CHAPTER-17

DIGITAL FINANCE AND THE TRANSFORMATION OF AGRICULTURAL LIVELIHOODS

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Abstract

Digital finance has emerged as a transformative force in reshaping agricultural livelihoods across developing and emerging economies. The persistent exclusion of rural populations from formal financial systems has long constrained agricultural productivity, investment capacity, and economic resilience. This chapter explores how digital financial services encompassing mobile banking, fintech platforms, blockchain-based transactions, AI-driven credit scoring, and agricultural insurance technologies are dismantling structural barriers to rural financial inclusion. Drawing on theoretical frameworks including the Diffusion of Innovation Theory, Technology Acceptance Model, and the Sustainable Livelihood Framework, the chapter examines the mechanisms through which digital finance reaches smallholder farmers, women, and marginalized communities. Evidence from Sub-Saharan Africa, South Asia, and Southeast Asia demonstrates that digital financial ecosystems are improving income security, enabling investment in smart farming technologies, reducing dependence on informal moneylenders, and fostering rural entrepreneurship. The chapter further identifies persistent challenges, including infrastructure gaps, digital literacy deficits, regulatory fragmentation, and gender-based exclusion, that continue to limit the transformative potential of these innovations. Key policy implications for governments, financial regulators, telecom companies, and development organizations are discussed, with emphasis on inclusive design, interoperability, and data governance. The chapter contributes to growing scholarship on digital agriculture and the role of financial technology in achieving Sustainable Development Goals, particularly SDG 1 (No Poverty), SDG 2 (Zero Hunger), and SDG 8 (Decent Work and Economic Growth).

Keywords: Digital Finance, Agricultural Livelihoods, Financial Inclusion, Fintech, Smart Agriculture, Blockchain, Rural Development. Agritech, Digital Economy, Sustainable Agriculture

1. Introduction

1.1. Background and Context

Agriculture remains the primary livelihood for more than 2.5 billion people worldwide, the vast majority of whom reside in rural areas of Sub-Saharan Africa, South Asia, and Southeast Asia (FAO, 2023). Despite its centrality to food security and rural employment, the agricultural sector has historically been underserved by formal financial institutions. Smallholder farmers who produce approximately 70 percent of the food consumed in developing countries face chronic difficulties accessing credit, savings instruments, insurance, and payment infrastructure (IFAD,

2021). These constraints perpetuate cycles of poverty, limit investment in productivity-enhancing inputs, and expose farm households to catastrophic income shocks from climate events, price volatility, and crop failure.

The global financial system has, for much of the twentieth century, been ill-equipped to serve rural agricultural communities. Conventional banks have historically avoided rural lending due to high transaction costs, limited collateral among smallholders, poor credit information, and the perceived riskiness of agriculture as a sector (Beck et al., 2007). As a result, rural populations have long relied on informal financial arrangements moneylenders, rotating savings groups, and trader credit which often involve exploitative interest rates and inadequate risk coverage (Collins et al., 2009).

The digital revolution has fundamentally altered this landscape. The rapid proliferation of mobile phones, particularly smartphones, across the developing world has created new channels through which financial services can reach previously excluded populations. Between 2014 and 2022, the number of mobile money accounts globally grew from 299 million to over 1.6 billion (GSMA, 2023). This technological shift, coupled with regulatory reforms, expanding telecom infrastructure, and the emergence of agritech startups, has laid the groundwork for a new paradigm of rural financial inclusion.

1.2. Emergence of Digital Finance

Digital finance refers to the delivery of financial services through digital channels, including mobile phones, the internet, and electronic payment systems (World Bank, 2014). It encompasses a broad ecosystem of innovations: mobile banking platforms, digital wallets, fintech lending applications, blockchain-based payment and traceability systems, AI-driven credit scoring tools, and agricultural insurance technologies that leverage satellite data and remote sensing (Demirgüç-Kunt et al., 2018). Unlike traditional banking infrastructure, digital finance dramatically reduces the physical and economic barriers to financial service delivery, making it especially relevant in low-density rural environments where brick-and-mortar branches are economically unviable.

The development of digital finance has been catalyzed by several converging trends. First, the global spread of mobile connectivity has created a universal interface for financial transactions that bypasses the need for physical banking infrastructure (Aker & Mbiti, 2010). Second, the explosion of digital data from satellite imagery to mobile transaction histories has enabled lenders and insurers to construct risk profiles for borrowers and farmers who lack formal credit histories (Bjorkegren & Grissen, 2020). Third, policy reforms in many developing countries have created enabling regulatory environments for mobile money, agent banking, and digital credit providers.

1.3. Problem Statement

Despite significant progress, the promise of digital finance for agricultural transformation remains only partially realized. Rural financial exclusion persists in many regions: globally, approximately 1.4 billion adults remain unbanked, with the majority concentrated in rural areas of developing countries (Demirgüç-Kunt et al., 2022). Credit markets continue to be characterized by stark inequality: large commercial farms receive the bulk of formal agricultural credit, while smallholders particularly women farmers and those in remote areas are systematically excluded (Fletschner & Kenney, 2014). Agricultural insurance penetration in low-income countries remains negligible, leaving farm households exposed to catastrophic losses from weather extremes (Carter et al., 2017). Meanwhile, informal moneylenders continue to extract substantial rents from farmers with no alternative sources of finance (Guérin et al., 2014).

The digital financial ecosystem, while expanding rapidly, is not inherently inclusive. Without deliberate design for rural contexts, digital finance risks replicating or even deepening existing inequalities bypassing the most marginalized, extracting data without fair compensation, and imposing digital literacy requirements that exclude older, less educated, and poorer farmers (Gabor & Brooks, 2017).

1.4. Objectives of the Chapter

This chapter pursues four primary objectives. First, it examines the principal mechanisms through which digital finance reaches agricultural communities, with attention to mobile banking, digital credit, insurtech, and blockchain applications. Second, it analyzes the documented impacts of digital financial services on agricultural livelihoods, including income, productivity, resilience, and social equity. Third, it identifies the structural barriers technological, institutional, regulatory, and social that limit adoption and impact. Fourth, it explores the policy and governance implications of expanding digital finance in agriculture, with attention to both enabling conditions and necessary safeguards.

1.5. Significance of the Study

This chapter contributes to an emerging body of scholarship at the intersection of digital technology, financial inclusion, and rural development. The findings are relevant to a wide range of stakeholders: policymakers designing digital financial infrastructure, development organizations crafting rural finance programs, fintech firms building agricultural products, and researchers studying the political economy of digital transformation. The analysis is also situated within the global sustainable development agenda digital financial inclusion is recognized as a cross-cutting enabler for achieving the Sustainable Development Goals, particularly SDG 1 (ending poverty), SDG 2 (zero hunger), SDG 8 (decent work and economic growth), and SDG 13 (climate action) (UNCTAD, 2020).

2. Conceptual Foundations of Digital Finance in Agriculture

2.1. Understanding Digital Financial Inclusion

Financial inclusion is broadly defined as the access and use of formal financial services by individuals and businesses, particularly those historically excluded from the formal financial system (World Bank, 2014). In rural agricultural contexts, financial inclusion encompasses access to credit for input procurement and investment, savings mechanisms to manage seasonal income variability, insurance products to hedge against production and price risks, and payment systems to reduce transaction costs in input and output markets (Cull et al., 2014).

Digital financial inclusion extends this framework to encompass services delivered through digital channels (Sahay et al., 2015). It is distinguished from traditional financial inclusion efforts by its potential to dramatically lower the cost-of-service delivery, to harness data from non-traditional sources for credit assessment, and to reach geographically dispersed rural populations without proportional increases in infrastructure investment (Klapper et al., 2016). The rural digital economy, as a broader concept, encompasses the digitally enabled production, exchange, and consumption of goods and services in agricultural and rural contexts, within which digital finance plays a foundational enabling role (ITU, 2022).

2.2. Theoretical Frameworks

Several theoretical frameworks inform the analysis of digital finance adoption and impact in agricultural settings.

Diffusion of Innovation Theory, developed by Rogers (2003), provides a foundational lens for understanding how digital financial technologies spread through rural communities. The theory identifies five adopter categories innovators, early adopters, early majority, late majority, and laggards and highlights how perceived relative advantage, compatibility with existing practices, complexity, trialability, and observability shape adoption rates. In agricultural contexts, digital finance adoption has frequently followed this diffusion pattern, with younger, more educated, and better-connected farmers serving as early adopters whose experiences influence their networks (Adeola & Evans, 2017).

The Technology Acceptance Model (TAM), originally proposed by Davis (1989) and subsequently elaborated by Venkatesh and Davis (2000), posits that perceived ease of use and perceived usefulness are the primary determinants of technology adoption. Research applying TAM to mobile financial services in rural contexts has consistently found that farmers' willingness to adopt digital payment and credit platforms is strongly shaped by their perceived utility particularly for time and cost savings and by trust in the platform provider (Lwoga & Lwoga, 2017).

The Sustainable Livelihoods Framework (SLF), developed by the UK Department for International Development (Chambers & Conway, 1992; Scoones, 1998), conceptualizes rural livelihoods in terms of five capital assets: human, social, natural, physical, and financial. Digital finance operates primarily through the financial capital dimension, but its effects cascade across other capitals enabling investment in physical assets (farm equipment), building human capital through financial literacy, and strengthening social capital through digital networks and cooperative finance platforms (Bebbington, 1999).

Digital Divide Theory draws attention to the structural inequalities in access to and use of digital technologies, which can undermine the inclusivity of digital finance (Warschauer, 2003; van Dijk, 2006). The digital divide operates across multiple dimensions access to devices and connectivity, skills to use them, and the ability to derive meaningful value from digital services all of which are particularly acute in rural agricultural settings (Duncombe, 2012).

2.3 Components of Agricultural Digital Finance

Digital Payment Systems form the foundational layer of agricultural digital finance. Mobile payment platforms enable farmers to receive payments for crop sales, pay for inputs, and access government agricultural subsidies through electronic channels, reducing the transaction costs, security risks, and time demands associated with cash-based transactions (Jack & Suri, 2011). QR-code-based payment systems have further simplified point-of-sale transactions in rural markets, lowering barriers for digitally inexperienced users (Aggarwal et al., 2020).

Digital Credit Platforms represent a major innovation frontier. AI-driven lending platforms assess borrower creditworthiness using alternative data sources including mobile transaction histories, airtime top-up patterns, satellite imagery of farm plots, and supply chain transaction records enabling credit decisions for borrowers with no formal credit history (Bjorkegren & Grissen, 2020). Peer-to-peer (P2P) lending platforms connect smallholder farmers with a broader pool of capital, sometimes at lower interest rates than conventional microfinance institutions (Dorfleitner et al., 2017).

Digital Insurance is addressing one of the most intractable problems in agricultural finance: the high cost of traditional indemnity-based insurance in rural settings. Weather-indexed insurance products, which pay out based on objective meteorological triggers rather than individual loss assessment, dramatically reduce administrative costs and moral hazard (Barnett & Mahul, 2007). Satellite-based crop assessment technologies further enable rapid, scalable damage assessment (Barnett et al., 2008). Parametric insurance products triggered automatically when predefined parameters (e.g., rainfall below a threshold) are breached have been deployed in East Africa, India, and Latin America with promising results (Clarke et al., 2012).

Blockchain in Agricultural Transactions offers potential for transforming transparency and trust in agricultural supply chains. Smart contracts self-executing agreements coded onto distributed ledger platforms can automate payment upon delivery, enforce quality standards, and reduce disputes between buyers and sellers (Kshetri, 2018). Blockchain-based traceability systems enable consumers to verify the provenance of agricultural products, potentially unlocking premium markets for smallholder producers who meet certification standards (Feng et al., 2020).

2.4. Stakeholders in the Digital Finance Ecosystem

The agricultural digital finance ecosystem involves a complex web of actors whose interactions shape access, quality, and impact. Governments provide regulatory frameworks, digital infrastructure, and public digital services such as direct benefit transfers. Commercial banks partner with fintech firms and mobile network operators to extend reach. Telecom companies provide the connectivity layer essential for mobile finance (Demirgüç-Kunt et al., 2018). Fintech startups innovate at the application layer, developing user interfaces, credit algorithms, and insurance products tailored to agricultural contexts. Farmers' cooperatives and self-help groups serve as intermediaries that aggregate smallholder demand and reduce per-unit transaction costs. Agritech startups integrate digital finance with agronomic advisory, market linkage, and input supply services to create embedded financial products (FAO, 2019).

3. Digital Finance Ecosystem and Agricultural Transformation

3.1. Mobile Banking and Rural Accessibility

Mobile banking has been the most transformative digital financial innovation for rural agricultural communities in the past two decades. Kenya's M-Pesa, launched in 2007, is widely recognized as the pioneering case. By 2023, M-Pesa served over 51 million customers across seven African countries, processing transactions equivalent to more than 50 percent of Kenya's GDP (Safaricom, 2023). Seminal research by Jack and Suri (2011) demonstrated that M-Pesa adoption significantly reduced transaction costs for rural Kenyans. A subsequent longitudinal study by Suri and Jack (2016) found that access to mobile money lifted approximately 194,000 Kenyan households out of poverty, with particularly pronounced effects for female-headed households.

In India, the government's Jan Dhan Yojana financial inclusion initiative, combined with the Aadhaar biometric identification system and mobile banking infrastructure, created a digital payment architecture that reached over 500 million previously unbanked citizens by 2022 (Ministry of Finance, India, 2022). The integration of this infrastructure with agricultural subsidy payments through direct benefit transfers to farmer accounts has reduced leakage, lowered administrative costs, and improved the timeliness of government support (Muralidharan et al., 2016). QR-based payment systems, promoted by the Unified Payments Interface (UPI) platform,

have further expanded digital payment adoption in rural Indian markets (Reserve Bank of India, 2023).

The expansion of mobile banking in rural areas is fundamentally dependent on telecom infrastructure. As of 2022, approximately 3.5 billion people globally lacked access to mobile internet, with the majority in rural areas of Sub-Saharan Africa and South Asia (GSMA, 2023). Closing this connectivity gap is a prerequisite for broadening the reach of mobile financial services, underscoring the critical importance of public and private investment in rural broadband and mobile network expansion.

3.2. Fintech Innovations in Agriculture

Fintech companies have introduced a range of innovations tailored to the specific financial needs and constraints of agricultural producers. Digital lending platforms such as Tala, Branch, and FarmDrive have developed proprietary credit scoring algorithms that assess smallholder creditworthiness using alternative data, enabling credit decisions in minutes rather than weeks (Ziegler et al., 2018). Embedded finance the integration of financial products directly into agricultural value chain platforms has emerged as a particularly promising model, providing credit, insurance, and payment services within the digital platforms that farmers already use for market access and agronomic advice (Mhlanga, 2021).

Crowdfunding models, including agricultural investment platforms that connect urban investors with rural producers, have mobilized new flows of capital to the agricultural sector. In sub-Saharan Africa, platforms such as Farmcrowdy and Thrive Agric have facilitated investments in smallholder farms, providing working capital for input procurement while generating returns for retail investors (Moritz & Block, 2016). These models face challenges of scale, investor trust, and default risk management, but represent an innovative channel for agricultural finance in contexts where traditional credit is scarce.

3.3. Artificial Intelligence in Agricultural Finance

Artificial intelligence is reshaping the economics of agricultural credit by dramatically reducing the cost of creditworthiness assessment. Traditional agricultural lending requires costly loan officers, physical collateral assessment, and extensive documentation a model that is economically unviable for small-value agricultural loans. AI-based credit models leverage machine learning algorithms trained on large datasets of mobile transaction histories, social network data, satellite imagery, and agricultural input purchase records to generate credit scores for farmers with no formal financial history (Bjorkegren & Grissen, 2020).

Beyond credit scoring, AI is being applied to risk profiling for agricultural insurance. Machine learning models trained on historical weather, soil, and yield data can generate spatially granular risk estimates that enable insurers to price products more accurately and extend coverage to previously uninsurable smallholder farmers (Barnett et al., 2008). Predictive financial analytics drawing on satellite-derived crop condition indices, commodity price forecasts, and climate models are also being integrated into farm management platforms to help farmers make better-informed input investment and marketing decisions (Liakos et al., 2018).

3.4. Blockchain and Smart Contracts

Blockchain technology offers transformative potential for agricultural supply chain finance, transparency, and trust. In agricultural commodity trade which involves complex chains of intermediaries between producer and consumer opacity and information asymmetries are

persistent sources of market inefficiency and exploitation. Blockchain-based traceability systems, which record transactions and physical attributes at each node in the supply chain on an immutable distributed ledger, enable buyers, regulators, and consumers to verify product provenance, quality certification, and sustainability credentials (Kshetri, 2018).

Smart contracts automated, self-executing agreements coded on blockchain platforms have been piloted in several agricultural finance applications. In Kenya, the AgriFin platform has experimented with smart contracts that automatically release payment to farmers upon third-party verification of delivery and quality, reducing payment delays that are a chronic source of cash flow problems for smallholders (Feng et al., 2020). Supply chain finance facilitated through blockchain platforms can provide input suppliers with receivables financing based on verified purchase orders, enabling them to extend input credit to smallholder farmers at lower cost (Cole et al., 2017).

Despite this promise, blockchain adoption in agricultural finance faces significant practical constraints, including the cost of hardware for digital verification at farm level, the complexity of governance in decentralized networks, and the risk of "garbage in, garbage out" if data inputs at farm level remain unreliable (Kshetri, 2018).

3.5. Digital Insurance and Risk Mitigation

Agricultural risk management is one of the most critical and underserved dimensions of rural financial inclusion. Smallholder farmers face multiple, often correlated risks drought, flood, pest infestation, price collapse that can destroy an entire season's income in a matter of days. Conventional crop insurance requires individual loss assessment, which is prohibitively expensive at small scale, and is subject to moral hazard and adverse selection problems that make products expensive and unsustainable (Carter et al., 2017).

Index-based agricultural insurance (IBAI) products, which pay indemnities based on objective climate indices rather than individual farm assessments, have emerged as a scalable alternative. Weather-indexed insurance products tied to rainfall, temperature, or crop-specific indices have been piloted across East Africa, South Asia, and Latin America (Clarke et al., 2012). Satellite-based crop assessment using normalized difference vegetation index (NDVI) data from Earth observation satellites enables rapid, low-cost assessment of agricultural losses at regional scale, further reducing the administrative costs of insurance delivery (Barnett et al., 2008). Parametric insurance products, which trigger automatic payouts when predefined parameters are breached, have been integrated with mobile money platforms to deliver rapid cash transfers to affected farmers (Karlan et al., 2014).

Research on the welfare effects of agricultural insurance in low-income contexts is broadly positive but nuanced. A randomized controlled trial by Karlan et al. (2014) in northern Ghana found that index insurance increased farmers' willingness to invest in productive inputs and led to higher agricultural output among insured households. However, basis risk the mismatch between payouts and actual farm-level losses remains a significant constraint on both willingness to pay and product viability (Clarke, 2016).

3.6. E-commerce and Market Integration

Digital finance is closely intertwined with the emergence of agricultural e-commerce platforms that are connecting smallholder farmers directly with buyers, reducing dependence on intermediaries, and improving price discovery. Platforms such as Twiga Foods in Kenya, Ninjacart

in India, and Sourcemap globally integrate digital payment infrastructure with logistics and market linkage services, enabling farmers to sell directly to urban retailers, processors, and exporters.

The integration of digital payment with e-commerce platforms reduces the cash handling risks associated with agricultural sales, creates verifiable transaction records that support credit applications, and enables more flexible and timely payment terms. In China, the rapid growth of agricultural e-commerce platforms facilitated by Alibaba's Taobao Rural program has been associated with significant increases in rural household income and reduced price-to-producer gaps (Qin et al., 2023). The direct farmer-to-consumer model, while still nascent in most developing country contexts, represents a potentially transformative pathway for premium market access by smallholder producers who can demonstrate quality and traceability.

4. Impact of Digital Finance on Agricultural Livelihoods

4.1. Income Enhancement and Economic Security

The most direct and widely documented impact of digital financial inclusion on agricultural livelihoods is through improved access to capital and its effects on farm income. Access to timely credit enables smallholder farmers to purchase improved seed varieties, fertilizers, and pesticides at the beginning of the season rather than being forced to rely on suboptimal, less productive inputs due to cash constraints (Karlan et al., 2016). A systematic review by Hermes and Lensink (2011) of microfinance impact studies found consistent, if modest, positive effects of credit access on farm household income across diverse contexts. More recent evidence from digital lending platforms suggests stronger effects: a study by Bharadwaj et al. (2019) found that access to mobile credit in Kenya significantly increased household consumption among borrowers.

Beyond credit, digital payment systems contribute to income security by reducing transaction costs, facilitating timely payment for crop sales, and enabling more effective income management. Research by Suri and Jack (2016) demonstrated that access to M-Pesa mobile money enabled Kenyan households to better manage income shocks, smooth consumption over time, and invest in more productive livelihood activities. The ability to receive and send money cheaply and rapidly even across long distances is particularly significant for agricultural households that are deeply integrated into networks of family support, seasonal migration, and cooperative labour.

4.2. Financial Inclusion and Social Equity

Digital finance has shown significant potential to improve financial inclusion for groups that have historically faced the greatest barriers to formal financial services, particularly women, youth, and ethnically or socially marginalized communities. Women in rural agricultural settings face compounded disadvantages in accessing formal finance: they are less likely to hold formal identification, less likely to own land that can serve as collateral, more likely to be engaged in informal economic activities, and subject to social norms that restrict their financial autonomy (Fletschner & Kenney, 2014).

Mobile money platforms have demonstrated notable success in reaching women in contexts where social and geographic factors limit their access to bank branches. Research by Dupas and Robinson (2013) in rural Kenya found that women who were provided with access to formal savings accounts including mobile savings increased their productive investment and resilience to health and economic shocks. In Bangladesh, the bKash mobile money platform has significantly expanded women's access to financial services, with evidence of positive effects on women's economic empowerment and household bargaining (Fahim et al., 2021).

Youth represent another critical constituency for agricultural digital finance. Young people in rural areas are often more digitally literate and more willing to adopt digital financial services than older farmers, and their inclusion in agricultural finance ecosystems is essential for the long-term viability of smallholder agriculture (IFAD, 2021). Digital platforms that combine financial services with agronomic advisory, market linkage, and peer learning networks are particularly well-positioned to engage rural youth in agricultural value chains (FAO, 2019).

4.3. Productivity and Technological Adoption

Digital finance enables productivity-enhancing technological adoption by removing the capital constraints that prevent smallholder farmers from investing in improved inputs, mechanization, and precision agriculture technologies. In contexts where credit is unavailable or prohibitively expensive, farmers are often locked into low-input, low-productivity farming systems that perpetuate poverty and food insecurity (Barrett et al., 2019). Digital credit platforms that can deliver small, short-term loans rapidly aligned with planting season timing are particularly well-suited to supporting agricultural input adoption (Karlan et al., 2016).

The financing of agricultural mechanization through digital credit is an increasingly important application. In Sub-Saharan Africa, where agricultural mechanization rates remain among the lowest in the world, digital lending platforms have begun offering equipment financing for tractors, irrigation pumps, and post-harvest processing equipment (Baudron et al., 2019). In India, fintech-enabled financing of drip irrigation systems has been credited with expanding adoption of water-efficient irrigation technologies among smallholder farmers in water-stressed regions. Smart farming technologies including precision soil monitoring, drone-based crop assessment, and AI-driven farm management platforms require capital investment that is beyond the reach of most smallholders without credit access (Liakos et al., 2018).

4.4. Rural Entrepreneurship Development

Digital finance is catalyzing a new wave of rural entrepreneurship in agricultural value chains. By lowering the barriers to capital access, market connectivity, and transaction efficiency, digital financial ecosystems are enabling the emergence of agritech startups, digital agribusinesses, and smallholder-led value-added enterprises (Mhlanga, 2021). In East Africa, mobile-enabled agricultural entrepreneurs are building businesses around farm input supply, agronomy services, produce aggregation, and digital market facilitation creating employment and generating value within rural economies.

The innovation ecosystem around agricultural digital finance is reinforced by the emergence of dedicated agritech accelerators, agricultural venture capital funds, and public-private partnerships that provide startups with funding, mentorship, and market access. Organizations such as the Mastercard Foundation's Agricultural Finance program and the Consultative Group to Assist the Poor (CGAP) have supported the development of digital agriculture ecosystems in multiple African and Asian countries (CGAP, 2020). These innovation ecosystems are not uniformly distributed, however: they tend to be concentrated in urban centers and to focus on commercially viable market segments, potentially bypassing the most marginalized and remote agricultural communities.

4.5. Employment Generation and Skill Development

The expansion of digital financial services in rural agricultural economies generates both direct and indirect employment effects. Direct employment is created in the mobile money agent

networks, digital platform operations, and agritech firms that deliver digital financial services. In Kenya, M-Pesa's agent network comprises over 600,000 active agents, many of whom are based in rural areas and earn significant income from transaction commissions (Safaricom, 2023). These agent networks also serve as trusted intermediaries that bridge the gap between digital platforms and less digitally literate users, particularly in the early stages of technology adoption.

Indirect employment effects arise from the productivity and investment effects of improved financial inclusion. Research by Dupas and Robinson (2013) and Suri and Jack (2016) documents significant increases in business investment, income diversification, and livelihood resilience associated with improved financial access, all of which contribute to rural employment generation. Financial literacy programs often delivered digitally through the same mobile platforms that provide financial services play an important role in building rural communities' capacity to use digital finance effectively and to avoid the risks of over-indebtedness and digital fraud (Hastings et al., 2013).

4.6. Climate Resilience and Sustainability

Digital finance is increasingly recognized as a critical enabler of climate resilience in agriculture. Parametric weather insurance products, digital savings mechanisms for building precautionary reserves, and digital credit for rapid recovery after climate shocks are all components of a digital climate finance architecture for smallholder farmers (Carter et al., 2017). In addition, digital financial platforms are beginning to facilitate access to climate-smart investment finance supporting adoption of drought-tolerant seed varieties, water conservation technologies, and agroforestry practices that simultaneously enhance productivity and reduce emissions (Barnett et al., 2008).

The emerging carbon credit economy represents a novel financial opportunity for smallholder farmers who adopt verified sustainable practices. Digital measurement, reporting, and verification (MRV) systems enabled by satellite monitoring, blockchain-based record-keeping, and mobile data collection are reducing the cost of smallholder participation in voluntary carbon markets. Projects such as the Gold Standard's agri-carbon programs and the Verra Verified Carbon Standard have developed methodologies for quantifying and certifying carbon sequestration by smallholder farmers, with payments facilitated through mobile money platforms (Shen et al., 2023). The scaling of these mechanisms holds significant potential for generating additional income streams for climate-smart smallholder farmers while contributing to global decarbonization goals.

5. Challenges and Structural Constraints

5.1. Digital Divide and Infrastructure Gaps

Despite the rapid proliferation of digital financial services, persistent infrastructure deficits continue to exclude large segments of the rural agricultural population from accessing these innovations. Internet connectivity remains deeply unequal: as of 2022, rural areas in Sub-Saharan Africa and South Asia had mobile internet penetration rates less than half those of their urban counterparts, with hundreds of millions of smallholder farmers effectively locked out of digital financial ecosystems due to absent or unreliable connectivity (Alliance for Affordable Internet, 2022). The problem is compounded by the unreliability of mobile network coverage in remote agricultural areas, where the commercial economics of network deployment are least attractive to private telecom operators.

Electricity shortages represent a parallel constraint. In Sub-Saharan Africa, electrification rates in rural areas remain below 30 percent in many countries, limiting farmers' ability to charge mobile devices and sustaining the reliance on cash-based transactions even among populations that have nominal mobile phone ownership (IEA, 2022). Device affordability further narrows the user base for digital finance: although smartphone penetration has grown rapidly, a significant proportion of rural agricultural populations in low-income countries still rely on basic feature phones with limited functionality for digital financial applications (GSMA, 2023). These overlapping infrastructure deficits constitute what Duncombe (2012) terms the "infrastructure layer" of the digital divide a foundational constraint that no amount of product innovation can overcome without parallel public investment in connectivity, electricity, and affordable devices.

5.2. Financial Literacy Challenges

Even where digital financial services are technically accessible, their effective use is constrained by low levels of digital and financial literacy among rural agricultural populations. Studies across Sub-Saharan Africa and South Asia consistently find that many smallholder farmers lack the basic numeracy, literacy, and digital skills needed to navigate mobile financial interfaces, understand loan terms, or assess insurance products (Klapper et al., 2016). This creates systematic barriers not only to adoption but also to informed use exposing fewer literate farmers to risks of over-indebtedness, fraud, and product misuse.

Cybersecurity concerns represent a growing and underappreciated challenge. As digital financial platforms expand into rural areas, so does the incidence of digital fraud, SIM-swap scams, phishing attacks, and predatory lending by unlicensed digital credit providers. For first-time digital financial service users with limited experience navigating digital environments, the risk of financial loss through fraud can be significant and can permanently undermine trust in digital platforms. A trust deficit rooted in unfamiliarity with digital institutions, previous negative experiences with formal financial systems, and cultural norms that favor face-to-face transactions remains a durable barrier to digital financial adoption in many rural contexts (Suri & Jack, 2016).

5.3. Regulatory and Governance Issues

The regulatory landscape for digital finance in developing countries remains fragmented, inconsistent, and in many cases ill-equipped to manage the risks that accompany rapid fintech expansion. Data privacy regulation is a particular concern: digital financial platforms accumulate vast quantities of personal financial, behavioral, and agronomic data from rural users, often without adequate disclosure of how this data is stored, shared, or used for commercial purposes (Gabor & Brooks, 2017). In the absence of robust data protection frameworks, rural users face the risk of unauthorized data monetization, discriminatory algorithmic decision-making, and surveillance by both private platforms and state actors.

Cyber fraud facilitated through digital financial channels is escalating rapidly in many developing country contexts, with limited regulatory capacity for investigation, prosecution, and consumer redress. The proliferation of unlicensed digital lenders particularly in East Africa and South Asia has exposed millions of low-income borrowers to exploitative interest rates, aggressive debt collection, and illegal data access. Weak fintech regulation, regulatory arbitrage by platform providers, and limited supervisory capacity in rural areas combine to create an environment in which the most financially vulnerable users bear a disproportionate share of the risks of digital finance expansion.

5.4. Gender and Social Barriers

Gender inequality constitutes one of the most persistent and structurally entrenched barriers to digital financial inclusion in agricultural settings. Women farmers are less likely to own mobile phones, less likely to have formal identification required for account registration, less likely to have the literacy and numeracy skills needed to use digital platforms, and more likely to face household-level restrictions on their financial autonomy (Fletschner & Kenney, 2014). Research by Demirgüç-Kunt et al. (2022) finds that the gender gap in financial account ownership while narrowing overall persists at 6 percentage points globally and is substantially wider in rural agricultural contexts.

Socio-cultural constraints further compound these material barriers. In many agricultural communities, social norms restrict women's public engagement with financial institutions, limit their ownership of mobile devices, and channel household financial decision-making through male heads of household reducing women's effective control over digital financial services even when they have nominal access (Jayachandran, 2021). Caste, ethnicity, and social marginalization similarly shape differential access to digital finance in contexts where social hierarchies mediate access to technology, markets, and institutional services (Guérin et al., 2014).

5.5. Technological and Institutional Limitations

A significant structural constraint on the development of effective agricultural digital finance ecosystems is the lack of interoperability between different digital platforms, payment systems, and data infrastructures. When mobile money systems operated by different telecom providers cannot transact with each other, or when digital lending platforms cannot access government agricultural databases, the fragmentation of the ecosystem increases costs for users and limits the potential for integrated financial services (Sahay et al., 2015). The development of interoperable payment systems such as India's Unified Payments Interface (UPI) demonstrates the potential of interoperability to accelerate adoption and competition, but similar achievements remain elusive in most developing country contexts.

Weak institutional coordination between governments, financial regulators, telecom operators, agricultural ministries, and development organizations further hampers the coherent development of agricultural digital finance infrastructure. The absence of shared data standards, unified digital identification systems, and coordinated rural digitalization strategies results in duplicated investments, incompatible systems, and missed opportunities for synergy (ITU, 2022).

6. Case Studies and Global Experiences

6.1. India

India represents one of the most instructive cases of state-led digital financial inclusion in agriculture. The foundational architecture of India's digital finance revolution the Jan Dhan–Aadhaar–Mobile (JAM) Trinity integrates universal bank account access through the Pradhan Mantri Jan Dhan Yojana scheme, biometric digital identification through the Aadhaar system, and mobile connectivity to create a platform for scalable, low-cost financial service delivery to rural populations (Muralidharan et al., 2016). By 2023, over 500 million Jan Dhan accounts had been opened, with approximately 56 percent held by women and a majority in rural areas (Ministry of Finance, India, 2022).

The Unified Payments Interface (UPI), developed by the National Payments Corporation of India, has become the world's largest real-time digital payments platform, processing over 11 billion

transactions per month by 2024 (Reserve Bank of India, 2023). Its integration with agricultural value chains enabling digital procurement payments to farmers, digital disbursement of government subsidies, and instant settlement in commodity markets has significantly reduced payment delays and leakage in India's agricultural support systems. The agritech startup ecosystem built on top of this digital infrastructure has generated hundreds of companies offering digital credit, insurance, market linkage, and agronomic services to smallholder farmers, attracting over USD 1 billion in venture capital investment between 2020 and 2023.

6.2. Kenya

Kenya's mobile money ecosystem, anchored by Safaricom's M-Pesa platform, represents the most studied and replicated digital financial inclusion model globally. Since its launch in 2007, M-Pesa has grown to serve over 51 million customers across seven African countries, fundamentally transforming the financial landscape for rural smallholder farmers (Safaricom, 2023). The landmark research by Suri and Jack (2016) documented M-Pesa's long-run effects on household welfare, finding that sustained access to mobile money increased per capita consumption and reduced the probability of extreme poverty with effects concentrated among female-headed households and those in agricultural occupations.

Building on the mobile money infrastructure, Kenya has developed a growing ecosystem of digital financial services specifically targeting smallholder farmers. Digital lending platforms such as M-Shwari, Fuliza, and FarmDrive have extended short-term agricultural credit to millions of previously unbanked farmers using mobile transaction data for credit scoring (Ziegler et al., 2018). The integration of digital insurance products including weather-indexed crop insurance distributed through mobile money channels has further expanded the risk management options available to Kenyan smallholders, particularly in the maize and tea sectors (Karlan et al., 2014).

6.3 China

China's experience with agricultural digital finance and rural e-commerce integration offers lessons at a scale unmatched elsewhere. The Alibaba Group's Taobao Rural program which established e-commerce service stations in over 100,000 villages enabled smallholder farmers to access digital markets, digital payments, and embedded financial services through a single platform (Qin et al., 2023). The integration of Ant Group's Alipay payment and credit infrastructure with agricultural e-commerce platforms created a virtuous ecosystem in which transaction data generated through online sales directly informed credit assessments for input financing. Research by Huang et al. (2022) found significant positive effects of agricultural e-commerce access on rural household income, with the greatest gains accruing to farmers in regions with better logistics connectivity.

China's rural digital revitalization policy framework which mandated investment in rural broadband, digital skills training, and e-commerce infrastructure provided the public investment backbone that enabled private sector digital finance innovation to reach scale (OECD, 2023). The scale of China's digital agriculture transformation reflects not only the strength of its technology sector but also the decisive role of state coordination and investment in creating the enabling environment for rural digital finance ecosystems.

6.4. Lessons from Comparative Analysis

Several cross-cutting lessons emerge from the experiences of India, Kenya, China, and other countries that have made significant progress in agricultural digital finance. First, scalability

requires a foundational layer of interoperable digital public infrastructure including digital identity, digital payments, and connectivity that private sector actors can build upon rather than recreate individually (Muralidharan et al., 2016). Second, institutional support from governments through regulatory enabling environments, public investment in infrastructure, and integration of digital finance with agricultural support programs is essential for achieving meaningful scale and inclusion (ITU, 2022). Third, public-private partnerships that align the commercial interests of fintech firms with the development objectives of governments and civil society organizations have consistently proved more effective than purely market-driven or purely public approaches (CGAP, 2020). Fourth, context specificity matters: the M-Pesa model is not mechanically transplantable to other environments, and successful digital finance ecosystems must be adapted to local regulatory conditions, social norms, and agricultural value chain structures (Aker & Mbiti, 2010).

7. Policy Framework and Future Directions

7.1. Strengthening Rural Digital Infrastructure

Expanding digital financial inclusion in agriculture requires sustained public investment in the foundational infrastructure layer. Governments and international development organizations must prioritize broadband expansion to rural and remote areas, including through regulatory reforms that incentivize private telecom investment and public funding for last-mile connectivity in commercially unviable areas (Alliance for Affordable Internet, 2022). Rural electrification through grid extension, solar microgrids, and off-grid renewable energy solutions is an equally critical prerequisite for digital finance adoption (IEA, 2022). Policies that reduce the cost of entry-level smartphones and basic data packages through taxation reform, device financing schemes, and competitive spectrum allocation are needed to address the device affordability barrier that excludes the poorest rural populations.

7.2. Building Financial Literacy

Policy investment in financial literacy and digital skills training for rural agricultural populations is essential for realizing the inclusive potential of digital finance. Training programs delivered through agricultural extension systems, farmer cooperatives, women's self-help groups, and community radio networks have demonstrated effectiveness in improving understanding of digital financial products, cybersecurity hygiene, and loan management (Hastings et al., 2013). Farmer awareness initiatives particularly those targeting women, youth, and first-generation digital users should be co-designed with community organizations to ensure cultural appropriateness and local language accessibility. The integration of financial literacy content into digital agricultural advisory platforms offers a cost-effective channel for reaching digitally connected farmers at scale.

7.3. Enhancing Regulatory Frameworks

Robust and adaptive regulatory frameworks are needed to protect rural users, foster innovation, and ensure the integrity of digital financial systems. Cybersecurity policies must establish minimum standards for data protection, fraud prevention, and incident response for all digital financial service providers operating in agricultural contexts, with particular attention to the protection of low-literacy and first-time users. Data governance systems including clear rules on data ownership, portability, and the terms under which agricultural data can be used for commercial purposes are needed to ensure that the value generated by rural users' data is equitably shared. Regulatory sandboxes and tiered licensing frameworks can enable responsible fintech innovation while maintaining consumer protection standards (Sahay et al., 2015).

7.4. Encouraging Innovation Ecosystems

Governments and development organizations should actively invest in agritech innovation ecosystems that support the development of digital financial products adapted to smallholder agricultural contexts. Agritech incubators and accelerators co-located with agricultural universities, research institutes, and farmer organization networks can provide early-stage startups with the technical, financial, and market access support needed to develop and scale inclusive products. Public-private partnerships that leverage the commercial capabilities of fintech firms, the distribution networks of telecom operators, the trust relationships of farmer cooperatives, and the enabling power of government programs offer the most promising pathway to achieving scale and inclusion simultaneously (CGAP, 2020). Blended finance instruments combining concessional public or donor capital with private investment can de-risk investment in underserved rural markets and catalyze the development of commercially sustainable digital finance models for smallholder agriculture.

7.5. Future Trends

The future of digital finance in agriculture is likely to be shaped by several converging technological and institutional trends. AI-integrated rural banking leveraging increasingly sophisticated machine learning models trained on satellite, climate, and agricultural data will continue to expand the frontier of credit and insurance provision for previously unserviceable farm populations, while raising new questions about algorithmic accountability and bias (Mhlanga, 2021). Central bank digital currencies (CBDCs), currently under development or pilot in over 130 countries, hold significant potential for transforming agricultural payment systems by enabling instant, low-cost settlement and programmable payments tied to agricultural support programs (BIS, 2023). Decentralized agricultural finance built on blockchain infrastructure and governed through decentralized autonomous organizations (DAOs) represents an emerging frontier that could enable new forms of cooperative finance, collective risk pooling, and peer-to-peer credit among farming communities, though its practical implementation at scale in low-income agricultural contexts remains nascent (Kshetri, 2018). Together, these trends point toward an agricultural financial ecosystem of significantly greater reach, sophistication, and adaptability provided that the foundational challenges of infrastructure, literacy, and regulation are addressed.

8. Conclusion

Digital finance stands at the frontier of agricultural transformation, offering unprecedented tools to address the deep-rooted financial exclusion that has constrained rural livelihoods across the developing world for generations. This chapter has traced the mechanisms through which mobile banking, fintech credit, digital insurance, blockchain traceability, and AI-driven analytics are reshaping access to financial services for smallholder farmers, with documented impacts on income, productivity, resilience, and social equity. Comparative evidence from India, Kenya, China, and beyond demonstrates that where enabling infrastructure, supportive regulation, and institutional coordination are in place, digital finance can generate transformative gains for rural agricultural communities. Yet structural barriers the digital divide, financial illiteracy, regulatory fragmentation, gender inequality, and interoperability failures continue to limit the reach and equity of these innovations. Realizing the full transformative potential of digital finance in

agriculture demands deliberate policy commitment to inclusive design, public investment in digital public goods, robust consumer protection frameworks, and governance structures that ensure the benefits of digital transformation are shared equitably across all segments of the rural population. Without such commitment, the digital finance revolution risks deepening existing inequalities rather than dismantling them.

References

Adeola, O., & Evans, O. (2017). Financial inclusion, financial development, and economic diversification in Nigeria. Journal of Developing Areas, 51(3), 1–15.https://d1wqtxts1xzle7.cloudfront.net/56428569/financial_inclusion_diversification-libre.pdf?1524764083=&response-content-disposition=inline%3B+filename=FINANCIAL_INCLUSION_FINANCIAL_DEVELOPMEN.pdf&Expires=1780945584&Signature=WPMztPnunGxbdbflOnIU4N9oDSEkeHpov83sYJvJOgUJtNbDLl~GxQXNy0ljMD8tnlvYpPQXrWGjqjVGGtbPOs4Qh7SpC8FPTuxR3BPFEBG8nqE3g0bM6tXoc2fGZ4dQ83cCjx2jl1pk5exMNhivakv-H00RMRbe5o0V8RKgme4Lyl2LlGfbLAYVJ7c7WmKMjKTQye~4OQAZUsAlkLPM-DzzkZpp6i7MjQ9ddJ8iyXdPqSePbsZAhhdKLM9h5yYcJGovS11Ue31WSTIa4QcvUuC78wJFQANZHk7bdm9QcS9gI2g2it-LJg6ccfhbRR2EcIWS7SAKwzccB209Ntxh6Q__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA

Aggarwal, S., Brailovskaya, V., & Robinson, J. (2020). Cashing in (and out): Experimental evidence on the effects of mobile money in Malawi. AEA Papers and Proceedings, 110, 599–604.https://www.aeaweb.org/content/file?id=12225

Fahim, S. M., Hossain, M. S., Sen, S., Das, S., Hosssain, M., Ahmed, T., Rahman, S. M. M., Rahman, M. K., & Alam, S. (2021). Nutrition and food security in Bangladesh: Achievements, challenges, and impact of the COVID-19 pandemic. Journal of Infectious Diseases, 224(Supplement_7), S901–S909. https://doi.org/10.1093/infdis/jiab473

Aker, J. C., & Mbiti, I. M. (2010). Mobile phones and economic development in Africa. Journal of Economic Perspectives, 24(3), 207–232. http://dx.doi.org/10.1257/jep.24.3.207

Barnett, B. J., & Mahul, O. (2007). Weather index insurance for agriculture and rural areas in lower-income countries. American Journal of Agricultural Economics, 89(5), 1241–1247.https://d1wqtxts1xzle7.cloudfront.net/42901862/Weather_Index_Insurance_for_Agriculture_20160221-2066-zl7os8-libre.pdf?1456068585=&response-content-disposition=inline%3B+filename=Weather_Index_Insurance_for_Agriculture.pdf&Expires=1780945702&Signature=NIF0qc3An34cOLSKWy5ZhrNNg09QIfP~GL4dBUUwXWGBPNBP0GSrZZsLm077TKGHhJ6Et4aSCIJ3QSKKUk~gvG1oaMapg-4Al9tLvC4v6oES748dobLmEIxdNkS43Fi3FM2pWvmWT7UcR5LX0Re2QbQAVVu7TLC9uiISCPkbDH5l7RvZZ2pnTSqjP6X99rtLZBARFbwn73J2PH2EtrOex0hqA3ykdDYcLZul1VvdRWbj5l~x7Z8ZiLoo7smbtiXthJht1fyUxlhJwDuP7U5HyLZGK6Axd~C6wdOdQXDnEcQL-v7eAbg84NO~DlKHKh1GuDWQUFSTzfhJD9CsoonxYw__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA

Barnett, B. J., Barrett, C. B., & Skees, J. R. (2008). Poverty traps and index-based risk transfer products. World Development, 36(10), 1766–1785.https://doi.org/10.1016/j.worlddev.2007.10.016.

Barrett, C. B., Carter, M., & Chavas, J.-P. (2019). The economics of poverty traps. University of Chicago Press.https://www.nber.org/system/files/chapters/c13828/revisions/c13828.rev2.pdf

Baudron, F., Misiko, M., Getnet, B., et al. (2019). A farm-level assessment of labor and mechanization in Eastern and Southern Africa. Agronomy for Sustainable Development, 39, 17. https://doi.org/10.1007/s13593-019-0563-5

Bebbington, A. (1999). Capitals and capabilities: A framework for analyzing peasant viability, rural livelihoods and poverty. World Development, 27, 2021–2044. https://doi.org/10.1016/S0305-750X(99)00104-7

Beck, T., Demirgüç-Kunt, A., & Levine, R. (2007). Finance, inequality and the poor. Journal of Economic Growth, 12, 27–49. https://doi.org/10.1007/s10887-007-9010-6

Bharadwaj, P., Jack, W., & Suri, T. (2019). Fintech and household resilience to shocks: Evidence from digital loans in Kenya (NBER Working Paper No. 25604). National Bureau of Economic Research.https://www.nber.org/system/files/working_papers/w25604/w25604.pdf

Björkegren, D., & Grissen, D. (2020). Behavior revealed in mobile phone usage predicts credit repayment. World Bank Economic Review, 34(3), 618–634.https://www.nber.org/system/files/working_papers/w25604/w25604.pdf

Carter, M., de Janvry, A., Sadoulet, E., & Sarris, A. (2017). Index insurance for developing country agriculture: A reassessment. Annual Review of Resource Economics, 9(1), 421–438.https://doi.org/10.1146/annurev-resource-100516-053352

CGAP (Consultative Group to Assist the Poor). (2020). Digital financial services and agriculture: Understanding the interplay. CGAP.https://www.cgap.org/

Chambers, R., & Conway, G. (1992). Sustainable rural livelihoods: Practical concepts for the 21st century (IDS Discussion Paper 296). IDS, Brighton.https://opendocs.ids.ac.uk/articles/report/Sustainable_rural_livelihoods_practical_concepts_for_the_21st_century/26473510/1/files/48232906.pdf

Clarke, D. J. (2016). A theory of rational demand for index insurance. American Economic Journal: Microeconomics, 8(1), 283–306.https://ora.ox.ac.uk/objects/uuid:3675339c-ff45-49df-8c4f-5b7df6f277d6/download_file?safe_filename=paper572.pdf&type_of_work=Working+paper

Clarke, D. J., Mahul, O., Rao, K. N., & Verma, N. (2012). Weather based crop insurance in India (Policy Research Working Paper No. 5985). World Bank.https://openknowledge.worldbank.org/bitstreams/9bdc0163-f662-5324-aed5-30efd838f5a1/download

Cole, S., Gine, X., Tobacman, J., Topalova, P., Townsend, R., & Vickery, J. (2010). Barriers to household risk management: Evidence from India (Policy Research Working Paper No. 5504). World Bank.https://pmc.ncbi.nlm.nih.gov/articles/PMC3995033/pdf/nihms-402073.pdf

Collins, D., Morduch, J., Rutherford, S., & Ruthven, O. (2009). Portfolios of the poor: How the world's poor live on $2 a day. Princeton University Press.https://books.google.com.pk/books?hl=en&lr=&id=esDhcbEHOfkC&oi=fnd&pg=PP2&dq=Collins,+D.,+Morduch,+J.,+Rutherford,+S.,+%26+Ruthven,+O.+(2009).+Portfolios+of+the+poor:+How+the+world%27s+poor+live+on+%242+a+day.+Princeton+University+Press.&ots=81Q1djbi4P&sig=OlqF1Iwjm8NGkvuzLSeF182Mjwo&redir_esc=y - v=onepage&q&f=false

Cull, R., Ehrbeck, T., & Holle, N. (2014). Financial inclusion and development: Recent impact evidence. https://www.cgap.org/sites/default/files/FocusNote-Financial-Inclusion-and-Development-April-2014.pdfhttps://www.cgap.org/sites/default/files/FocusNote-Financial-Inclusion-and-Development-April-2014.pdf

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly, 13(3), 319–340. https://doi.org/10.2307/249008

Demirguc-Kunt, A., Klapper, L., Singer, D., Ansar, S., & Hess, J. (2018). The Global Findex Database 2017: Measuring financial inclusion and the fintech revolution. World Bank. http://dx.doi.org/10.1596/978-1-4648-1259-0

Demirgüç-Kunt, A., Klapper, L., Singer, D., & Ansar, S. (2022). The Global Findex Database 2021: Financial inclusion, digital payments, and resilience in the age of COVID-19. World Bank. https://doi.org/10.1596/978-1-4648-1897-4

Dorfleitner, G., Hornuf, L., Schmitt, M., & Weber, M. (2017). The FinTech market in Germany. Springer.https://www.scirp.org/reference/referencespapers?referenceid=2955892

Duncombe, R. A. (2014). Understanding the impact of mobile phones on livelihoods in developing countries. Development Policy Review, 32(5), 567–588.https://onlinelibrary.wiley.com/doi/pdf/10.1111/dpr.12073?casa_token=0nOsV_QCxjIAAAAA:qKoKIh2icuLJgl-hON5xrVE0ZohnGfK2NxmDVexQAtF3xjP_5Br6c-UJC1GfAbZmTDK79JGrcr5E8kQR

Dupas, P., & Robinson, J. (2013). Savings constraints and microenterprise development: Evidence from a field experiment in Kenya. American Economic Journal: Applied Economics, 5(1), 163–192.https://www.nber.org/system/files/working_papers/w14693/w14693.pdf

FAO. (2019). Food and Agriculture Organization of the United Nations: Crops 2014. FAOSTAT Crops Databasehttp://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567 - ancor

FAO. (2023). The state of food and agriculture 2023. Food and Agriculture Organization of the United Nations.https://openknowledge.fao.org/items/1516eb79-8b43-400e-b3cb-130fd70853b0

Feng, H., Wang, X., Duan, Y., Zhang, J., & Zhang, X. (2020). Applying blockchain technology to improve agri-food traceability: A review of development methods, benefits and challenges. Journal of Cleaner Production.10.1016/j.jclepro.2020.121031

Fletschner, D., & Kenney, L. (2014). Rural women's access to financial services: Credit, savings, and insurance. In A. R. Quisumbing, R. Meinzen-Dick, T. L. Raney, A. Croppenstedt, J. A. Behrman, & A. Peterman (Eds.), Gender in agriculture: Closing the knowledge gap (pp. 187–208). Springer.https://ageconsearch.umn.edu/record/289014/files/a-am312e.pdf

Gabor, D., & Brooks, S. (2017). The digital revolution in financial inclusion: International development in the fintech era. New Political Economy, 22(4), 423–436. https://doi.org/10.1080/13563467.2017.1259298

GSMA. (2023). State of the industry report on mobile money 2023. GSMA.https://www.gsma.com/solutions-and-impact/connectivity-for-good/mobile-for-development/gsma_resources/state-of-the-industry-report-on-mobile-money-2023/

Guérin, I., Morvant-Roux, S., & Villarreal, M. (Eds.). (2014). Microfinance, debt and over-indebtedness: Juggling with money. Routledge.https://horizon.documentation.ird.fr/exl-doc/pleins_textes/2023-12/010061017.pdf

Hastings, J., Madrian, B., & Skimmyhorn, W. (2013). Financial literacy, financial education, and economic outcomes. Annual Review of Economics, 5, 347–373. https://doi.org/10.1146/annurev-economics-082312-125807

Hermes, N., & Lensink, R. (2011). Microfinance: Its impact, outreach, and sustainability. World Development, 39(6), 875–881. https://doi.org/10.1016/j.worlddev.2009.10.021

Qin, Q., Guo, H., Shi, X., & Chen, K. (2023). Rural e-commerce and county economic development in China. China & World Economy, 31(5), 26–60.https://doi.org/10.1111/cwe.12501

IFAD. (2021). Rural development report 2021: Transforming food systems for rural prosperity. International Fund for Agricultural Development.https://www.ifad.org/en/rural-development-report/

ITU. (2022). Measuring digital development: Facts and figures 2022. International Telecommunication Union.https://www.itu.int/itu-d/reports/statistics/facts-figures-2022/

Jack, W., & Suri, T. (2011). Mobile money: The economics of M-PESA (NBER Working Paper No. 16721). National Bureau of Economic Research. https://doi.org/10.3386/w16721

Karlan, D., Osei, R., Osei-Akoto, I., & Udry, C. (2014). Agricultural decisions after relaxing credit and risk constraints. The Quarterly Journal of Economics, 129(2), 597–652. https://doi.org/10.1093/qje/qju002

Klapper, L., El-Zoghbi, M., & Hess, J. (2016). *Achieving the sustainable development goals: The role of financial inclusion*. CGAP.https://www.cgap.org/sites/default/files/Working-Paper-Achieving-Sustainable-Development-Goals-Apr-2016_0.pdf

Kshetri, N. (2018). Blockchain's roles in meeting key supply chain management objectives. *International Journal of Information Management, 39*, 80–89. https://doi.org/10.1016/j.ijinfomgt.2017.12.005

Shen, C.-Y., Huang, Y.-F., Weng, M.-W., Lai, I.-S., & Huang, H.-F. (2023). The role of Industry 4.0 and circular economy for sustainable operations: The case of bike industry. *Applied Sciences, 13*(10), 5986. https://doi.org/10.3390/app13105986

Liakos, K. G., Busato, P., Moshou, D., et al. (2018). Machine learning in agriculture: A review. *Sensors, 18*, 2674. https://doi.org/10.3390/s18082674

Lwoga, E. T., & Lwoga, N. B. (2017). User acceptance of mobile payment: The effects of user-centric security, system characteristics and gender. *The Electronic Journal of Information Systems in Developing Countries, 81*, 1–24. https://doi.org/10.1002/j.1681-4835.2017.tb00595.x

Mhlanga, D. (2020). Industry 4.0 in finance: The impact of artificial intelligence (AI) on digital financial inclusion. *International Journal of Financial Studies, 8*(3), 45. https://doi.org/10.3390/ijfs8030045

Ministry of Finance, India. (2022). *Pradhan Mantri Jan Dhan Yojana: Progress report 2022*. Government of India. https://www.pmjdy.gov.in/

Moritz, A., & Block, J. H. (2016). Crowdfunding: A literature review and research directions. In D. Brüntje & O. Gajda (Eds.), *Crowdfunding in Europe* (pp. 25–53). Springer.doi: 10.1007/978-3-319-18017-5_3

Muralidharan, K., Niehaus, P., & Sukhtankar, S. (2016). Building state capacity: Evidence from biometric smartcards in India. *American Economic Review, 106*(10), 2895–2929.https://www.nber.org/system/files/working_papers/w19999/w19999.pdf

Reserve Bank of India. (2023). *Annual report on payment systems 2022–23*. RBI.https://www.scribd.com/document/678880680/RBI-ANNUAL-REPORT-2023-by-Anuj-Jindal-in

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press.https://www.scirp.org/reference/referencespapers?referenceid=3275637

Safaricom. (2023). *Safaricom annual report 2023*. Safaricom PLC.https://www.safaricom.co.ke/images/Downloads/Safaricom_Annual_Report_2023.pdf

Sahay, R., Cihak, M., N'Diaye, P. M., Barajas, A., Mitra, S., Kyobe, A. J., Mooi, Y. N., & Yousefi, S. R. (2015). *Financial inclusion: Can it meet multiple macroeconomic goals?* IMF Staff Discussion Notes, 2015/017. International Monetary Fund.https://www.researchgate.net/profile/Srobona-Mitra/publication/281821048_Financial_Inclusion_Can_It_Meet_Multiple_Macroeconomic_Goals/links/55f97e7a08aec948c493e404/Financial-Inclusion-Can-It-Meet-Multiple-Macroeconomic-Goals.pdf

Scoones, I. (1998). *Sustainable rural livelihoods: A framework for analysis* (IDS Working Paper 72). IDS.https://www.staff.ncl.ac.uk/david.harvey/AEF806/Sconnes1998.pdf

Suri, T., & Jack, W. (2016). The long-run poverty and gender impacts of mobile money. *Science, 354*, 1288–1292. https://doi.org/10.1126/science.aah5309

UNCTAD (United Nations Conference on Trade and Development). (2020). *Digital economy report 2020: Value creation and capture implications for developing countries*. UNCTAD.https://unctad.org/system/files/official-document/tdr2020_en.pdf

Van Dijk, J. A. (2006). Digital divide research, achievements and shortcomings. *Poetics, 34*, 221–235. https://doi.org/10.1016/j.poetic.2006.05.004

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science, 46*, 186–204. https://doi.org/10.1287/mnsc.46.2.186.11926

Warschauer, M. (2003). *Technology and social inclusion: Rethinking the digital divide*. MIT Press.10.7551/mitpress/6699.001.0001

World Bank. (2014). *Global financial development report 2014: Financial inclusion*. World Bank.https://documents1.worldbank.org/curated/en/225251468330270218/pdf/Global-financial-development-report-2014-financial-inclusion.pdf

Ziegler, T., Shneor, R., Garvey, K., Wenzlaff, K., Yerolemou, N., Rui, H., & Zhang, B. Z. (2018). *Expanding horizons: The 3rd European alternative finance industry report*. SSRN. https://ssrn.com/abstract=3106911.

Alliance for Affordable Internet. (2022). *Affordability report 2022*. Web Foundation.https://adi.a4ai.org/affordability-report/

IEA (International Energy Agency). (2022). *Africa energy outlook 2022*. IEA.https://www.iea.org/reports/africa-energy-outlook-2022

Jayachandran, S. (2021). Social norms as a barrier to women's employment in developing countries. *IMF Economic Review*, 69(3), 576–595.https://www.nber.org/system/files/working_papers/w27449/w27449.pdf

OECD. (2023). *Digital government in China: Evolving priorities and key achievements*. OECD Publishing.https://www.oecd.org/en/topics/policy-issues/digital-government.html