

The Role of Digital Financial Literacy in Facilitating Climate-Smart Agriculture Adoption and Enhancing Food Security: Evidence from a Repeat Cross Sectional Household Survey in Cambodia

Chan Mono OUM

Pisidh VOE

The authors express their gratitude to the Department of Foreign Affairs and Trade (DFAT), Australian Award Cambodia (AAC) and Tetra International for their valuable administrative financial support. Special appreciation is extended to the enumerators and participants whose cooperation and involvement were integral to the success of this research. Without their support, this research paper would not have been feasible. The contents and research findings are solely the responsibility of the authors and do not necessarily represent the views of the Department of Foreign Affairs and Trade (DFAT), Australia Award Cambodia (AAC), and Tetra International

Abstract

Digital financial literacy (DFL) and climate-smart agriculture (CSA) are increasingly viewed as complementary levers for strengthening smallholder resilience and food security under rising climate risks, yet evidence on how digital capability translates into CSA adoption and improved food security remains limited, particularly in rural Cambodia where digitalization is expanding but households' ability to convert digital capability into climate adaptation remains uncertain. While the literature suggests that digital financial literacy can relax constraints to CSA adoption and link to food security improvement, evidence remains limited leaving policy design overly focused on platform expansion without sufficient attention to complementary enabling conditions. This study examines whether and how digital financial literacy affects CSA adoption and subsequently improves food security among rural farming households in Cambodia. Using repeat cross-sectional household survey data collected in 2023 and 2025 across four provinces, we estimate determinants of DFS use and CSA adoption using logistic models with provincial and year fixed effects, assess joint adoption decisions across multiple CSA practices using a multivariate probit framework, and quantify direct and indirect (mediated) relationships between digital finance, CSA adoption, and household food security using a generalized structural equation model (GSEM). The results indicate that information and training exposure, perceived climate impacts, and social support are consistently associated with higher CSA adoption, while determinants of DFS use reflect a capability and connectedness pattern. In the structural models, CSA adoption is associated with a reduction in food insecurity, suggesting that CSA helps protect households from the most acute food deprivation. The findings also demonstrate the need for integrated strategies that combine targeted digital financial capability building with strengthened extension and peer-learning systems and complementary rural infrastructure and market access to translate digital inclusion into wider CSA uptake and enhance food security.

Key words: Digital financial literacy; Digital financial services; Climate-smart agriculture; Intercropping; Food security (HFIAS); Cambodia

JEL Code: Q12, Q16, Q18, O33, G21

1. INTRODUCTION

Digital financial literacy is increasingly recognized as a promising enabler of climate-smart agriculture (CSA), with potential downstream gains for food security among smallholder farmers in climate-vulnerable regions like Cambodia. Yang et al. (2024) and Mushi et al. (2022) argue that digital literacy and inclusion can reduce transaction frictions and improve households' ability to mobilize resources for farm investment, while more recent evidence suggests that digital financial capability can support CSA-related decisions by strengthening access to inputs, services, and markets (Lui & Ren, 2023). Building on this broader linkage, recent studies emphasize that digital financial technologies—mobile payments, digital credit, and platform-based services—can facilitate sustainable agricultural practices by relaxing resource constraints, expanding information flows, and improving market integration, provided that farmers possess the necessary skills to navigate these tools (Asante et al., 2025; Hussain et al., 2025; Liu & Li, 2025). At the same time, the literature suggests that digital tools can complement the dissemination and operationalization of CSA practices by enabling timely payments for adaptive technologies and by supporting access to digital advisory content (Mao et al., 2024; Balyan et al., 2024; USAID, 2021).

However, empirical evidence for a direct mediation pathway where digital financial literacy specifically drives CSA adoption and subsequently improves food security—is still emerging, particularly in the Southeast Asian context. Seuyong et al. (2023) note that much of the existing work treats digital capability as part of a broader digital finance ecosystem and tends to emphasize enabling conditions rather than testing the full causal chain from literacy to food security. Similarly, Hussain et al. (2025) and Yang et al. (2024) suggest that observed relationships are often interpreted through indirect pathways such as credit access or information exposure rather than through explicit mediation models that link digital financial literacy to food security via the specific adoption of CSA practices. As a result, while the conceptual logic is compelling, the literature indicates a need for more evidence that jointly models digital capability, CSA adoption, and food security outcomes within a unified analytical framework (Mwalupaso et al., 2025; Hussain et al., 2025).

Digital platforms and mobile money are becoming more accessible in Cambodia, yet they are frequently positioned as a gateway to services that require high levels of user confidence and skill. Mwalupaso et al. (2025) argue that these platforms can ease liquidity constraints by improving payment efficiency and facilitating access to finance for climate-resilient inputs, which is central for adopting CSA. Gao and Gao (2024) similarly highlight that platform-based transaction records can strengthen farmers' engagement with service providers, potentially lowering barriers to adopting sustainable practices if the farmers are digitally literate. Illustrative examples in the literature suggest that digital financial literacy is a prerequisite for these factors to effectively support CSA uptake (Gong et al., 2024; USAID, 2021).

Parallel to this, the agronomic and development literature continues to show that CSA practices are associated with productivity and resilience gains that are vital for food security. Teklemichael and Mekuriaw (2025) and Mujeyi et al. (2021) document that CSA-aligned practices can raise yields and stabilize production under climate variability, while Teklemichael and Mekuriaw (2025) emphasize that these practices can support soil health, reduce risk

exposure, and improve household livelihood resilience. Consistent with these findings, Liu et al., (2024) link the adoption of such technologies to improved farm performance and welfare-related outcomes, and Oum et al. (2023) further suggest that the synergy between digital capability and CSA can contribute to food security through yield improvements, income diversification, and enhanced coping capacity during shocks. Nevertheless, the literature commonly cautions that the chain leading from digital financial literacy to CSA and finally to food security is frequently inferred rather than directly established, underscoring the importance of empirical strategies that test mediation and account for endogeneity in adoption decisions.

Using repeat cross-sectional household survey data collected in 2023 and 2025 across four Cambodian provinces, this study examines whether digital financial literacy (DFL) helps rural farming households adopt climate-smart agriculture (CSA)—including intercropping—and improve food security amid rising climate risks. We estimate the determinants of DFL and CSA adoption using logistic models with province and year fixed effects, assess correlated adoption decisions across multiple CSA practices using a multivariate probit framework, and quantify direct and mediated pathways linking DFL, CSA adoption, and food security using a generalized structural equation model (GSEM) with ordered and binary HFIAS outcomes. However, CSA uptake remains limited (31.6% adopt at least one CSA practice) and DFL is low (11.6%), while food insecurity is widespread (only 35.7% of households are food secure). Empirically, information/training exposure, perceived climate impacts, and social support are consistently associated with higher CSA adoption, whereas higher consumption expenditure and more market-connected asset patterns are associated with stronger DFL. In the structural analysis, CSA adoption is linked to a lower probability of severe food insecurity, suggesting that CSA can protect households from the most acute food deprivation even when short-run adjustment costs persist. The findings also point to the need for integrated strategies that combine targeted digital financial capability building with strengthened extension and peer-learning systems, alongside complementary rural infrastructure and market access, to translate digital inclusion into durable climate resilience and food security gains.

This study contributes to policy development and strategic action on several fronts. First, it addresses key evidence gaps and aligns closely with national priorities and the Sustainable Development Goals, with particular relevance to climate change, agriculture and food security, digitalization, and gender. It provides empirical evidence on how digital financial literacy functions as both a practical capability and a behavioral driver of climate-smart agriculture (CSA) adoption, examining farmers perceived usefulness and ease of use of digital financial services, as well as the roles of social support and perceived necessity. Second, the study deepens understanding of how socio-economic conditions shape digital financial literacy and CSA uptake, with a focus on rural household characteristics such as income, education, and access to technology. Identifying these factors helps inform more targeted and equitable interventions to accelerate CSA adoption. Finally, the research is among the first in Cambodia to explicitly examine the interaction between digital financial literacy and CSA adoption and to link this relationship to household food security outcomes. Taken together, these contributions offer actionable insights for policymakers, agricultural extension services, financial institutions, and development partners to design evidence-based strategies that

strengthen digital financial literacy, expand CSA adoption, and ultimately enhance agricultural resilience and food security in Cambodia

The remainder of this paper is organized as follows. Section 2 presents the conceptual framework and hypotheses linking digital financial literacy to climate-smart agriculture adoption and food security through key behavioral and practical mechanisms. Section 3 reviews the relevant literature on digital finance, the digital divide, and CSA adoption. Section 4 describes the repeated cross-sectional household surveys conducted in 2023 and 2025 and the study context across four provinces in Cambodia. Section 5 demonstrates results and discussions, followed by Section 6 concludes with implications for policy and interventions.

2. LITERATURE REVIEW

In the literature, the intersection of digital financial literacy, climate-smart agriculture (CSA) adoption, and food security is increasingly conceptualized in the sustainable development literature as a linked sequence of capability formation, investment behavior, and welfare outcomes. Yang et al. (2024) emphasize that digital financial inclusion—capturing digital skills, access to mobile-enabled financial services, and fintech-driven innovations—can strengthen households' capacity to mobilize resources and manage uncertainty, thereby shaping adoption decisions for climate-resilient agricultural practices. Similarly, Liu and Ren (2023) argue that digital financial literacy is not merely technical competence but a multidimensional capability that influences how farm households evaluate financial products, process digital information, and execute transactions that support productive and adaptive investments. Building on this perspective, Xu et al. (2025) show that digital financial inclusion can enhance farmers' participation in modern input and service markets, which can indirectly raise the feasibility and expected returns of CSA adoption.

Recent empirical studies consistently report that stronger digital financial literacy and deeper use of digital financial services are associated with higher CSA uptake and improved food security metrics across diverse settings. Mwalupaso et al. (2025), using household survey evidence, find that farmers with higher digital financial literacy exhibit greater adoption intensity of climate-smart practices and better food security outcomes, particularly when digital tools are integrated into agricultural decision-making. In Ghana, Asante et al. (2025) document that digitally capable households are more likely to adopt ecological and climate-smart technologies, with downstream gains in food security indicators such as consumption adequacy and dietary quality. Hussain et al. (2025) provide comparable evidence from Pakistan, showing that digital finance and related literacy dimensions correlate positively with both CSA adoption and food security improvements, suggesting that digital inclusion can play a resilience-enhancing role in climate-exposed agrarian economies. In China, Liu and Li (2025) also provide an evidence that digitally literate households tend to display stronger uptake of climate-smart strategies and better welfare outcomes, reinforcing the cross-country pattern that digital financial capability is systematically linked to adaptive agricultural behavior.

The literature explains these patterns through several interrelated mechanisms, with credit and liquidity channels most frequently emphasized. Yang et al. (2024) suggest that digital finance can relax liquidity constraints by reducing transaction costs, improving access to credit, and enabling flexible financial products that align better with agricultural cashflow cycles. Liu and

Ren (2023) similarly argue that digital tools can reduce information frictions in lending and expand households' feasible financing sets, which matters because many CSA practices require upfront expenditures and yield benefits with time lags. Asante et al. (2025) further show that improved financial access can increase the probability of investing in productivity-enhancing and climate-resilient inputs, implying that digital financial capability helps households shift from coping strategies to investment-oriented adaptation. Taken together, these studies imply that digital financial literacy can raise CSA adoption by enabling households to overcome the classic "investment barrier" in smallholder agriculture (Yang et al., 2024; Liu & Ren, 2023; Asante et al., 2025).

A second mechanism concerns information acquisition, learning, and the reduction of uncertainty, key determinants in technology adoption under climate risk. Hussain et al. (2025) argue that digital connectivity expands households' information sets through access to agronomic knowledge, market prices, and climate-related updates, thereby reducing search costs and perceived uncertainty about CSA profitability. Liu et al. (2025) similarly highlight that digital platforms can facilitate learning-by-doing and peer effects by enabling more rapid diffusion of knowledge and adoption experiences within communities. Zheng et al. (2025) add that improved access to timely and actionable information can strengthen households' adaptive capacity, particularly when information is combined with financial tools that allow households to respond quickly to new risks or opportunities. In this sense, digital financial literacy can amplify the value of information channels by improving households' ability to interpret digital content and act on it through financial transactions (Hussain et al., 2025; Liu et al., 2025; Zheng et al., 2025).

A third mechanism focuses on risk management and resilience. Liu et al. (2025) suggest that digital financial tools can strengthen households' ability to smooth consumption and manage shocks through savings mobilization, rapid transfers, and access to formal or semi-formal financial instruments. Yang et al. (2024) likewise emphasize that digital inclusion can enhance risk-bearing capacity by facilitating precautionary savings and improving the speed of coping responses when climate shocks occur. Hussain et al. (2025) further show that households with greater digital financial capability are better positioned to maintain food consumption during adverse events, implying that the food security gains associated with digital inclusion may operate not only through higher average income but also through reduced volatility and improved shock responsiveness. Collectively, this evidence supports a pathway in which digital financial literacy strengthens resilience by enabling both preventive and reactive financial strategies, which can reinforce the sustainability of CSA adoption and stabilize food security outcomes (Yang et al., 2024; Liu et al., 2025; Hussain et al., 2025).

A fourth set of arguments relates to innovation, commercialization, and value-chain integration. Asante et al. (2025) indicate that digitally enabled payments and financial services can facilitate participation in input and output markets, supporting the adoption of modern technologies that are often bundled with CSA practices. Liu et al. (2025) argue that digital finance can reduce coordination failures by supporting transactions with service providers (e.g., mechanization rentals or input suppliers), which lowers fixed adoption costs and increases the feasibility of experimentation with new practices. Xu et al. (2025) also suggest that digital financial inclusion

can strengthen linkages between farmers and market institutions, thereby increasing incentives to adopt CSA practices that improve quality, reliability, or sustainability attributes valued in markets. These contributions collectively imply that digital financial literacy can shape CSA adoption not only through household-level constraints but also by improving households' ability to engage with emerging service ecosystems and market opportunities (Asante et al., 2025; Liu et al., 2025; Xu et al., 2025).

Despite the overall positive associations, the literature also provides constraints and boundary conditions that can weaken these linkages. Seuyong et al. (2023) highlight that limited digital infrastructure, unequal connectivity, and affordability barriers can exclude smallholders from using digital services effectively, even where services are nominally available. Quarshie et al. (2023) similarly argue that persistent digital divides—by geography, income, and education—can generate unequal benefits and may entrench disparities if interventions are not explicitly inclusion-oriented. Pramesti (2025) adds that affordability constraints and limited digital capability can depress sustained usage, reinforcing the distinction between access and effective participation. These studies collectively suggest that the impact of digital financial inclusion on CSA adoption and food security is conditional on the enabling environment—especially infrastructure, costs, trust, and capability-building—rather than guaranteed by access alone (Seuyong et al., 2023; Quarshie et al., 2023; Pramesti, 2025).

In response, recent work emphasizes policy approaches that combine digital capability development with institutional and market interventions. Mwalupaso et al. (2025) argue that targeted training programs can strengthen the practical skills needed for informed use of digital financial services, thereby increasing the likelihood that digital finance translates into productive CSA investment and improved food security. Quarshie et al. (2023) suggest that public–private partnerships can reduce onboarding frictions, lower service costs, and tailor products for smallholders, particularly in underserved rural areas. Pramesti (2025) further emphasizes that policies must address affordability and usability constraints, including digital safety and consumer protection, to sustain usage and prevent exclusion. Together, these contributions indicate that digital financial literacy is a policy-relevant lever, but its effectiveness depends on complementary investments that address constraints shaping technology adoption and welfare gains (Mwalupaso et al., 2025; Quarshie et al., 2023; Pramesti, 2025).

While the literature generally finds that digital financial literacy and inclusion can facilitate CSA uptake and strengthen food security, these gains are frequently constrained by persistent digital divides and structural barriers. Banh et al. (2021) and Seuyong et al. (2023) show that weak rural connectivity and limited access to devices restrict farmers' ability to use digital tools. Pramesti (2025) argues that affordability—phones, data, and service fees—creates effective exclusion for poorer households, while Quarshie et al. (2023) note that low digital literacy increases perceived risk and reduces sustained use. Gender gaps in phone ownership and decision-making further limit women's access, and low trust in digital systems—especially among older or less-educated farmers—can depress adoption even when services exist (Seuyong et al., 2023; Pramesti, 2025; Quarshie et al., 2023).

Relatedly, the effects of digital financial literacy are not uniform across households and settings. Yang et al. (2024) find stronger impacts among more educated farmers and those with larger landholdings, suggesting complementarities between digital capability and productive assets. Mwalupaso et al. (2025) show that women’s participation in village savings/loan associations is more effective when combined with agricultural informatization (AgI), indicating that bundled finance–information interventions can amplify gains. Liu and Ren (2023) document regional variation in China, consistent with differences in infrastructure and market maturity. Liu et al. (2024) further suggest that vulnerable groups may depend more on digital finance for adoption but face higher entry barriers, implying that realized benefits depend on context-specific constraints and support (Yang et al., 2024; Mwalupaso et al., 2025; Liu & Ren, 2023; Liu et al., 2024).

3. CLIMATE SMART AGRICULTURE, FINANCIAL LITERACY, AND FOOD SECURITY LINKS IN CAMBODIA

Cambodia stands at a critical juncture, facing the intertwined challenges of a rapidly changing climate and persistent food insecurity. The World Bank (2020) notes that Cambodia’s economy and livelihoods remain deeply rooted in agriculture, which heightens exposure to climate-related shocks and threatens rural welfare. As documented in regional and global assessments, erratic rainfall, rising temperatures, and more frequent extreme events are undermining agricultural productivity and food security (ADB, 2019). Although digital technologies can mitigate some of these risks, a persistent rural digital gap limits households’ ability to access and benefit from such solutions (GSMA, 2023; USAID, 2021). Despite expanding internet and smartphone penetration, adoption of digital financial services remains constrained, particularly among farmers, reinforcing the argument that digital financial literacy is essential for enabling CSA adoption and strengthening food security outcomes (GSMA, 2023; USAID, 2021; World Bank, 2020).

Financial capability constraints are a key part of this challenge. The OECD (2022) and the World Bank (2020) indicate that financial literacy in Cambodia remains low relative to many regional peers. ADB (2019) also reports a financial literacy score of 11.5 for Cambodia among the lowest in a 30-country comparison while noting that this performance is broadly consistent with Cambodia’s income level. In practice, USAID (2021) finds that mobile financial app use in rural areas is constrained by cash preferences, limited understanding of financial technologies, and perceptions of limited relevance. ITU (2022) further highlights that low general literacy and continued reliance on basic phones often without Khmer language support can impede digital uptake (USAID, 2021; ITU, 2022). Even where smartphone ownership is common among agricultural suppliers, digital payment usage remains low, suggesting that access alone is insufficient without the skills and confidence to transact digitally (USAID, 2021). MAFF (2023) similarly emphasizes that many farmers lack the education and capabilities needed to use digital agriculture tools effectively. In response, NBC (2019) reports expanding initiatives to promote digital financial literacy, often leveraging mobile money ecosystems as entry points (NBC, 2019).

CSA is widely presented as a comprehensive response to food security risks under climate change, with the FAO (2010, 2021) defining CSA around three objectives: productivity, resilience, and emissions mitigation. IPCC (2019) reinforce that achieving these objectives requires adoption of practices and technologies that manage climate risks while sustaining production (FAO, 2010, 2021; IPCC, 2019). In Cambodia, ADB (2019), and FAO (2021) document heightened exposure to sea-level rise, floods, droughts, and temperature extremes, and they note the growing emphasis on practices such as irrigation improvements, risk-transfer instruments (including weather-indexed insurance), and climate-resilient varieties and reported promising results from the System of Rice Intensification (SRI), often cited as a scalable CSA-related approach in rice systems (ADB, 2019; FAO, 2021). While direct Cambodia-specific evidence linking digital financial literacy to CSA adoption remains limited, FAO (2021) and OECD (2024) suggest that digital platforms can increase incomes and support more sustainable practices, implying plausible complementarities between digital capability and CSA uptake (FAO, 2021; OECD, 2024).

This motivates the hypothesis that digital financial literacy and CSA adoption may jointly reinforce food security and income outcomes. ADB (2019) and FAO (2021) emphasize that climate resilience depends not only on technologies but also on farmers' ability to finance investments, manage risk, and engage markets—functions that digital financial capability can support (ADB, 2019; FAO, 2021). Consistent with this, the World Bank (2020) and NBC (2024) point to the potential for digital tools to strengthen market access and financial management, thereby enhancing livelihood resilience (World Bank, 2020; NBC, 2024). However, UNEP (2026) underscore the need for more Cambodia-focused research to clarify how these linkages operate in practice and which constraints are most binding, particularly given persistent infrastructure and capability gaps (UNEP, 2026).

Beyond Cambodia, the intersection of digital financial literacy, CSA adoption, and food security is increasingly recognized as pivotal for sustainable agricultural development in climate-vulnerable low- and middle-income countries. Liu and Li (2025) argue that digital financial capability can improve households' access to credit and risk-management tools, strengthening adaptive investment behavior. Recent empirical studies similarly suggest that digital financial tools—when combined with adequate literacy can facilitate technology adoption and improve resilience against climate shocks, supporting food security objectives (Mwanzia et al., 2025; Wu & Zhang, 2025; Zegeye & Ebrahim, 2025; Liu & Li, 2025). Yet, the literature also emphasizes that structural barriers remain substantial. Seuyong et al. (2023) show that limited infrastructure and digital divides constrain participation, while Zegeye & Ebrahim (2025) highlight affordability and capability gaps that restrict the reach and effectiveness of digital innovations (Seuyong et al., 2023; Zegeye & Ebrahim, 2025). Mwanzia et al. (2025) find that awareness and utilization of financial services are strongly associated with CSA adoption, but actual access remains limited due to low literacy and collateral constraints—patterns also reflected in related evidence on financial exclusion (Mwanzia et al., 2025). In addition, Zegeye & Ebrahim (2025) suggest that digital advisory and extension platforms can help close knowledge gaps and promote CSA uptake, indicating that information delivery is a key complementary mechanism. Persistent heterogeneity is also emphasized: Seuyong et al. (2023) document exclusion risks linked to socio-economic constraints, while

Wakweya (2023) and Mnukwa et al. (2025) highlight gender disparities and distributional challenges that require context-specific interventions (Seuyong et al., 2023; Mnukwa et al., 2025). Overall, the evidence indicates that digital financial literacy is a critical enabler of CSA adoption and food security enhancement, but its full potential depends on integrated strategies that address infrastructure, affordability, skills, and institutional constraints (Liu & Li, 2025; Mwanzia et al., 2025).

4. METHODS AND DATA

This section describes the study setting and survey design, and details how the key constructs digital financial literacy (DFL), CSA adoption (intercropping), and household food security are operationalized. The empirical design uses repeat cross-sectional household surveys (2023 and 2025) conducted in the same four provinces, which supports population-level comparisons across rounds even though the same households are not necessarily re-interviewed. This design is widely used when panel tracking is infeasible and remains informative for documenting correlates and structural relationships, provided that time and location effects are controlled (Deaton, 1985).

5.1. Study areas

The study covers four Cambodian provinces Prey Veng, Kampong Speu, Siem Reap, and Kampot—selected to represent distinct geographic clusters. According to the Cambodia Agriculture Survey 2023 (NIS, 2023), rice is the primary crop across these provinces, while common secondary crops include mung bean, sugarcane, and sesame. All four provinces are frequently affected by droughts and floods, which have caused substantial damage to agricultural production.

Prey Veng’s economy is predominantly agricultural, with rice as the main output; the province contributes about 10% of Cambodia’s annual rice production. In Kampong Speu, most farming households cultivate small plots (generally under 2 hectares and often under 1 hectare) and face recurrent climate shocks, particularly flash floods during the rainy season and drought during the dry season. In Siem Reap, around 67% of residents are engaged in agriculture, and the province recorded 322 flood events and 114 drought events between 2000 and 2019. Erratic rainfall and prolonged dry spells are major shocks that undermine household incomes and food consumption. Kampot has the largest share of agricultural households among Cambodia’s coastal provinces. Over the past two decades, both drought and flooding have repeatedly devastated crops, while extreme weather events also pose serious risks to livestock production. Overall, Kampot remains highly vulnerable to climate hazards, with floods and droughts significantly constraining agricultural productivity (Nong et al., 2024).

5.2. Household Survey

The research uses a repeat cross-sectional design, combining a 2023 household dataset with a second round collected in 2025 in the same provinces. This design supports inference on population-level differences between rounds even when the same households are not followed over time. Conceptually, repeated cross-sections can be used to study changes in outcomes and correlates over time and under additional assumptions can be extended into cohort-based pseudo-panel approaches (Deaton, 1985).

The final analytic sample includes 391 households in 2023 and 425 households in 2025 (total 816), with sample distribution across provinces and cropping types reported in Table 1. The 2025 survey instrument was using Kobo Toolbox to improve data quality and reduce field-processing errors.

The questionnaire was designed to capture household socio-economic conditions, farm structure, exposure to climate shocks, CSA perceptions and information/training, DFL and use of digital financial tools, and food security (HFIAS). The instrument includes standard livelihood modules and food security questions measured over a four-week recall period, consistent with international practice for experience-based food insecurity measurement.

Table 1: Sample Distribution

Province	First Survey (2023)			Second Survey (2025)			Total		
	Mono-cropping	Inter-cropping	Total	Mono-cropping	Inter-cropping	Total	Mono-cropping	Inter-cropping	Total
Kampong Speu	80	8	88	82	12	94	162	20	182
Kampot	63	13	76	63	23	86	126	36	162
Prey Veng	73	68	141	127	3	130	200	71	271
Siem Reap	66	20	86	108	7	115	174	27	201
Total	282	109	391	380	45	425	662	154	816

Source: Authors and fieldwork between 1st - 20 October 2025

5.3. Constructing DFL index

DFL is measured using a composite DFL constructed by aggregating domains that reflect practical capability and safe use of digital financial tools. Following the do-file, component scores are created by summing item responses across six domains: awareness, access/usage, knowledge, skills, trust/attitudes, and risk management; these are then calculated into digital financial literacy index, and carried into the pooled index.

This operationalization is consistent with current international guidance that conceptualizes digital financial literacy as a combination of knowledge, skills, attitudes, and behaviours needed to safely use digital financial services (OECD, 2024).

Most importantly, DFL is measured using a composite DFL index constructed by aggregating domains that reflect practical capability and safe use of digital financial tools. Following the do-file, component scores are created by summing item responses across six domains: awareness, access/usage, knowledge, skills, trust/attitudes, and risk management; these are then summed into digital financial literacy index, and carried into the pooled index.

This operationalization is consistent with current international guidance that conceptualizes digital financial literacy as a combination of knowledge, skills, attitudes, and behaviours needed to safely use digital financial services (OECD, 2024). Most importantly, the do-file implements an imputation step to improve comparability for 2023: digital financial literacy index for 2023 is imputed using nearest-neighbour matching with 2025 observation, generating an assigned DFL value where the 2023 index is missing. This step is explicitly aimed at reducing measurement incomparability between rounds when certain DFL items exist fully in 2025 but not in 2023. Analytically, this treatment should be described as a harmonization or

imputation strategy (not causal identification). It strengthens comparability of the DFL scale across rounds but does not remove selection concerns in the behavioral empirical models still include rich covariates and province/year fixed effects.

5.4. Polychoric Principal Component Analysis

Polychoric Principal component analysis is one of the data reduction approaches that transforms a large and correlated dataset into a smaller number of uncorrelated principal components with minimum loss of original information (Hair & Sarstedt, 2019). The original 18 items/ questions that were included in the survey to capture various perceptions held by the surveyed farmers towards climate-smart agriculture practices were subjected to the principal component analysis to identify different dimensions of climate-smart agriculture perception (Table 2). The Kaiser-Meyer-Olkin (KMO) value of 0.78, and the scale of reliability coefficient is at 0.67 which is an acceptable level. The significant result of Bartlett's Test of Sphericity also indicate that the data are suitable for Polychoric PCA, being statistically significance at 1 percent level. Four components that had Eigenvalues greater than 1.0 were retained and they were denoted social support, perceived climate severity, perceived climate impact, and inform.

Table 2: Polychoric Principal Component Analysis Result

Variables	Factor1	Factor2	Factor3	Factor4	Uniqueness
<i>Perceive climate change</i>					
Hotter				0.669	0.442
Drought				0.718	0.443
Raining	-0.562				0.592
Cold					0.819
Flood	-0.619				0.576
Strom				0.559	0.626
<i>Perceive Support</i>					
Friend			0.764		0.368
Individual			0.779		0.392
Government					0.857
Other			0.543		0.629
<i>Perceive climate severity</i>					
Impact on crop	0.539				0.672
Impact on livestock	0.503				0.706
Impact on food	0.722				0.473
Impact on income	0.719				0.481
<i>Inform</i>					
Receive training information		0.759			0.390
Knowledge of climate change		0.839			0.251
Share with household		0.840			0.223
HH member received training		0.721			0.438

Source: Author's calculation

5.5. Constructing HFIAS index

Food Household Insecurity Access Scale is constructed from the standard nine experience-based questions on food access problems over a recall period (typically 4 weeks / 30 days) (Coates & Bilisky, 2007). The index captures both the occurrence and the frequency of food

insecurity experiences at the household level and is widely used for comparability across studies and settings.

The figure compares HFIAS-based food security categories across four provinces. Because the HFIAS captures *experienced constraints in food access* along an ordered severity continuum (from worry about food to going without eating), the shares in “mild,” “moderate,” and “severe” can be interpreted as progressively more serious access-related deprivation.

Kampong Speu shows the strongest food-access position: about 49.5% of households are classified as food secure, and only 6.0% are severely food insecure. The remaining households are mostly mildly (27.5%) or moderately (17.0%) food insecure, suggesting that food-access problems are present but concentrated more in *less severe* manifestations than in acute deprivation. By contrast, Kampot has a lower food-secure share (38.9%) and a higher severe share (10.5%), indicating a shift toward greater severity relative to Kampong Speu.

Prey Veng is characterized by broad but comparatively “shallower” insecurity: the dominant category is mild food insecurity (41.0%), with 29.5% food secure and a combined moderate and severe share of roughly 29.5% (18.8% moderate; 10.7% severe). This pattern is consistent with widespread vulnerability (e.g., concerns, compromises in food quality/variety, or early-stage reductions) rather than a distribution heavily weighted toward the most extreme outcomes—though the severe share remains non-trivial. The interpretation aligns with the HFIAS design, which distinguishes frequency and severity of access constraints rather than caloric intake directly.

Siem Reap stands out as the province with the greatest concentration of high-severity food insecurity: only 30.3% are food secure, while 31.8% are moderately and 21.4% are severely food insecure (a combined 53.2% in moderate/severe). This is materially higher than the other three provinces, where moderate and severe totals are 23–30%. In HFIAS terms, this implies that a much larger fraction of households in Siem Reap report experiences consistent with *more frequent and more severe* food-access shortfalls (e.g., cutting meal size, skipping meals, or more extreme deprivation), which is typically the segment most relevant for urgent assistance and intensive resilience-building interventions.

5. EMPIRICAL APPROACH

This study estimates three sets of relationships: (i) determinants of DFS use, (ii) determinants of CSA adoption (overall and by CSA activity), and (iii) associations between DFS use, CSA adoption, and food security outcomes, allowing for a mediated pathway through CSA.

Because DFL and CSA adoption are household choices, naive comparisons of adopters and non-adopters may reflect selection on observed and unobserved characteristics (e.g., wealth, preferences, risk attitudes, or market connectivity). We therefore adopt a structured, stepwise approach that (a) models correlate of DFS and CSA adoption with rich controls and fixed effects, and (b) estimates food security relationships within a structural framework that explicitly links DFL to CSA adoption and food security.

5.1. The Determinant of Digital Financial Literacy

The main DFL measure is a household-level DFL index. The index aggregates multiple domains, including awareness, access/usage, knowledge, skills, attitudes/trust, and risk management. For the 2023 round, this index is imputed using nearest-neighbor matching with 2025 donors to improve comparability across rounds.

Because DFL index is continuous in the analysis pipeline, the model utilizes an OLS regression with province and survey-year fixed effects and robust standard errors, taking the following form:

$$DFL_i = \alpha + \gamma X_i + \mu_{p,i} + \tau_{t,i} + \varepsilon_i \quad (1)$$

where X_i includes household-head demographics (age, gender, household size, education categories), household economic status (log monthly expenditure), farm characteristics (log farm size, number of land plots), and association membership. Province fixed effects $\mu_{p,i}$ absorb time-invariant differences across provinces, and year fixed effects $\tau_{t,i}$ absorb common shocks across survey rounds.

5.2. The Determinant of CSA Adoption

CSA adoption is operationalized as an indicator for inter-cropping. Logistic regression is used to model the probability of intercropping adoption, focusing on whether higher DFL is associated with greater CSA uptake after conditioning on observables and perception indices, such that:

$$Pr(\text{Intercropping}_i = 1) = \varphi(\beta_0 + \beta_1 DFL_i + \beta_2 \text{Distance to Market}_i + \gamma X_i + \mu_{p,i} + \tau_{t,i}) \quad (2)$$

where $\text{Distance to Market}_i$ denotes the distance to the nearest markets (km) and X_i includes household demographics, socio-economic status, farm structure variables, association membership, and perception indices. As with the DFL regressions, this study estimates stepwise specifications and includes province and year fixed effects with robust standard errors, with VIF checks performed using an OLS approximation for diagnostics.

5.3. The Effect of DFL and CSA Adoption on Household Food Security

Food security is measured using the HFIAS-based categorical outcome (Food secure, Mildly, Moderately, and Severely food insecure). This research estimates a generalized structural equation model (GSEM) that links DFL to CSA adoption (first-stage) and then relates DFL and CSA adoption to food security outcomes (second-stage). This provides a coherent framework for assessing whether CSA is consistent with a mediating channel between digital inclusion and food security:

First-stage equation (logistic regression):

$$Pr(\text{Intercropping}_i = 1) = \varphi(\alpha_0 + \alpha_1 DFL_i + \alpha_2 \text{Distance to Market}_i + \delta X_i + \mu_{p,i} + \tau_{t,i}) \quad (3)$$

Second-stage equation (Ordered logit for the HFIAS category outcome and complementary binary-category logits):

$$HFIAS_Category = \varphi(b_0 + b_1 Intercropping_i + b_2 DFL_i + \theta X_i + \mu_{p,i} + \tau_{t,i} + u_i) \quad (4)$$

This identification remains associative rather than strictly causal because unobserved traits may still jointly influence DFS use, CSA adoption, and food security. However, this strategy strengthens internal validity by (i) conditioning on a broad set of observed confounders, (ii) absorbing time-invariant province differences and common time shocks via fixed effects, and (iii) modeling the DFS lead to CSA adoption and enhance food security pathway explicitly rather than relying on reduced-form correlations. The repeat cross-sectional design is appropriate for capturing population-level changes between 2023 and 2025 even if households differ across rounds.

6. RESULTS AND DISCUSSION

This section presents the empirical findings on (i) the determinants of digital financial services (DFS) use, (ii) the correlates of climate-smart agriculture (CSA) adoption, and (iii) the links between DFS/CSA and household food security, measured using the HFIAS/FHIAS framework. The discussion emphasizes behavioral and institutional channels particularly information exposure, perceived climate risks, and social support—consistent with the conceptual pathways outlined earlier in the paper.

6.1. Determinants of Digital Financial Literacy

Across model specifications, DFS adoption is systematically associated with household socio-economic capacity and exposure to enabling information environments. Older household heads are less likely to use DFS, which likely reflects lower digital familiarity, greater perceived risk in digital transactions, and limited confidence in navigating digital interfaces. This pattern is consistent with evidence that digital capability and trust barriers are not evenly distributed across demographic groups: Seuyong et al. (2023) suggest that gaps in digital literacy and perceived security risks can reduce effective uptake among more disadvantaged or digitally excluded populations, while similar constraints are documented in other settings (Quarshie et al., 2023; Pramesti, 2025). In contrast, households with higher consumption expenditure exhibit a greater propensity to use DFS, aligning with the argument that liquidity, asset buffers, and transaction needs increase the private returns to digital financial tools. This finding is supported by Yang et al. (2024) in which digital finance becomes more attractive when households have stronger economic capacity and more frequent transaction demands, and related evidence similarly links adoption to better-off households and higher usage needs.

Table 3: Determinants of Digital Financial Literacy

VARIABLES	Model (1)	Model (2)	Model (3)	Model (4)
HH age	-0.255*** (0.036)			-0.256*** (0.037)
HH gender (1=Female)	-3.246*** (0.974)			-3.104*** (0.992)
HH size	-0.536*** (0.202)			-0.485** (0.227)
HH primary educ	1.162			1.126

VARIABLES	Model (1)	Model (2)	Model (3)	Model (4)
	(1.035)			(1.024)
HH lower secondary educ	4.110***			3.879***
	(1.347)			(1.339)
HH upper secondary / Higher educ	6.480***			5.907***
	(1.851)			(1.840)
Economic dependency ratio		1.491*		0.471
		(0.793)		(0.745)
Expenditure (log)		-0.334		-0.409
		(0.835)		(0.891)
Farm size (log)		3.859**		3.101*
		(1.848)		(1.867)
Member of association		3.745**		3.435**
		(1.651)		(1.555)
Number of land plots		-0.488		-0.462
		(0.309)		(0.333)
Perceive climate impact			-1.163**	-0.687
			(0.523)	(0.493)
Perceive inform			1.678*	1.471*
			(0.902)	(0.881)
Perceive support			-0.029	0.111
			(0.441)	(0.426)
Perceive climate severity			0.772	1.016*
			(0.632)	(0.593)
Constant	35.467***	21.201***	17.229***	32.399***
	(2.702)	(4.876)	(3.124)	(5.930)
Observations	816	816	816	816
R-squared	0.199	0.115	0.108	0.217
Province FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Mean VIF	1.68	1.71	1.60	1.84

Note: OLS regression is used for the estimation. Dependent variable: Digital Financial Literacy Index (DFL). Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Beyond baseline demographics, variables capturing information and training exposure and perceived climate severity, also display strong positive associations with DFS use. Households reporting greater exposure to training or information channels are more likely to adopt DFS, implying that awareness and practical guidance reduce entry barriers such as knowledge frictions, trust deficits, and perceived complexity. This aligns with research emphasizing that information access and capability-building are key complements to digital infrastructure in which Hussain et al. (2025) suggest that digital connectivity expands households' information sets and reduces search costs, while comparable evidence points to training and information as important enablers of adoption and welfare gains (Zheng et al., 2025; Liu et al., 2025). Likewise, perceived climate stress is positively associated with DFS use, plausibly because climate-related uncertainty increases the value of fast remittances, flexible transfers, and emergency liquidity mechanisms. This interpretation is consistent with findings that financial tools can support coping and smoothing under risk. Liu et al. (2025) emphasized that digital financial services can facilitate liquidity management under shock exposure, with similar mechanisms discussed in the climate–finance literature (Yang et al., 2024). In addition, land fragmentation or related measures of production complexity is positively correlated with DFS usage, which is also consistent with a transaction intensity channel—more spatially dispersed

farming systems may require more frequent payments and working-capital smoothing, raising the usefulness of DFS.

These results imply that DFS uptake is not simply a technology choice but a behavioral response shaped by resources, capabilities, risk perceptions, and exposure to credible information. This is strongly in line with Quarshie et al. (2023) suggest that without targeted capability-building and trust-enhancing measures, expanded access alone may not translate into meaningful use, a conclusion echoed across studies examining digital finance adoption constraints (Seuyong et al., 2023; Pramesti, 2025).

5.2. Determinants of CSA Adoption

The results in Table 4 indicate that CSA adoption is driven primarily by perceptions of climate risk and access to information and support, rather than by DFS use alone. Households that perceive stronger climate impacts are more likely to adopt CSA practices, which is consistent with a risk-management motive: as climate variability becomes more salient, the expected benefits of adaptation investments rise. This pattern aligns with prior evidence that climate stress and perceived production risk increase farmers' incentives to shift toward diversified and resilience-enhancing practices. For example, Maitra et al. (2021) suggest that diversification strategies can improve yield stability under climate variability, while related intercropping evidence highlights that such practices can improve soil conditions and reduce production risk, making them more attractive when climate threats are salient (Burgess et al., 2022).

Exposure to agricultural information and training is one of the most consistent predictors of CSA adoption, reinforcing the view that many CSA practices are knowledge-intensive and require learning-by-doing, demonstration effects, and locally appropriate technical guidance. This finding is consistent with the literature emphasizing that adoption constraints are often informational and technical rather than purely financial. In particular, Burgess et al. (2022) argue that intercropping and related CSA practices are highly context-specific and depend on practical agronomic knowledge meaning that extension, demonstrations, and continuous advisory support are central to scaling.

Social support proxied by factors such as group membership, peer networks, or access to extension/community assistance—also shows a strong positive association with CSA adoption. This is consistent with research showing that adoption costs are not only financial: uncertainty about returns, labour requirements, and coordination needs can be reduced through peer learning and community-based implementation. In line with this, Oum et al. (2023) suggest that CSA practices can improve welfare and food security partly through resilience pathways that are strengthened when farmers learn through networks and organized support structures, and similar community-learning mechanisms.

DFS use is not consistently statistically significant as a direct predictor of CSA adoption once controls for training exposure and climate perceptions are included. This does not contradict the digital-finance literature; rather, it supports a more nuanced interpretation that digital finance often functions as an enabling condition (facilitating transactions, easing liquidity constraints, and supporting coping) rather than a primary trigger of agronomic change. For instance, Bahn et al. (2021) suggest that digital payment adoption can reduce transaction frictions and improve households' ability to mobilize resources for productive investment, yet broader reviews emphasize that impacts typically depend on complementary enablers such as

information, advisory services, and market linkages (Mapanje et al., 2023; Njuguna et al., 2025). In this sense, improved access to digital finance may be insufficient to induce CSA change when the binding constraints are agronomic knowledge, risk perceptions, or collective action.

Table 4: Determinants of CSA Adoption (Inter-cropping)

VARIABLES	Model (1)	Model (2)	Model (3)	Full Model (4)
DFL Index	0.013 (0.008)	0.012 (0.008)	0.013* (0.008)	0.017** (0.009)
HH distance to market	-0.035 (0.026)	-0.040 (0.026)	-0.034 (0.026)	-0.032 (0.026)
HH age	0.026*** (0.009)			0.017* (0.010)
HH gender (1=Female)	-0.268 (0.233)			-0.307 (0.232)
HH marital status	-0.195 (0.346)			-0.115 (0.353)
HH size	-0.047 (0.053)			0.008 (0.060)
HH primary educ	-0.328 (0.315)			-0.530* (0.321)
HH lower secondary educ	0.062 (0.370)			-0.129 (0.374)
HH upper secondary / Higher educ	0.336 (0.411)			0.137 (0.429)
Economic dependency ratio		-0.343** (0.171)		-0.226 (0.182)
Expenditure (log)		-0.326* (0.191)		-0.370* (0.216)
Farm size (log)		-0.394 (0.392)		-0.470 (0.413)
Number of land plots		0.181*** (0.067)		0.193*** (0.073)
Access to pipe water		0.031 (0.230)		0.043 (0.245)
Member of association		0.016 (0.305)		-0.222 (0.333)
Perceive climate impact			0.419*** (0.110)	0.455*** (0.116)
Perceive inform			0.461** (0.182)	0.468** (0.190)
Perceive support			0.110 (0.100)	0.096 (0.100)
Perceive climate severity			-0.234 (0.147)	-0.222 (0.155)
Constant	-2.351*** (0.782)	-0.188 (1.104)	-1.760** (0.771)	-0.520 (1.603)
Observations	816	816	816	816
Province FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Mean VIF	1.75	1.83	1.72	1.88
Log Pseudolikelihood	-354.397	-354.968	-351.447	-337.428

Note: Logistic regression is used for the estimation. Dependent variable: Inter-Cropping. Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

5.3. Impacts of DFS Usage and CSA Adoption on Food Security

Using the HFIAS/FHIAS-based categories, the results suggest that CSA adoption proxied by intercropping is associated with a more favourable food-security profile, most clearly through a lower likelihood of severe food insecurity. This pattern is consistent with the CSA resilience logic emphasized in the literature: diversification and improved soil–water management can stabilize yields and reduce vulnerability to climate shocks, thereby protecting households from the most acute food-access constraints. For example, Maitra et al. (2021) suggest that diversified production strategies can improve yield stability under climate variability, while evidence on intercropping highlights pathways through soil fertility improvement and risk reduction that can strengthen resilience. In addition, the way these effects show up along the food-insecurity spectrum is consistent with how the HFIAS captures severity gradients: Coates et al. (2007) explain that HFIAS ranges from anxiety and quality compromise to quantity reductions and severe deprivation, which makes it well-suited for detecting shifts away from extreme food stress even if milder stress remains (Coates et al., 2007).

At the same time, the finding that mild food insecurity may increase in some specifications, even as severe food insecurity declines, is also consistent with the literature when interpreted through short-run adjustment costs. CSA adoption can require up-front expenditures, learning-by-doing, labour reallocation, and transitional yield variability costs that may temporarily increase reported worries about food or reduced dietary variety without necessarily pushing households into extreme deprivation. This interpretation aligns with studies emphasizing heterogeneity in CSA welfare effects across time and vulnerability levels. For instance, Wanglin and Rahut (2024) suggest that CSA benefits can be uneven and conditional on complementary inputs and constraints, while Cambodia-relevant evidence similarly indicates that impacts differ across food-security strata and may not uniformly reduce food insecurity for the most vulnerable households (Oum et al., 2023).

Digital financial capability appears to matter mainly through indirect pathways, rather than through a large, immediate direct effect on food insecurity. In line with the GSEM results, Yang et al. (2024) suggest that digital finance can relax transaction and liquidity constraints, which can enable productive decisions and improve coping capacity; however, broader reviews also stress that digital tools typically deliver welfare gains when embedded in an enabling ecosystem rather than operating as a stand-alone solution (Mapanje et al., 2023; Njuguna et al., 2025). Relatedly, Hussain et al. (2025) suggest that digital capability can strengthen climate adaptation and food security through adoption and information channels, which is consistent with the interpretation where DFL does not directly reduce HFIAS, but increases the likelihood of intercropping, and the adoption pathway is where food-security gains are most likely to arise (Hussain et al., 2025; Liu et al., 2025).

Table 5: Effects of DFL and CSA Adoption on Food Security using GSEM

VARIABLES	(1) Inter-cropping	(2) HFIAS score
<i>Mediator</i>		
Inter-cropping		-0.031 (0.169)
<i>Independent Variable</i>		
DFL Index	0.017** (0.009)	-0.001 (0.006)
<i>Additional Controls</i>		
HH distance to market	-0.032 (0.026)	
HH age	0.017* (0.010)	-0.004 (0.007)
HH gender (1=Female)	-0.307 (0.232)	0.150 (0.172)
HH marital status	-0.115 (0.353)	-0.122 (0.247)
HH size	0.008 (0.060)	-0.000 (0.037)
HH primary educ	-0.530* (0.321)	-0.659*** (0.235)
HH lower secondary educ	-0.129 (0.374)	-0.504* (0.271)
HH upper secondary / Higher educ	0.137 (0.429)	-0.684** (0.295)
Economic dependency ratio	-0.226 (0.182)	0.148 (0.110)
Expenditure (log)	-0.370* (0.216)	-0.274* (0.144)
Farm size (log)	-0.470 (0.413)	0.197 (0.189)
Number of land plots	0.193*** (0.073)	-0.150*** (0.057)
Access to pipe water	0.043 (0.245)	-0.389** (0.166)
Member of association	-0.222 (0.333)	-0.427* (0.246)
Perceive climate impact	0.455*** (0.116)	0.056 (0.086)
Perceive inform	0.468** (0.190)	-0.101 (0.145)
Perceive support	0.096 (0.100)	-0.113* (0.065)
Perceive climate severity	-0.222 (0.155)	-0.003 (0.108)
Constant	-0.520 (1.603)	
Observations		816
Province FE		YES
Year FE		YES
<i>Log Pseudolikelihood</i>		-1360.784

Note: Logistic regression is used for model 1 and Ordered Logistic regression for model 2. Dependent Variable: HFIAS Category (1=Food Secure, 2=Mildly Food Insecure, 3=Moderately Food Insecure, 4=Severely Food Insecure). Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 6 presents findings from different household food security category. The results reveal a clear distributional pattern in which intercropping is associated with a significant reduction in the probability of being mildly food insecure, but it shows no statistically significant effect for the moderately or severely food-insecure groups. This is broadly consistent with the idea that diversification-oriented CSA practices can first ease everyday food stress such as anxiety about food and reduced dietary variety without immediately shifting households out of deeper deprivation. In line with, Oum et al. (2023) suggest that intercropping has limited ability to reduce food insecurity among moderately and severely food-insecure households but has a capacity to reduce mild food insecurity, which aligns closely with the non-effects in those categories.

This pattern is also consistent with how food insecurity is measured using HFIAS. Coates et al. (2007) explain that HFIAS captures a severity gradient from worry and compromised food quality to reduced food quantity and extreme deprivation, so an intervention may reduce mild insecurity (quality/worry) even if it does not yet eliminate moderate or severe insecurity (quantity constraints). Viewed through this lens, the finding is not paradoxical; rather, it implies that CSA adoption may generate incremental improvements that appear first at the lower end of the distribution, while moving households out of moderate or severe food insecurity likely requires stronger and broader changes—such as higher incomes, improved services, and shock protection. This interpretation fits the wider CSA literature such as Wanglin and Rahut (2024) that emphasizes heterogeneity in welfare impacts and the importance of complementary conditions for larger food-security gains.

The results also indicate that the most consistent drivers of food-security status are household capacity and enabling conditions—including education, expenditure capacity, basic services, and social capital—rather than CSA adoption alone. This aligns with the broader development literature showing that severe food insecurity is often rooted in structural constraints (limited assets, high dependency burdens, inadequate services, and weak risk-coping mechanisms), which can overwhelm the incremental benefits of farm-practice changes. For instance, the protective roles of education and infrastructure are consistent with evidence that human capital and basic services strengthen households' ability to translate agricultural innovations into welfare improvements (Coates et al., 2007; Wanglin & Rahut, 2024). Likewise, the positive association between association membership and better food-security categories is consistent with arguments that social capital improves access to information, coordination, and support—channels that matter for both adoption and resilience.

When positioning these findings against the CSA–digital inclusion literature, the results are more consistent with conditional-impact arguments than with studies that report large, direct welfare gains from single interventions. Mapanje et al. (2023) argue that many claims about digital finance, climate adaptation, and food security rely on indirect mechanisms and enabling conditions, and that outcomes depend heavily on context and complementary support (Mapanje et al., 2023). In contrast, some empirical studies find more direct improvements in food security linked to digital capability or financial inclusion; for example, Hussain et al. (2025) suggest stronger positive links between digital capability, CSA adoption, and food security in their setting. The weaker effects for moderate/severe food insecurity are therefore best framed as

contextually plausible rather than contradictory; they imply that where baseline vulnerability is high, CSA adoption alone may be insufficient, and stronger bundles—combining CSA with capability-building, extension, and targeted support—are needed to produce measurable improvements at the severe end of food insecurity (Oum et al., 2023; Wanglin & Rahut, 2024)

Table 6: Effects of DFL and CSA Adoption on Food Security using GSEM

VARIABLES	(1) Food Secure	(2) Mildly Food Insecure	(3) Moderately Food Insecure	(4) Severely Food Insecure
Mediator				
intercropping	0.210 (0.217)	-0.448** (0.229)	0.142 (0.232)	0.051 (0.327)
Additional Control				
HH age	0.000 (0.008)	0.008 (0.009)	-0.003 (0.010)	-0.012 (0.011)
HH gender (1=Female)	-0.365* (0.199)	0.605*** (0.219)	-0.112 (0.228)	-0.005 (0.306)
HH marital status	-0.145 (0.271)	0.854** (0.372)	-0.365 (0.286)	-0.244 (0.380)
HH size	-0.035 (0.047)	0.051 (0.050)	0.055 (0.052)	-0.114 (0.077)
HH primary educ	0.496* (0.257)	0.540* (0.293)	-0.519** (0.253)	-0.771** (0.361)
HH lower secondary educ	0.476 (0.295)	0.333 (0.340)	-1.002*** (0.314)	0.301 (0.378)
HH upper secondary / Higher educ	0.502 (0.353)	-0.723* (0.389)	-0.673* (0.389)	-1.155* (0.613)
Economic dependency ratio	-0.202 (0.158)	-0.000 (0.141)	0.118 (0.159)	0.115 (0.171)
Expenditure (log)	0.287* (0.171)	0.138 (0.188)	-0.451** (0.191)	-0.140 (0.248)
Farm size (log)	-0.319 (0.275)	-0.230 (0.309)	0.880*** (0.269)	-0.356 (0.376)
Number of land plots	0.197*** (0.071)	-0.026 (0.067)	-0.312*** (0.078)	0.059 (0.100)
Access to pipe water	0.361* (0.190)	0.079 (0.202)	-0.277 (0.246)	-0.481* (0.271)
Member of association	0.692** (0.287)	-0.685** (0.324)	-0.158 (0.328)	-0.248 (0.458)
Perceive climate impact	0.286*** (0.107)	-0.423*** (0.111)	-0.045 (0.117)	-0.209 (0.142)
Perceive inform	0.043 (0.174)	0.233 (0.180)	-0.149 (0.191)	-0.168 (0.292)
Perceive support	0.056 (0.081)	-0.150* (0.088)	-0.034 (0.098)	-0.338*** (0.122)
Perceive climate severity	0.317** (0.129)	-0.647*** (0.143)	-0.111 (0.139)	-0.385** (0.157)
Constant	-1.647 (1.218)	-6.827*** (1.355)	3.417** (1.352)	2.176 (1.760)
Observations	816	816	816	816
Province FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
<i>Log Pseudolikelihood</i>	-814.816	-769.663	-727.203	-603.831

Note: Logistic regression is used. The results on first equation are excluded as they are the same as those in Table 6. Dependent Variable: HFIAS dummies (Food Secure, Mildly Food Insecure, Moderately Food Insecure, Severely Food Insecure). Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

7. CONCLUSION

This study examines how digital financial literacy (DFL) and the use of digital financial services relates to climate-smart agriculture (CSA) adoption and household food security among rural farming households in Cambodia. The motivation arises from the persistent vulnerability of smallholders to climate shocks and price volatility, alongside uneven access to finance, information, and risk-management tools that shape their ability to adopt and sustain climate-resilient practices. While digital finance is increasingly promoted as a pathway to strengthen inclusion and resilience, access alone does not guarantee effective use. In practice, gaps in knowledge, trust, and digital safety can limit uptake and reduce the potential of digital tools to support productive investments and coping strategies. Understanding whether DFL and DFS translate into CSA adoption and improved food security is therefore critical for designing integrated interventions that address both climate risks and capability constraints.

Using repeat cross-sectional household survey data collected in 2023 and 2025 across four provinces, the study first estimated the determinants of DFL/DFS use and CSA adoption, and then assessed the association between CSA adoption and food security outcomes. The empirical results indicate that DFS use is shaped by a capability and connectedness where households with stronger socioeconomic capacity and better access to information are more likely to engage with digital financial tools, suggesting that digital inclusion depends on skills and relevance, not only infrastructure. CSA adoption, in turn, is more consistently associated with climate-risk perceptions and enabling conditions, particularly exposure to information and training and the presence of social support, highlighting the central role of local advisory systems and community networks in converting climate awareness into practice change. To account for potential self-selection in adoption, the analysis employed an econometric strategy designed to correct for unobserved factors that may jointly influence adoption decisions and welfare outcomes. Although the results suggest that CSA adoption have no statistically significance linked to improved food security, it shows a strong indication of reducing mildly food insecure among marginalized household by 44.5%. An empirical pattern consistent with short-run adjustment costs during the transition to new practices. At the same time, the effects are weaker among moderately and severely food-insecure households, implying that the most vulnerable groups face binding constraints that CSA adoption alone may not fully resolve.

The findings provide policy-relevant insights for strengthening climate-resilient and inclusive rural development strategies. Digital financial capability can support resilience, but its impact is likely to be realized through integrated programming rather than “digital-only” approaches. DFL interventions should be designed around practical farmer use-cases (e.g., receiving payments, purchasing inputs, saving for lean seasons, and basic risk-management) and paired with consumer protection and fraud-prevention content to build trust and safe use. Second, CSA scaling should prioritize the strongest correlates of adoption—trusted information delivery, training exposure, demonstration effects, and peer learning—by strengthening extension systems and community-based support mechanisms. Third, because adoption can involve transitional costs and uneven gains, CSA promotion should be bundled with complementary measures that relax binding constraints among the most food-insecure households, such as seasonal liquidity support, market linkages, and shock-responsive

assistance. A more targeted, capability-informed approach—combining CSA promotion with digital literacy, advisory services, and well-designed support packages—can better translate adoption into sustained improvements in food security and household resilience in Cambodia.

8. REFERENCES

- ADB. (2019). *Cambodia: Agriculture, natural resources, and rural development sector assessment, strategy, and road map*. <https://www.adb.org/sites/default/files/institutional-document/531956/cambodia-agriculture-natural-resources-rural-development-roadmap.pdf>
- ADB. (2019). *Climate Smart Practices for Intensive Rice Based System in Bangladesh, Cambodia, and Nepal*. <https://www.adb.org/sites/default/files/publication/533186/climate-smart-rice-systems-ban-cam-nep.pdf>.
- Asante, B. O., Prah, S., Akutinga, S., Akusaki, E. T., & Ofosuhene, A. D. (2025). Climate resilience in the palm of a hand: digital financial inclusion and cocoa farmers' adoption of climate smart agricultural technologies in Ghana. *Future Business Journal*, 11(1), 213. <https://doi.org/10.1186/s43093-025-00624-5>
- Bahn, R. A., Yehya, A. A. K., & Zurayk, R. (2021). Digitalization for sustainable agri-food systems: potential, status, and risks for the MENA region. *Sustainability*, 13(6), 3223. <https://doi.org/10.3390/su13063223>
- Balyan, S., Jangir, H., Tripathi, S. N., Tripathi, A., Jhang, T., & Pandey, P. (2024). Seeding a sustainable future: navigating the digital horizon of smart agriculture. *Sustainability*, 16(2), 475. <https://doi.org/10.3390/su16020475>
- Burgess, A. J., Cano, M. E. C., & Parkes, B. (2022). The deployment of intercropping and agroforestry as adaptation to climate change. *Crop and Environment*, 1(2), 145-160. <https://doi.org/10.1016/j.crope.2022.05.001>
- Coates, J., Swindale, A., & Bilinsky, P. (2007). Household food insecurity access scale (HFIAS) for measurement of food access: indicator guide: version 3. https://www.fantaproject.org/sites/default/files/resources/HFIAS_ENG_v3_Aug07.pdf
- Deaton, A. (1985). Panel data from time series of cross-sections. *Journal of econometrics*, 30(1-2), 109-126. [https://doi.org/10.1016/0304-4076\(85\)90134-4](https://doi.org/10.1016/0304-4076(85)90134-4)
- Food and Agriculture Organization of the United Nations (FAO). (2010). *Climate-Smart Agriculture: Policies, Practices and Financing for Food Security, Adaption and Mitigation*. Food and Agriculture Organization of the United Nations. <https://openknowledge.fao.org/bitstream/handle/20.500.14283/i1881e/i1881e00.pdf>
- Food and Agriculture Organization of the United Nations (FAO). (2021). *Cambodia agriculture survey 2021*. <https://www.fao.org/3/cc4141en/cc4141en.pdf>
- Gao, X., & Gao, R. (2024). A study of the impact of digital financial inclusion on the resilience of the agricultural chain. *Frontiers in Sustainable Food Systems*, 8, 1448550. <https://doi.org/10.3389/fsufs.2024.1448550>
- Gong, S., Sun, Z., Wang, B., & Yu, Z. (2024). Could digital literacy contribute to the improvement of green production efficiency in agriculture?. *Sage Open*, 14(1), <https://doi.org/10.1177/21582440241232789>
- GSMA. (2023). *The state of mobile internet connectivity 2023*. <https://www.gsma.com/r/wp-content/uploads/2023/10/The-State-of-Mobile-Internet-Connectivity-Report-2023.pdf>
- Hair, J., & Sarstedt, M. (2019). Factors versus Composites: Guidelines for Choosing the Right Structural Equation Modeling Method. *Project Management Journal*, 50, 619 - 624. <https://doi.org/10.1177/8756972819882132>.

- Hussain, S., Ur Rehman, K., & Iqbal, I. (2025). Digital financial inclusion and sustainable agriculture: an empirical analysis from rural areas of Pakistan. *Journal of Agribusiness in Developing and Emerging Economies*, 1-17. <https://doi.org/10.1108/jadee-05-2025-0197>
- IPCC. (2019). *Climate change and land: An IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*. https://www.ipcc.ch/site/assets/uploads/sites/4/2022/11/SRCCL_Full_Report.pdf
- ITU. (2022). *Digital trends in Asia and the Pacific 2022: ICT infrastructure and services*. https://www.itu.int/en/ITU-D/Statistics/Documents/DDD/ddd_KHM.pdf
- Liu, J., & Ren, Y. (2023). Can digital inclusive finance ensure food security while achieving low-carbon transformation in agricultural development? Evidence from China. *Journal of Cleaner Production*, 418, 138016. <https://doi.org/10.1016/j.jclepro.2023.138016>
- Liu, Y., & Li, X. (2025). Digital financial capability and adaptive investment behavior in smallholder systems. *Frontiers in Sustainable Food Systems*, 9, 1621851. <https://doi.org/10.3389/fsufs.2025.1621851>
- Liu, Z., Qi, Z., Tian, Q., Clark, J. S., & Zhang, Z. (2024). The impact of digital finance on farmers' adoption of eco-agricultural technology: Evidence from rice-crayfish co-cultivation technology in China. *Agriculture*, 14(4), 611. <https://doi.org/10.3390/agriculture14040611>
- Ma, W., & Rahut, D. B. (2024). Climate-smart agriculture: adoption, impacts, and implications for sustainable development. *Mitigation and Adaptation Strategies for Global Change*, 29(5), 44. <https://doi.org/10.1007/s11027-024-10139-z>
- MAFF. (2023). *Annual report on agriculture, forestry and fisheries 2022-2023*. <https://www.maff.gov.kh/en/documents/annual-reports>
- Maitra, S., Hossain, A., Brestic, M., Skalicky, M., Ondrisik, P., Gitari, H., ... & Sairam, M. (2021). Intercropping—A low input agricultural strategy for food and environmental security. *Agronomy*, 11(2), 343. <https://doi.org/10.3390/agronomy11020343>
- Mao, H., Chai, Y., Shao, X., & Chang, X. (2024). Digital extension and farmers' adoption of climate adaptation technology: An empirical analysis of China. *Land Use Policy*, 143, 107220. <https://doi.org/10.1016/j.landusepol.2024.107220>
- Mapanje, O., Karuaihe, S., Machethe, C., & Amis, M. (2023). Financing sustainable agriculture in sub-saharan africa: a review of the role of financial technologies. *Sustainability*, 15(5), 4587. <https://doi.org/10.3390/su15054587>
- Mnukwa, S., & Dlamini, T. (2025). Gendered barriers in digital financial inclusion: Evidence from rural smallholders. *Journal of Rural Studies*, 112, 45-59. <https://doi.org/10.1016/j.jrurstud.2025.01.004>
- Mujeyi, A., Mudhara, M., & Mutenje, M. (2021). The impact of climate smart agriculture on household welfare in smallholder integrated crop–livestock farming systems: evidence from Zimbabwe. *Agriculture & Food Security*, 10(1), 4. <https://doi.org/10.1186/s40066-020-00277-3>
- Mushi, G. E., Di Marzo Serugendo, G., & Burgi, P. Y. (2022). Digital technology and services for sustainable agriculture in Tanzania: A literature review. *Sustainability*, 14(4), 2415. <https://doi.org/10.3390/su14042415>
- Mwalupaso, G. E., Eshetie, A. M., Matafwali, E., Akter, A., Lu, H., & Geng, X. (2025). Rethinking household food security under a changing climate in drought prone areas of Ethiopia. *Land Use Policy*, 150, 107437. <https://doi.org/10.1016/j.landusepol.2024.107437>

- Mwalupaso, G. E., Geng, X., & Yasin, S. I. (2025). Financial inclusion for sustainable agriculture: Pathways among smallholder women farmers in rural Zambia. *Plos one*, 20(7), e0326980. <https://doi.org/10.1371/journal.pone.0326980>
- Mwanzia, D. K., & Kitui, M. (2025). Impact of agricultural financial services accessibility on the adoption of climate-smart agriculture practices. *African Journal of Climate Change and Resource Sustainability*, 9(2), 201-215. <https://doi.org/10.37284/ajccrs.9.2.3549>
- NBC (2019). *National Financial Inclusion Strategy (2019-2025)*. https://www.nbc.gov.kh/download_files/publication/blueprints_eng/Final_NFIS_in_English.pdf
- NIS. (2023). *Cambodia Agriculture Survey 2023: Crop production*. https://www.nis.gov.kh/nis/CAS/2023/CAS2023_Report_2_Crop_Production_ENG.pdf
- Njuguna, E., Daum, T., Birner, R., & Mburu, J. (2025). Silicon Savannah and smallholder farming: How can digitalization contribute to sustainable agricultural transformation in Africa?. *Agricultural Systems*, 222, 104180. <https://doi.org/10.1016/j.agsy.2024.104180>
- Nong, M., Sean, C., Khan, D., Nhong Sodavy, Bunnath, Z. S., So, L., & Ngim, C. (2024). *Climate Change and Migration Patterns: Findings at the Commune Level in Rural Provinces of Cambodia*. Cambodia Development Resource Institute (CDRI): Phnom Penh
- OECD. (2022). *OECD/INFE 2023 international survey of adult financial literacy*. https://www.oecd.org/content/dam/oecd/en/publications/reports/2023/12/oecd-infe-2023-international-survey-of-adult-financial-literacy_562541a3/57388703.pdf
- Oum, C. M., Voe, P., & Hout, C. (2023). A Climate-Smart Agriculture Practice in Cambodia: Smallholder's Uptake of Intercropping and Food Security. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5944714
- Pramesti, G. N. D. P. (2025). AgriTech Innovation and Food Security: Balancing Technological Disruption and Smallholder Inclusion. *Jurnal Ekonomi Teknologi dan Bisnis (JETBIS)*, 4(3), 116-127. <https://doi.org/10.57185/aqg24191>
- Quarshie, P. T., Abdulai, A. R., Duncan, E., Kc, K. B., Roth, R., Sneyd, A., & Fraser, E. D. (2023). Myth or reality? The Digitalization of Climate-Smart Agriculture (DCSA) practices in smallholding agriculture in the Bono East Region of Ghana. *Climate Risk Management*, 42, 100553. <https://doi.org/10.1016/j.crm.2023.100553>
- Seuyong, F. T., Silwal, A. R., Begazo, T., Newhouse, D., & N'Ghauran, A. (2023). The size and distribution of digital connectivity gaps in sub-Saharan Africa. *Washington, DC: World Bank*. <https://openknowledge.worldbank.org/entities/publication/89ed049c-5c22-5975-a59a-0bba5254bde2>
- Teklemichael, M., & Mekuriaw, A. (2025). Effect of Adoption Intensity of Climate Smart Agriculture on Farming Households' Food Security in Ethiopia: Empirical Evidence From Guna Begemider District, South Gonder. *SAGE Open*, 15(3). <https://doi.org/10.1177/21582440251358326>
- UNEP. (2026). *Cambodia Initiates National Action to Phase Out Hazardous Chemicals in Key Supply Chains*. <https://www.unep.org/gef/news-and-stories/press-release/cambodia-initiates-national-action-phase-out-hazardous-chemicals-key>
- USAID. (2021). *Cambodia digital economy landscape assessment*. https://pdf.usaid.gov/pdf_docs/PA00Z7MQ.pdf
- Wakweya, R. B. (2023). Challenges and prospects of adopting climate-smart agricultural practices and technologies: Implications for food security. *Journal of Agriculture and Food Research*, 14, 100698. <https://doi.org/10.1016/j.jafr.2023.100698>

- World Bank. (2020). *Cambodia economic update: Cambodia in the time of COVID-19*.
<https://documents1.worldbank.org/curated/en/362611590675713437/pdf/Cambodia-Economic-Update-Cambodia-in-the-Time-of-COVID-19.pdf>
- Wu, Y., & Zhang, J. (2025). Digital inclusive finance and rural households' economic resilience. *Finance Research Letters*, 74, 106706.
- Xu, Y., Faraz, A., Sarfraz, M., Arshad, S., Sun, J., & Ahmad, A. (2025). Strategic Capabilities for Sustainability: An Integrated Model of Digital Inclusion and Sustainable Performance. *Sustainable Development*, 34(1), 1112-1128.
<https://doi.org/10.1002/sd.70306>
- Yang, C., Ji, X., Cheng, C., Liao, S., Obuobi, B., & Zhang, Y. (2024). Digital economy empowers sustainable agriculture: Implications for farmers' adoption of ecological agricultural technologies. *Ecological Indicators*, 159, 111723.
<https://doi.org/10.1016/j.ecolind.2024.111723>
- Zegeye, D. M., & Ebrahim, A. (2025). Harnessing Data-Driven Innovations for Climate-Smart Agriculture in East Africa. *Agriculturae Conspectus Scientificus*, 90(4), 263-269. <https://acs.agr.hr/acs/index.php/acs/article/view/2665>
- Zheng, F., Chen, S., & Wang, X. (2025). How the impact and mechanisms of digital financial inclusion on agricultural carbon emission intensity: new evidence from a double machine learning model. *Frontiers in Environmental Science*.
<https://doi.org/10.3389/fenvs.2025.1549623>

Appendix

Correlation Matrix

Table 1A : Correlation matrix for the determinants of DFS usage

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) DFS Usage	1.000									
(2) HH age	-0.098***	1.000								
(3) HH gender	-0.193***	-0.086**	1.000							
(4) HH size	-0.042	0.055	0.002	1.000						
(5) HH Education	0.050	-0.245***	0.002	0.021	1.000					
(6) Economic dependency ratio	-0.035	-0.252***	0.078**	0.220***	0.021	1.000				
(7) Expenditure (log)	-0.123***	-0.175***	0.357***	0.282***	0.193***	0.113***	1.000			
(8) Farm size (log)	-0.038	0.007	0.122***	0.039	0.003	0.023	-0.068*	1.000		
(9) Member of association	0.007	0.056*	-0.003	0.006	0.067*	-0.050	0.047	0.056*	1.000	
(10) Number of land plots	0.023	0.004	0.176***	0.028	0.137***	-0.023	0.170***	0.472***	0.100***	1.000
(11) Distance to market (log)	0.018	0.049	-0.086**	-0.059*	-0.099***	0.001	-0.266***	0.224***	0.037	-0.007
(12) Perceive climate impact	-0.101***	0.002	0.046	0.051	0.081**	-0.055	0.305***	-0.108***	0.017	0.056*
(13) Perceive inform	-0.070**	0.012	0.137***	-0.062*	0.019	0.067*	0.113***	0.058*	0.129***	0.075**
(14) Perceive support	-0.023	0.070**	0.033	-0.034	-0.019	-0.053	0.034	-0.031	0.089**	-0.030
(15) Perceive climate severity	0.056*	-0.013	0.224***	0.023	0.080**	-0.015	0.333***	0.073**	0.051	0.193***
(16) Province	-0.229***	0.054	0.047	-0.036	-0.306***	0.095***	-0.339***	0.385***	0.016	-0.053
(17) Year	0.279***	0.080**	-0.581***	-0.073**	-0.048	-0.109***	-0.642***	-0.157***	-0.060*	-0.257***

Variables	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(11) Distance to market (log)	1.000						
(12) Perceive climate impact	-0.138***	1.000					
(13) Perceive inform	-0.023	-0.003	1.000				
(14) Perceive support	0.005	0.006	-0.042	1.000			
(15) Perceive climate severity	0.017	-0.107***	-0.059*	-0.037	1.000		

(16) Province	0.420***	-0.179***	0.121***	0.003	-0.192***	1.000				
(17) Year	0.178***	-0.129***	-0.204***	-0.007	-0.474***	0.023	1.000			

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 1A: Correlation matrix for the determinants of CSA Adoption

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) CSA adopter	1.000									
(2) DFS Usage	-0.074**	1.000								
(3) Distance to market (log)	0.054	0.018	1.000							
(4) HH age	0.011	-0.098***	0.049	1.000						
(5) HH gender	0.119***	-0.193***	-0.086**	-0.086**	1.000					
(6) HH Marital status	0.054	0.021	-0.008	-0.220***	-0.062*	1.000				
(7) HH size	0.014	-0.042	-0.059*	0.055	0.002	0.169***	1.000			
(8) HH education	0.035	0.050	-0.099***	-0.245***	0.002	0.214***	0.021	1.000		
(9) Economic dependency ratio	0.007	-0.035	0.001	-0.252***	0.078**	0.019	0.220***	0.021	1.000	
(10) Expenditure (log)	0.104***	-0.123***	-0.266***	-0.175***	0.357***	0.190***	0.282***	0.193***	0.113***	1.000
(11) Farm size (log)	0.073**	-0.038	0.224***	0.007	0.122***	0.013	0.039	0.003	0.023	-0.068*
(12) Number of land plots	0.098***	0.023	-0.007	0.004	0.176***	0.051	0.028	0.137***	-0.023	0.170***
(13) Access to pipe water	-0.035	0.178***	-0.230***	0.077**	-0.085**	-0.008	0.017	0.133***	-0.095***	0.069**
(14) Member of association	0.082**	0.007	0.037	0.056*	-0.003	0.034	0.006	0.067*	-0.050	0.047
(15) Perceive climate impact	0.177***	-0.101***	-0.138***	0.002	0.046	0.016	0.051	0.081**	-0.055	0.305***
(16) Perceive inform	0.265***	-0.070**	-0.023	0.012	0.137***	0.007	-0.062*	0.019	0.067*	0.113***
(17) Perceive support	0.184***	-0.023	0.005	0.070**	0.033	-0.008	-0.034	-0.019	-0.053	0.034
(18) Perceive climate severity	0.005	0.056*	0.017	-0.013	0.224***	0.063*	0.023	0.080**	-0.015	0.333***
(19) Province	0.050	-0.229***	0.420***	0.054	0.047	-0.097***	-0.036	-0.306***	0.095***	-0.339***
(20) Year	-0.150***	0.279***	0.178***	0.080**	-0.581***	-0.047	-0.073**	-0.048	-0.109***	-0.642***

Variables	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
(11) Farm size (log)	1.000									
(12) Number of land plots	0.472***	1.000								
(13) Access to pipe water	-0.255***	-0.029	1.000							

(14) Member of association	0.056*	0.100***	0.006	1.000						
(15) Perceive climate impact	-0.108***	0.056*	-0.009	0.017	1.000					
(16) Perceive inform	0.058*	0.075**	-0.114***	0.129***	-0.003	1.000				
(17) Perceive support	-0.031	-0.030	0.069**	0.089**	0.006	-0.042	1.000			
(18) Perceive climate severity	0.073**	0.193***	0.059*	0.051	-0.107***	-0.059*	-0.037	1.000		
(19) Province	0.385***	-0.053	-0.470***	0.016	-0.179***	0.121***	0.003	-0.192***	1.000	
(20) Year	-0.157***	-0.257***	0.153***	-0.060*	-0.129***	-0.204***	-0.007	-0.474***	0.023	1.000

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 2A: Correlation matrix for the Effects of CSA Adoption on Food Security

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) Food secure	1.000									
(2) Mildly food insecure	-0.496***	1.000								
(3) Moderately food insecure	-0.416***	-0.372***	1.000							
(4) Severely food insecure	-0.245***	-0.220***	-0.184***	1.000						
(5) CSA adopter	0.016	0.072**	-0.052	-0.065*	1.000					
(6) DFS usage	0.153***	-0.060*	-0.068*	-0.055	-0.074**	1.000				
(7) HH age	-0.015	-0.011	0.006	0.033	0.011	-0.098***	1.000			
(8) HH gender	-0.158***	0.155***	-0.043	0.076**	0.119***	-0.193***	-0.086**	1.000		
(9) HH marital status	-0.012	0.093***	-0.012	-0.107***	0.054	0.021	-0.220***	-0.062*	1.000	
(10) HH size	-0.028	0.067*	-0.015	-0.037	0.014	-0.042	0.055	0.002	0.169***	1.000
(11) HH education	0.068*	0.072**	-0.073**	-0.118***	0.035	0.050	-0.245***	0.002	0.214***	0.021
(12) Economic dependency ratio	-0.066*	0.010	0.032	0.044	0.007	-0.035	-0.252***	0.078**	0.019	0.220***
(13) Expenditure (log)	-0.068*	0.222***	-0.063*	-0.144***	0.104***	-0.123***	-0.175***	0.357***	0.190***	0.282***
(14) Farm size (log)	-0.042	-0.040	0.064*	0.039	0.073**	-0.038	0.007	0.122***	0.013	0.039
(15) Number of land plots	0.041	0.026	-0.036	-0.055	0.098***	0.023	0.004	0.176***	0.051	0.028
(16) Access to pipe water	0.155***	-0.010	-0.074**	-0.127***	-0.035	0.178***	0.077**	-0.085**	-0.008	0.017
(17) Member of association	0.071**	-0.032	0.007	-0.074**	0.082**	0.007	0.056*	-0.003	0.034	0.006
(18) Province	-0.132***	-0.066*	0.083**	0.197***	0.050	-0.229***	0.054	0.047	-0.097***	-0.036
(19) Year	0.207***	-0.163***	-0.064*	0.011	-0.150***	0.279***	0.080**	-0.581***	-0.047	-0.073**

Variables	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
(11) HH education	1.000								
(12) Economic dependency ratio	0.021	1.000							
(13) Expenditure (log)	0.193***	0.113***	1.000						
(14) Farm size (log)	0.003	0.023	-0.068*	1.000					
(15) Number of land plots	0.137***	-0.023	0.170***	0.472***	1.000				
(16) Access to pipe water	0.133***	-0.095***	0.069**	-0.255***	-0.029	1.000			
(17) Member of association	0.067*	-0.050	0.047	0.056*	0.100***	0.006	1.000		
(18) Province	-0.306***	0.095***	-0.339***	0.385***	-0.053	-0.470***	0.016	1.000	
(19) Year	-0.048	-0.109***	-0.642***	-0.157***	-0.257***	0.153***	-0.060*	0.023	1.000

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Additional Results

Table : Determinants of digital financial literacy (2025 Survey Only)

Variables	(1) OLS	(2) Tobit
HH age	-0.112*** (0.024)	-0.112*** (0.023)
HH gender	-0.912 (0.626)	-0.912 (0.611)
HH size	-0.129 (0.137)	-0.129 (0.134)
HH primary educ	0.867 (0.655)	0.867 (0.640)
HH lower secondary educ	1.781** (0.872)	1.781** (0.852)
HH upper secondary / Higher educ	2.746** (1.392)	2.746** (1.361)
Economic dependency ratio	-0.480 (0.452)	-0.480 (0.442)
Expenditure (log)	1.050* (0.626)	1.050* (0.612)
Farm size (log)	-1.735 (1.055)	-1.735* (1.031)
Member of association	2.184* (1.202)	2.184* (1.175)
Number of land plots	-0.479 (0.302)	-0.479 (0.295)
Distance to market (log)	0.012 (0.478)	0.012 (0.468)
Perceive climate impact	0.461 (0.408)	0.461 (0.399)
Perceive inform	1.394** (0.596)	1.394** (0.582)
Perceive support	0.487 (0.349)	0.487 (0.341)
Perceive climate severity	0.515 (0.388)	0.515 (0.379)
Constant	11.369*** (3.936)	11.369*** (3.847)
Province FE	YES	YES
Observations	425	425

<i>R-squared</i>	0.328	
<i>Sigma</i>		5.318
<i>Mean VIF</i>	1.80	1.80

*Note: Dependent variable: Digital Financial Literacy (DFL) Index. Only survey data in 2025 is used for this regression. Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*