and reach of financial services [1, 2]. Dependency on informal or non-institutional funding is reinforced in many rural economies because smallholders lack the knowledge and skills necessary to interact with formal bankers. The necessity for a methodical synthesis of theoretical and practical ideas is further highlighted by the fact that empirical evidence about the long-term efficacy of new financing models in enhancing agricultural productivity, income stability, and climate resilience is still developing. Policymakers and practitioners find it challenging to identify which models produce durable results and under what circumstances in the absence of strong evaluative frameworks and longitudinal data.

The purpose of this review is to provide a comprehensive and integrative assessment of sustainable agricultural finance with a focus on innovative models and instruments tailored to smallholder farmers. This review synthesises conceptual frameworks and empirical evidence to examine how diverse financial approaches address persistent barriers to financial inclusion, productive investment, and resilience building in smallholder agriculture. It examines important innovations, such as risk-sharing tools, value chain financing, blended finance mechanisms, digital and fintech solutions, and enabling institutional and legislative frameworks that either facilitate or limit their efficacy. For academics, policymakers, financial institutions, and practitioners interested in bolstering equitable and sustainable agricultural finance systems, the analysis also identifies evidence gaps and new research directions. This review seeks to influence the design and implementation of financial solutions that increase smallholder farmers' ability to invest in sustainable agriculture and support resilient rural development by using insights from various geographic contexts and financial conditions.

## Conceptual Foundations of Sustainable Agricultural Finance

Sustainable agricultural finance refers to financial systems, instruments, and practices that not only provide capital to farmers and agribusinesses but also explicitly support social inclusion, economic resilience, and environmental sustainability in agriculture. This concept moves beyond traditional credit provision, embracing a broader agenda that aligns agrarian development with climate adaptation, risk management, and long-term productivity goals. Sustainable agricultural finance emerges at the intersection of financial inclusion and climate-smart agricultural investment, reflecting a growing scholarly and policy consensus that access to appropriate finance is foundational to achieving resilient and sustainable food systems [7].

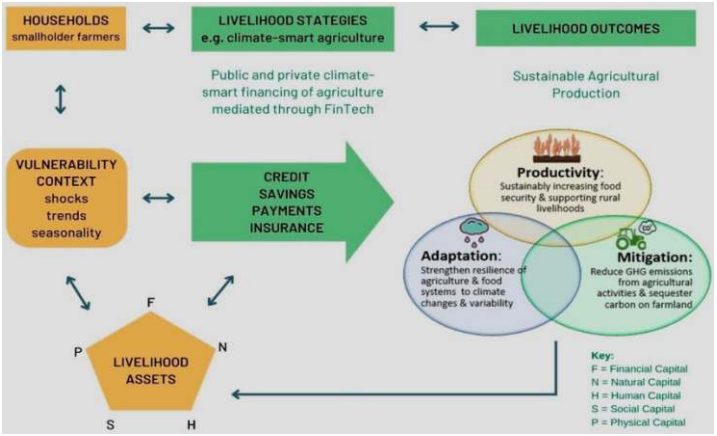


***Figure 1:*** *The conceptual framework for financing sustainable agriculture. The figure illustrates how financial mechanisms, institutional support, and policy frameworks jointly influence the financing of sustainable agriculture. It shows the linkages between funding sources, delivery channels, and agricultural practices, highlighting their combined role in promoting productivity, resilience, and environmental sustainability.*
***Source:*** *[4, 8]*

## Principles of Inclusion, Resilience, and Environmental Sustainability

Inclusion is a core principle of sustainable agricultural finance. Inclusive finance means that not only large commercial farmers but also smallholder and marginalised farmers, including women and youth, have access to financial services that meet their needs [9]. Formal financial inclusion enables smallholders to use credit for productive investment, savings for liquidity and risk buffering, and insurance to mitigate shocks. The Global Findex Database highlights persistent gaps in rural financial inclusion globally, underscoring the necessity of tailored financial approaches to reduce exclusion and broaden participation in formal financial markets [10].

Resilience is another foundational principle. Agricultural systems are inherently vulnerable to climate variability, market volatility, and production risks. Sustainable agricultural finance should therefore incorporate tools that enhance the capacity of farmers and agribusinesses to adapt and recover from shocks. For example, risk-sharing instruments such as index-based insurance, flexible microcredit arrangements, and blended financial mechanisms can enable risk-tolerant investment and

reduce vulnerability to climate-related disruptions [11, 12]. Environmental sustainability is central to aligning finance with sustainable agricultural outcomes. Sustainable finance encourages investments in practices and technologies that conserve natural resources, reduce environmental degradation, and support ecosystem health. This includes financing for climate-smart practices such as soil and water conservation, agroforestry, drought-tolerant seed varieties, and renewable energy systems on farms, all of which contribute to enhanced productivity while maintaining environmental integrity. Support for such practices aligns agricultural finance with broader climate objectives and sustainable development goals [13].

***Table 1. Core principles of sustainable agricultural finance***

| Principles | Concise Definition | Relevance to Smallholder Farmers |
|---|---|---|
| Financial Inclusion | Access to affordable and appropriate financial services (credit, savings, insurance, payments) | Enables investment in inputs, technology adoption, and market participation |
| Resilience | Capacity to absorb and recover from economic and climate shocks | Reduces vulnerability to climate variability and income instability |
| Environmental Sustainability | Alignment of finance with sustainable natural resource management | Supports long-term productivity and ecosystem protection |

*Modified from [8, 9]*

## Linkages to Climate-Smart Agriculture and Development Frameworks

Sustainable agricultural finance is conceptually linked to climate-smart agriculture (CSA), which provides a framework for addressing the interrelated challenges of food security, climate change, and sustainable development. CSA emphasizes the simultaneous pursuit of increased agricultural productivity, enhanced resilience to climate variability, and reduced greenhouse gas emissions where feasible. However, the adoption of climate-smart practices often requires upfront investment and risk tolerance that exceed the financial capacity of most smallholder farmers. Access to appropriate financial services is therefore a critical enabling factor for the implementation and scaling of CSA practices [8].

From a development policy perspective, sustainable agricultural finance supports broader frameworks such as the Sustainable Development Goals (SDGs). For instance, SDG 1 (No Poverty), SDG 2 (Zero Hunger), and SDG 13 (Climate Action) all underscore the importance of finance that enables inclusive growth, food security, and climate resilience. Climate finance initiatives, such as blended finance and targeted agricultural insurance programs supported by multilateral development institutions and the United Nations, seek to bridge the gap between high-level climate commitments and on-farm investment needs. These initiatives mobilize public and private capital in ways that align financial flows with sustainability goals and help smallholders transition toward resilient agricultural practices [12].

***Table 2. Linkages between sustainable agricultural finance and climate-smart agriculture objectives***

| CSA Objectives | Financing Requirements | Role of Sustainable Agricultural Finance |
|---|---|---|
| Productivity enhancement | Upfront investment capital | Credit and savings instruments enable input use and technology adoption |
| Climate resilience | Risk-mitigation mechanisms | Insurance and flexible finance reduce exposure to climate shocks |
| Environmental Sustainability | Long-term, patient capital | Financing supports sustainable land and resource management practices |

*Modified from [8, 9]*

## Innovative Financing Models

Innovative financing models for smallholder agriculture have evolved to address structural constraints that limit access to capital through conventional credit markets. Traditional financial instruments often fail to accommodate the seasonal nature of agricultural income, high transactional and monitoring costs, and the lack of formal collateral, particularly for smallholder farmers. As a result, alternative models that embed financial services within agricultural value chains and leverage blended finance and risk-sharing partnerships have gained prominence as mechanisms to expand access to credit, reduce risk, and align finance with broader sustainability and inclusion goals [14, 15].

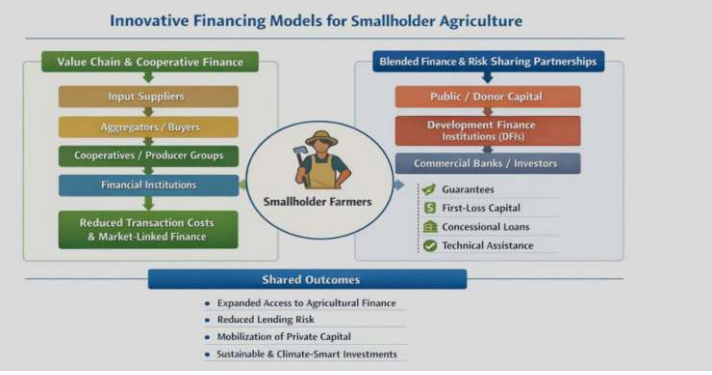


***Figure 2:*** *Innovative financing models for smallholder agriculture. The figure highlights key innovative financing models designed to improve smallholder farmers' access to credit, risk-sharing tools, and investment capital, supporting inclusive and sustainable agricultural development.*
***Sources:*** *Modified from [8, 16, 17]*

## Value Chain–Based and Cooperative Financing

Value chain–based financing integrates financial services into agricultural production and marketing relationships, leveraging cash flows and contracts that exist between value chain actors such as farmers, aggregators, processors, and buyers to reduce risk and improve credit access [15]. The core premise is that financial providers can use observable transactions and predictable timing of payments within the value chain as implicit collateral or repayment assurance, mitigating information asymmetry and reducing lenders' risk exposure. As a result, value chain finance broadens the scope of who can access finance beyond conventional bank lending, facilitating input provision, working capital, and market-linked credit that better fits agricultural cycles.

Empirical and conceptual work demonstrates that agriculture value chain finance is associated with increased access to financial services for smallholders and improved integration into higher-value markets, which can enhance productivity and rural income. Research reviewing agricultural value chain finance in Uganda found that value chain mechanisms, including outgrower schemes and supplier credit, help link smallholders to formal finance through structured contractual arrangements and relationships, reducing reliance on informal and costly sources [18]. Cooperatives and producer organisations play complementary roles within value chain models by aggregating farmers, pooling risk, and enhancing bargaining power with financial institutions. These organisational arrangements lower transaction costs and provide economies of scale, making finance easier to deliver than when farmers are addressed

individually. Through collective action, smallholders can secure better loan terms, access group-based savings facilities, and engage in negotiations with input suppliers or buyers' outcomes that contribute to broader rural development goals [19].

**Blended Finance and Risk-Sharing Partnerships**

Blended finance refers to the strategic use of public or concessional capital to mobilise additional private investment into sectors that are otherwise perceived as too risky or commercially unattractive, such as smallholder agriculture and climate-smart investments. In the context of agriculture, blending helps reduce risk for private investors and financial institutions by absorbing part of the upfront risk or by improving returns through concessional terms, guarantees, or technical assistance [20]. One prominent application of blended finance in agricultural systems is through climate-smart agrifood systems investment frameworks, which combine grant funding, concessional debt, and risk-sharing instruments to support investments that generate both financial and environmental impacts. These mechanisms help smallholders access finance for sustainable practices such as soil conservation, water efficiency, and climate adaptation technologies by lowering the cost of capital and sharing risk with public or philanthropic partners [20].

Risk-sharing partnerships are often embedded in blended finance structures to spread exposure among multiple stakeholders, including commercial banks, development agencies, and value chain actors. Such partnerships can involve partial credit guarantees, subsidised insurance schemes, or first-loss capital arrangements, all of which incentivise mainstream lenders to extend credit to smallholder farmers who would otherwise be excluded. By shifting some risk away from lenders, these partnerships broaden the availability of financial products and encourage investment in agriculture that supports inclusive and sustainable outcomes [21]. Overall, innovative financing models that link value chain structures with blended finance and risk-sharing principles have demonstrated potential in expanding financial inclusion for smallholders, integrating sustainable practices into agricultural production, and mobilising diverse sources of capital for rural development. However, the success of these models depends on supportive institutional frameworks, effective stakeholder collaboration, and continuous innovation to adapt financial products to the evolving needs of smallholder contexts.

*Table 3. Comparison of innovative financing models for smallholder farmers*

| Financing Models | Structural Basis | Risk-Reduction Mechanism | Sustainable Contribution |
|---|---|---|---|
| Value chain–based finance | Finance embedded within buyer–supplier relationships and contractual market arrangements [16] | Predictable cash flows and output-linked repayment reduce default risk [16] | Encourages productivity-enhancing investments aligned with sustainable value chains [8] |
| Cooperative financing | Collective organization of farmers to aggregate demand, supply, and credit access [17] | Risk pooling and peer monitoring lower transaction and enforcement costs [17] | Strengthens social capital and enables adoption of sustainable practices at scale [8] |
| Blended finance | Strategic use of concessional public capital to crowd in private investment [20] | First-loss capital and guarantees absorb downside risk for commercial lenders [20] | Mobilizes long-term finance for climate-smart and environmentally sustainable agriculture [20] |
| Risk-sharing partnerships | Formal collaboration between DFIs and private lenders [16] | Partial credit guarantees and portfolio risk sharing expand lending to underserved farmers [16] | Enables financing of resiliencen -building and low-carbon agricultural investments [8] |

**Financial Instruments and Digital Innovations**

Financial instruments tailored to the specific characteristics of smallholder agriculture are central to advancing sustainable agricultural finance. Conventional financial products are often poorly aligned with agricultural production cycles, irregular cash flows, and exposure to climate risk. In response, customised credit, insurance, and savings mechanisms have emerged as more appropriate tools for addressing smallholders' financing constraints while supporting productivity, resilience, and long-term sustainability [16].

**Customised Credit, Insurance, and Savings Mechanisms**

Customised credit instruments tailored to agricultural conditions, including flexible repayment schedules and input–output–linked financing, help farmers manage seasonality and improve access to productive investments. Evidence suggests that access to finance enables farmers to increase investments in inputs, leading to enhanced productivity and improved livelihoods [3]. Insurance products also play a critical role in mitigating the climate and production risks inherent in agriculture. Weather index insurance, which pays out based on objective weather indicators such as rainfall or temperature, protects farmers against adverse climatic events and can encourage investment in higher-yielding practices by reducing downside risk.

Index insurance has been identified as a promising innovation to improve risk mitigation for smallholders who are typically excluded from traditional indemnity-based insurance due to high administrative costs and lack of tailored products [4]. Savings mechanisms, especially those embedded in digital platforms, allow farmers to smooth consumption, manage shocks, and accumulate funds for future investment. Increased access to savings is associated with improvements in food security and investment capacity among smallholders, as farmers who can save are better able to finance agricultural inputs and withstand income volatility [3].

**FinTech, Digital Platforms, and Data-Driven Finance**

Digital financial services (DFS), including mobile money, digital credit, and digital savings platforms, have become transformative in expanding access to financial services among smallholder farmers. Mobile money platforms enable secure, low-cost transactions that help farmers receive payments, save funds, and access remittances without relying on traditional banks, a critical advantage in regions where rural banking infrastructure is limited. Mobile payment systems also serve as entry points for broader financial inclusion because they lay the foundation for digital credit and savings products [4]. Empirical evidence shows that digital financial innovations improve agricultural finance outcomes by reducing transaction costs, increasing transparency, and creating financial histories that can support credit decisions. For instance, digital finance improves smallholders' access to supply chain financing and enhances financial literacy, which in turn reduces risk and supports sustainable agricultural practices.

Mobile platforms have been instrumental in connecting farmers with tailored credit products. Services such as M-SHWARI and M-KOPA in East Africa illustrate how digital credit delivered through mobile networks can support smallholder investments in inputs, equipment, and renewable energy systems. Although not without limitations due to infrastructure gaps and digital literacy challenges, digital platforms continue to expand the reach of financial services to previously excluded rural populations [4]. Digital agriculture technology adoption, including mobile financial services, digital wallets, and integrated digital platforms, is growing rapidly in low- and middle-income countries and is linked with improvements in financial inclusion, access to credit, and uptake of risk management instruments [22].

**Institutional, Policy, and Market Enablers**

Expanding access to sustainable agricultural finance for smallholder farmers depends not only on innovative products but also on enabling institutional frameworks, supportive policies, and functional market systems that reduce barriers, coordinate actors, and promote capacity building. Institutional enablers include formal financial institutions, development finance actors, government agencies, and producer organisations. Policy and regulatory incentives shape the behaviour of market actors and strengthen the capacity of both providers and users of financial services [23, 24, 25].

**Role of public institutions, financial intermediaries, and NGOs**

Public institutions and governance bodies play a central role in defining rural finance policy frameworks that facilitate inclusive access to credit, savings, and risk mitigation tools. The Food and Agriculture Organization's policy gateway on rural finance emphasizes that governments must develop tailored policies and regulatory frameworks aimed at enhancing smallholder access to financial services by coordinating stakeholders, promoting innovation in financial products, and encouraging cooperation among public, private, and civil society actors [23]. Financial intermediaries such as commercial banks, microfinance institutions (MFIs), and cooperatives are critical actors in operationalizing rural finance policies.

Empirical research shows that MFIs contribute significantly to rural financial inclusion by extending microcredit, savings, and insurance services to smallholder farmers, thereby enabling investment in production inputs and reducing vulnerability to shocks [26]. Producer organizations and community-based financial groups, such as Village Savings and Loan Associations (VSLAs), complement formal financial markets by aggregating smallholder demand, reducing transaction costs, and improving financial literacy. Evidence from Zambia shows that participation in VSLAs significantly enhances women's access to financial services and contributes to the adoption of climate-smart agricultural practices linking institutional participation with sustainable outcomes [24].

**Regulatory incentives and capacity-building strategies**

Regulatory incentives can reduce barriers that financial institutions face in serving agricultural markets. Tailored regulatory measures such as credit guarantees, risk-sharing facilities, and differential capital requirements for agricultural portfolios encourage banks and MFIs to expand lending to smallholder farmers. In contexts where cooperatives are legally recognised and supported, institutions are more willing to invest in rural finance, given the reduced adverse selection and improved information flows. Such regulatory frameworks help bridge the supply-demand divide in rural credit markets by lowering perceived risk for lenders [27]. Capacity building is equally vital on both the supply and demand sides. On the supply side, strengthening financial institutions' ability to assess agricultural risk, design suitable products, and leverage digital channels can improve outreach and reduce operational costs.

On the demand side, financial literacy training enhances smallholders' ability to understand credit, savings, and insurance products and make informed decisions, which is especially critical for climate-related financing behaviour [25]. Effective market enablers also include policies that promote digital financial services (DFS) and integration of fintech innovations into rural finance ecosystems. By facilitating mobile money, digital wallets, and alternative data usage for credit assessment, regulators can reduce transaction costs and extend financial services to previously excluded smallholders. Empirical studies recommend that regulatory frameworks support both consumer protection and innovation in DFS while ensuring that digital infrastructure investments prioritise rural connectivity [25].

*Table 4. Institutional, policy, and market enablers supporting smallholder agricultural finance*

| Enabler Category | Key Actors | Primary Function | Contribution to Smallholder Finance |
|---|---|---|---|
| Public institutions | Governments, regulators | Policy formulation, guarantees, incentives | Reduce risk and encourage rural lending |
| Financial intermediaries | Banks, MFIs, cooperatives | Credit delivery, savings mobilization | Extend tailored financial services |
| NGOs and producer groups | NGOs, VSLAs, cooperatives | Aggregation, literacy, trust building | Improve inclusion and reduce information gaps |
| Regulatory incentives | Central banks, policymakers | Risk-sharing, regulatory flexibility | Increase supply of agricultural finance |
| Capacity building | Public agencies, NGOs | Training, literacy, institutional strengthening | Improve effective use and delivery of finance |

**Impacts, Constraints, and Emerging Pathways**

Understanding the impacts of financial access on smallholder farmers, including productivity, income, and resilience outcomes, is critical for assessing the value of agricultural finance interventions. At the same time, identifying key constraints to scalability and outlining future research directions can help build more effective, equitable, and sustainable financing systems for smallholder agriculture.

**Evidence on Productivity, Income, and Resilience Outcomes**

A growing body of empirical research demonstrates that improved access to financial services, particularly credit, has measurable impacts on agricultural productivity, income, and resilience outcomes among smallholder farmers. In Benin, family farms that accessed finance experienced significant productivity gains, with credit beneficiaries showing higher yields relative to farmers lacking credit access, indicating that financial support directly enables the adoption of productivity-enhancing inputs and technologies [28]. Evidence from Ghana also highlights the beneficial effects of finance on farm-level efficiency: maize farmers who used innovative financing mechanisms exhibited higher technical, allocative, and economic efficiency scores than those who did not, suggesting that access to tailored financial products can reduce production inefficiencies and support optimal resource allocation [6].

Financial inclusion also contributes to household economic resilience and broader rural welfare. For instance, access to formal credit was found to enhance smallholders' capacity to manage risks and invest in off-farm opportunities, which in turn improved their welfare outcomes and resilience to shocks [29]. Similarly, improvements in income capacity linked to financial access are associated with reduced rural poverty and more stable livelihoods, reinforcing theoretical claims that finance enables smoother consumption, investment in human capital, and adaptive responses to economic stressors. Collectively, these findings suggest that expanding access to appropriate financial services can lead to positive productivity differentials, higher incomes, and improved resilience, especially when financial products are aligned with smallholders' production cycles, risk profiles, and livelihood strategies [30].

**Scalability Challenges and Future Research Directions**

Despite demonstrated benefits, scalability remains a major challenge for many agricultural finance innovations. Limitations in infrastructure, high transaction costs, and weak institutional coordination restrict the ability of formal financial institutions to scale products for geographically dispersed and heterogeneous smallholder populations. Empirical and theoretical work highlights that constraints such as supply-side risk aversion, lack of reliable data, and insufficient digital and physical infrastructure continue to inhibit the expansion of scalable rural finance systems [31].

The complexity of smallholder contexts characterised by diverse cropping systems, market access conditions, and livelihood portfolios, also complicates the design of universally scalable financial products. Heterogeneity in credit needs, risk exposure, and production environments necessitates localised adaptation of financing models, which in turn raises costs and logistical barriers for financial service providers. Another notable barrier is the limited integration of climate risk into financial systems. Although some financial tools such as index insurance have shown promise in enhancing climate resilience, their scalability is constrained by data gaps and the need for robust weather-monitoring infrastructure, especially in regions with weak meteorological networks [31, 32].

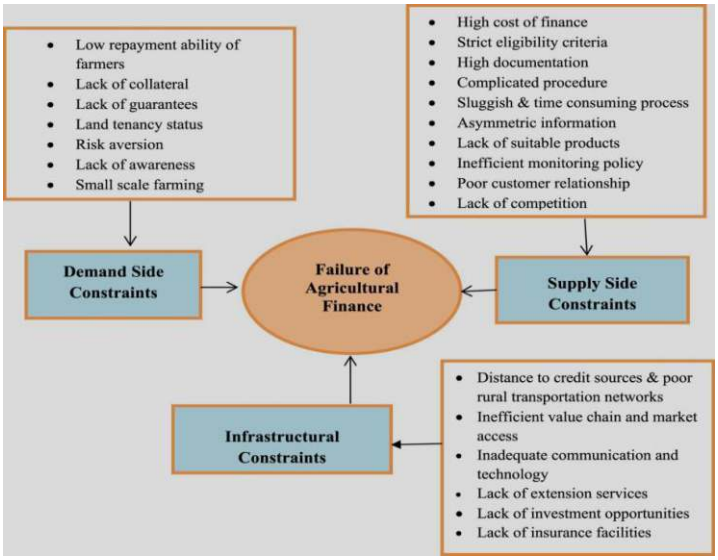


***Figure 3:*** *Agricultural finance constraints. The figure outlines the major financial constraints affecting agriculture, including limited access to credit, high risk exposure, and institutional and market barriers that restrict investment and growth.*
***Source:*** *[32]*

**Future Research Directions**

For future research, scholars emphasise the need for longitudinal impact assessments to track productivity, income, and resilience outcomes over multiple seasons, as current studies often rely on cross-sectional data that limit understanding of dynamic effects [10]. There is also a clear call for mixed-method research that combines quantitative measures with qualitative insights to better capture smallholder perceptions and adoption barriers, given persistent gaps in empirical evidence on how digital and financial services are experienced in practice [10]. Research on digital finance scalability is another priority, particularly regarding how mobile and alternative data can be operationalised responsibly to expand inclusion without reinforcing exclusion [4]. Finally, interdisciplinary studies linking agricultural finance with crop commercialisation, supply chain integration, and rural livelihoods are needed to reveal how financial services interact with broader economic and non-market factors shaping smallholder outcomes [10, 33].

**Conclusion**

This review highlights the critical role of sustainable agricultural finance in improving productivity, income stability, and resilience among smallholder farmers. Evidence indicates that customised financial instruments such as flexible credit, insurance, and savings mechanisms enable farmers to invest in improved technologies and manage production and climate-related risks more effectively. When integrated with digital and data-driven innovations, these financial solutions significantly expand financial inclusion by reducing transaction costs, enhancing risk assessment, and extending outreach to underserved rural populations.

However, the effectiveness and scalability of these innovations remain constrained by structural and institutional challenges, including weak rural infrastructure, limited financial literacy, regulatory gaps, and heterogeneous smallholder contexts. The review underscores that technological advancement alone is insufficient without supportive policies, strong institutions, and coordinated public–private partnerships. Future pathways for sustainable agricultural finance lie in developing integrated financing ecosystems that align financial innovation with institutional capacity building and inclusive policy frameworks. Further longitudinal and impact-oriented research is needed to assess long-term welfare outcomes and to guide scalable, context-sensitive solutions. Overall, advancing inclusive and resilient agricultural finance is essential for fostering sustainable smallholder livelihoods and achieving broader rural development goals.

**Acknowledgement**

We thank all the researchers who contributed to the success of this research work.

**Conflict of Interest**

The authors declared that there are no conflicts of interest.

**Funding**

No funding was received for this research work.

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