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Climate-smarts agriculture and the sustainable livelihoods approach: An integrated framework for smallholder resilience

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Abstract

Climate-Smart Agriculture (CSA) has emerged as a dominant paradigm for addressing the triple challenge of food security, climate adaptation, and mitigation. However, CSA interventions frequently focus on technological and biophysical dimensions while neglecting the broader socio-economic and institutional contexts that shape smallholder livelihoods. This paper proposes an integrated conceptual framework combining CSA with the Sustainable Livelihoods Approach (SLA). Drawing on a comprehensive review of literature, we argue that SLA's five capital assets — human, social, natural, physical, and financial — provide an operational lens for diagnosing vulnerability and designing context-specific CSA interventions. The integrated framework highlights three critical pathways: (1) asset-building as the foundation for adaptive capacity; (2) institutional and policy environments as mediators of CSA outcomes; and (3) feedback loops between livelihood outcomes and asset stocks. Information and Communication Technologies (ICT) are positioned as a cross-cutting enabling mechanism within this framework. We illustrate the framework's utility through examples from South Asia and sub-Saharan Africa — including the information-to-income gap observed in ICT interventions, index-based insurance, sustainable land management, and cash transfer programmes. The paper concludes with implications for research, policy, and practice, emphasising that CSA's success depends on addressing the structural constraints that limit smallholders' ability to convert information and technologies into sustainable livelihood outcomes.

Keywords: Climate-smart agriculture, sustainable livelihoods approach, smallholder resilience, ICT in agriculture, adaptive capacity, asset-based framework, South Asia

1. Introduction

Climate change disproportionately affects smallholder farmers in developing countries, who depend on rain-fed agriculture and possess limited adaptive capacity (IPCC, 2014; Lipper *et al.*, 2014) ^[13, 16]. In South Asia alone, over 300 million smallholder households face compounding vulnerabilities: rising temperatures, erratic monsoon patterns, declining groundwater tables, and structural deprivation across capital asset categories (Nelson *et al.*, 2009; FAO, 2018) ^[20, 9]. The urgency of supporting smallholder resilience is underscored by projections that climate change could reduce agricultural yields in South Asia by 15–25 per cent by mid-century without significant adaptation (Lobell *et al.*, 2011) ^[17].

In response, Climate-Smart Agriculture (CSA) has gained global prominence as an approach that simultaneously pursues three objectives: sustainably increasing agricultural productivity and incomes; adapting and building resilience of food systems to climate change; and reducing greenhouse gas emissions where possible (FAO, 2013; Lipper *et al.*, 2014) ^[8, 15]. CSA has been widely endorsed by governments, international organisations, and development agencies as a guiding framework for agricultural investment and policy across the Global South.

Despite its widespread acceptance, CSA faces persistent

critiques that limit its practical effectiveness. It is often operationalised as a set of technological prescriptions — drought-resistant seeds, conservation tillage, agroforestry — without adequate attention to the socio-economic contexts in which farmers operate (Caron *et al.*, 2018; Taylor, 2018) ^[3, 28]. CSA interventions frequently assume that information and technology adoption will automatically translate into improved livelihoods, ignoring structural barriers such as credit constraints, insecure tenure, and weak market access (McCarthy *et al.*, 2018) ^[18]. The framework also lacks an explicit theory of how assets, institutions, and livelihood outcomes interact under climate stress — leaving a significant gap between technical prescription and household-level reality.

The Sustainable Livelihoods Approach (SLA), developed by Chambers and Conway (1992) ^[5] and operationalised by the UK Department for International Development (DFID, 1999) ^[7], offers a powerful complementary lens. SLA focuses on the capital assets that households possess, the vulnerability context they face, the institutions and policies that shape their choices, and the livelihood strategies they pursue to achieve sustainable outcomes. While SLA has been applied to climate adaptation (Scoones, 2009; Tanner *et al.*, 2015) ^[24, 27], it has not been systematically integrated with CSA — a gap with significant practical consequences.

This paper addresses this gap by proposing an integrated framework that combines CSA's climate-specific focus with SLA's holistic, asset-based perspective, incorporating Information and Communication Technologies (ICT) as a cross-cutting enabling dimension. We argue that such integration is essential for designing interventions that build genuine resilience rather than simply transferring technologies. The paper makes three original contributions: first, a systematic mapping of CSA's three pillars onto SLA's five capital assets, revealing synergies, tensions, and design implications; second, the positioning of ICT as a cross-cutting sixth dimension that enables — but cannot substitute for — capital asset development; and third, the CSA–SLA–ICT Nexus Model as an actionable conceptual tool for programme design and evaluation.

The paper proceeds as follows. Section 2 reviews the conceptual foundations of CSA and SLA and diagnoses why their integration matters. Section 3 presents the five-component integrated framework. Section 4 positions ICT within the framework. Section 5 illustrates the framework through four applications from the literature. Section 6 discusses theoretical contributions, policy implications, a research agenda, and limitations. Section 7 concludes.

2. Conceptual Foundations

2.1 Climate-Smart Agriculture: Strengths and Limitations

CSA was launched by FAO in 2010 to address the neglect of agriculture in climate negotiations (Lipper and Zilberman, 2018) ^[16]. Its three pillars — productivity, adaptation, and mitigation — have been widely endorsed, and numerous empirical studies demonstrate their potential. Sustainable land management can offset climate-induced yield declines in sub-Saharan Africa (Nkonya *et al.*, 2018) ^[21]; improved feeding and livestock management can reduce emissions while increasing productivity (Thornton *et al.*, 2018) ^[29]; index-based insurance can buffer pastoralists against drought (Carter *et al.*, 2018) ^[4]; and ICT-mediated agro-advisory services can improve farmers' adaptive decision-making (Chettri *et al.*, 2021; Gangopadhyay *et al.*, 2019) ^[6, 10].

However, critics identify several persistent limitations. First, CSA is frequently implemented as a top-down technology package, with insufficient attention to local knowledge, participation, and farmer heterogeneity (Caron *et al.*, 2018) ^[3]. Second, the three pillars embody inherent trade-offs: productivity-enhancing practices may increase emissions; mitigation-focused interventions may divert resources from adaptation; and adaptation strategies may be capital-intensive and therefore exclusionary for asset-poor households (Smith and Olesen, 2010; Antle *et al.*, 2018) ^[26]. Third, and most critically, CSA pays inadequate attention to the structural determinants of vulnerability — land tenure, gender inequality, market exclusion, and political marginalisation (Taylor, 2018) ^[28]. As a result, CSA interventions frequently benefit better-off farmers while bypassing the most vulnerable — the very households for whom climate resilience is most urgent.

2.2 The Sustainable Livelihoods Approach: An Asset-Based Framework

The Sustainable Livelihoods Approach emerged from

critiques of narrowly economic development models. Its core premise is that livelihoods are shaped by access to five capital assets. Human capital encompasses skills, knowledge, labour, and health — the capacity to pursue livelihood strategies. Social capital includes networks, groups, trust, and norms that facilitate collective action and risk-sharing. Natural capital covers land, water, forests, and biodiversity — the resource base on which agriculture depends. Physical capital comprises infrastructure, tools, equipment, and technology — the means of production. Financial capital includes savings, credit, remittances, and insurance — the liquidity to invest and cope with shocks.

SLA posits that households combine these assets within a vulnerability context — defined by shocks, seasonality, and long-term trends — and an institutional context — shaped by policies, laws, and power relations — to pursue livelihood strategies that achieve desired outcomes. Outcomes are assessed across multiple dimensions: income, well-being, food security, reduced vulnerability, and environmental sustainability. The framework is explicitly people-centred, multi-dimensional, and participatory (DFID, 1999; Chambers and Conway, 1992) ^[7, 5]. Critically, outcomes feed back into asset stocks: positive outcomes build capitals, enabling future resilience; negative outcomes deplete assets, deepening vulnerability traps.

SLA has been applied extensively to climate adaptation. Tanner *et al.* (2015) ^[27] demonstrated its utility for assessing adaptive capacity in coastal Bangladesh. Scoones (2009) ^[24] argued that livelihood perspectives are essential for understanding climate vulnerability, precisely because they centre the household and community rather than the agricultural system. However, SLA has rarely been systematically integrated with CSA — a gap that limits the analytical power of both frameworks when applied to climate-agriculture nexus problems.

2.3 Why Integration Matters

CSA and SLA address different but deeply overlapping questions. CSA asks: what agricultural practices enhance productivity, adaptation, and mitigation? SLA asks: what assets, institutions, and strategies enable households to achieve sustainable livelihoods under stress? CSA provides the climate-agriculture specificity that SLA lacks; SLA provides the asset-based, multi-dimensional vulnerability analysis that CSA lacks.

An integrated framework enables researchers and practitioners to diagnose which capital assets are weakest and require strengthening; identify how CSA practices affect different assets and which assets they require as prerequisites; assess how institutional constraints mediate CSA outcomes; and design interventions that build assets holistically rather than transferring technologies in isolation. The integration also provides an explanation for a phenomenon widely observed in the empirical literature but poorly theorised within either framework: the information-to-income gap — the consistent finding that improvements in information access do not automatically translate into income gains or livelihood improvements (Hanson and Heeks, 2020; Kush and Patel, forthcoming) ^[11, 14].

3. The Integrated CSA–SLA Framework

The integrated framework has five interconnected

components, together constituting a dynamic system in which climate vulnerability, household assets, institutional context, livelihood strategies, and outcomes interact in

continuous feedback loops. Table 1 presents the core mapping of CSA pillars onto SLA capital assets, followed by a narrative development of each framework component.

Table 1: Mapping of CSA Pillars onto SLA Capital Assets

SLA Capital Asset	CSA Pillar 1 Productivity	CSA Pillar 2 Adaptation	CSA Pillar 3 Mitigation	Key Synergies	Key Trade-offs / Risks
Human Capital (Skills, knowledge, health)	Primary	Primary	Secondary	Training builds adaptive decision-making capacity	Knowledge demands may exclude low-literacy farmers
Social Capital (Networks, institutions, trust)	Secondary	Primary	Secondary	Community networks accelerate practice diffusion	Elite capture may exclude marginal and female farmers
Natural Capital (Land, water, ecosystem services)	Primary	Primary	Primary	All pillars converge on soil and water management	Mitigation may restrict land-use flexibility
Physical Capital (Infrastructure, tools, technology)	Primary	Secondary	Secondary	ICT infrastructure enables real-time climate advisory	Capital-intensive technology excludes marginal households
Financial Capital (Income, credit, insurance, savings)	Primary	Secondary	Tertiary	Index insurance links risk reduction to adaptive investment	Upfront costs of CSA practices create adoption barriers

Note: Primary = direct, central engagement; Secondary = indirect or enabling engagement; Tertiary = peripheral or assumed. Colours: Green = Primary; Yellow = Secondary; Orange = Tertiary.

3.1 Vulnerability Context

The vulnerability context includes climate-related shocks — droughts, floods, heatwaves, pest outbreaks — as well as long-term trends such as rising temperatures, groundwater depletion, and soil degradation. It also encompasses non-climate stressors — market volatility, policy shifts, conflict, demographic pressure — that interact with and amplify climate risks. The vulnerability context is not static; it changes as climate change intensifies and as structural economic conditions evolve. This dynamic character makes the vulnerability context the essential starting point for both diagnostic assessment and programme design: interventions designed for a specific vulnerability configuration may become obsolete as conditions shift.

3.2 Asset Pentagon

The five capital assets constitute the household-level resource base from which climate responses are constructed. The asset pentagon in the integrated framework is dynamic and interdependent — assets interact across capitals in ways that create both virtuous and vicious cycles. Adopting drip irrigation (physical capital) requires financial capital for upfront investment and human capital to operate and maintain it effectively; conversely, improved natural capital in the form of higher soil organic matter can reduce the financial capital needed for synthetic fertiliser. This interdependence means that single-capital interventions frequently fail: strengthening one capital without attention to binding constraints in others produces limited and often short-lived gains.

Within the CSA context, each capital has specific implications. Human capital is enhanced by ICT-mediated extension, climate information services, and training in CSA practices. Social capital is built through Farmer Producer Organisations, self-help groups, and collective natural resource management arrangements. Natural capital is improved by soil and water conservation practices, agroforestry, and biodiversity management — the biophysical core of CSA's adaptation and mitigation pillars. Physical capital includes irrigation infrastructure, storage facilities, and digital technologies, all of which condition the

efficiency of agricultural production. Financial capital is strengthened through access to credit, crop insurance, savings mechanisms, and social protection transfers that provide the liquidity to invest in CSA practices and absorb climate shocks.

3.3 Institutional and Policy Environment

Institutions and policies mediate the relationship between assets and livelihood outcomes — they determine whether household capital endowments can be converted into resilience or whether structural barriers prevent this conversion. The integrated framework identifies five critical institutional dimensions. Land tenure security affects incentives for long-term investments in soil health, tree planting, and water harvesting — farmers without secure tenure rationally under-invest in natural capital improvements. Market access determines whether increased productivity translates into income — production gains that cannot be marketed at fair prices do not build financial capital. Extension services govern the quality, timeliness, and equity of information and training flows — critical for human capital development. Social protection — including cash transfers, food assistance, and employment guarantee schemes — provides safety nets that enable risk-taking, such as adopting new technologies. Finally, governance and power relations shape who benefits from CSA interventions and who is systematically excluded — a dimension that CSA frameworks have historically undertheorised.

3.4 Livelihood Strategies

Livelihood strategies are the combinations of activities that households pursue to achieve desired outcomes within their asset and institutional context. In the context of climate-resilient agriculture, these strategies include: on-farm intensification through the adoption of CSA practices and crop diversification; off-farm diversification into wage labour, small enterprises, and migration; asset accumulation through investment in livestock, equipment, or savings; and risk management through insurance, social network participation, and grain storage. The integrated framework does not prescribe a single optimal strategy — rather, it

recognises that different households, with different asset portfolios and institutional contexts, will rationally pursue different strategies, and that effective programme design must accommodate this heterogeneity rather than assume it away.

3.5 Livelihood Outcomes and Feedback Loops

Outcomes are multi-dimensional and include food security, income stability, asset accumulation, wellbeing, and environmental sustainability. The integrated framework's most distinctive structural feature is the explicit feedback loop between outcomes and asset stocks. Improved outcomes — higher income, better nutrition, reduced climate losses — increase capital asset endowments, enabling households to invest further in CSA practices and build greater resilience over time. Negative outcomes — crop failure, health shocks, income loss — deplete asset stocks, reducing households' capacity to respond to future climate events and potentially trapping them in deepening vulnerability. This feedback structure explains why early intervention to build assets among the most capital-poor households is not merely equitable but strategically efficient: it prevents the formation of poverty-vulnerability traps that become progressively more costly to address.

4. ICT as the Cross-Cutting Enabling Dimension

Within the integrated CSA–SLA framework, Information and Communication Technologies (ICT) function as a cross-cutting enabling mechanism that modulates all five capital assets and all three CSA pillars simultaneously. ICT is not a sixth capital asset in the SLA sense — it is an enabling

infrastructure that conditions how effectively the five capitals can be built and deployed. This positioning reflects the growing empirical evidence that ICT's contribution to agricultural transformation is conditional and mediated rather than direct and automatic (Ospina and Heeks, 2010; Hanson and Heeks, 2020) ^[22, 11].

ICT's enabling role operates through five specific pathways within the framework. First, it builds human capital by enabling access to agro-meteorological advisories, crop management information, and peer knowledge exchange — improving decision-making quality without requiring formal education as a prerequisite (Chetri *et al.*, 2021; Haworth *et al.*, 2018) ^[6, 12]. Second, it strengthens social capital by facilitating farmer network formation through platforms such as WhatsApp groups, online Farmer Producer Organisation portals, and community radio — channels that accelerate the diffusion of CSA practices and build collective adaptive capacity. Third, it supports natural capital management through precision agriculture applications — remote sensing for soil moisture monitoring, GIS-based groundwater mapping, and satellite weather advisory services (Gangopadhyay *et al.*, 2019; Sheokand and Singh, 2017) ^[10, 25]. Fourth, ICT itself constitutes physical capital — smartphones, data connectivity, and digital platforms are productive infrastructure whose availability determines the reach of all other pathways. Fifth, ICT enables financial capital formation through digital financial services — mobile banking, digital credit scoring, and weather-indexed crop insurance increasingly delivered through mobile platforms.

Table 2: ICT's Enabling Role across SLA Capitals and CSA Pillars

SLA Capital	ICT Enabling Pathway	CSA Pillars Enabled	Example ICT Tools	Conditional Risk
Human	Knowledge access; advisory services	Productivity; Adaptation	Agro-apps; YouTube; KCC	Information quality not guaranteed on peer platforms
Social	Network formation; practice diffusion	Adaptation; Productivity	WhatsApp groups; FPO platforms	Social stratification limits reach to marginal farmers
Natural	Precision resource monitoring	All three pillars	Remote sensing; GIS; IoT sensors	Data poverty in smallholder contexts
Physical	Digital infrastructure as capital	Productivity; Adaptation	Smartphones; 4G connectivity	Geographic coverage gaps persist
Financial	Digital finance; insurance delivery	Productivity; Mitigation	Mobile banking; e-insurance	Digital literacy required for effective use

However, the framework also acknowledges ICT's limitations as an enabling mechanism. Hanson and Heeks (2020) ^[11], in a comprehensive review across developing countries, found that while ICT generally strengthens household resilience, its impact on community-level resilience and equality dimensions is more variable — with digital tools sometimes amplifying existing inequalities between better-connected and less-connected households. This finding is consistent with the SLA insight that asset heterogeneity within communities means the same intervention can build capital for some while bypassing or even disadvantaging others. ICT governance — who controls platforms, whose knowledge is validated, and who bears connectivity costs — is therefore an essential consideration within the integrated framework.

5. Illustrative Applications from the Literature

5.1 The Information-to-Income Gap in ICT Interventions

A striking empirical regularity in the ICT-for-agriculture literature is the information-to-income gap: digital tools consistently demonstrate high effectiveness in improving farmers' access to weather information and agricultural knowledge, but show only neutral or weak association with income outcomes (Hanson and Heeks, 2020; Mittal and Hariharan, 2018) ^[11, 19]. Kush and Patel (forthcoming), in a study of 452 farmers in Kanina Block, Mahendragarh, Haryana, found that ICT's perceived impact on weather information access scored 4.81 out of 5, while its perceived impact on income outcomes scored 3.04 — a gap that was consistent across education levels, landholding sizes, and

age groups, suggesting a systemic rather than individual-level barrier.

The integrated CSA–SLA–ICT framework provides a theoretically grounded explanation for this gap. ICT effectively builds human capital through knowledge delivery, but the conversion of human capital into financial capital — the pathway from better information to higher income — requires the simultaneous activation of physical capital (storage, transport, market infrastructure), financial capital (credit for inputs, insurance against risk), and social capital (market linkages, FPO membership). When these complementary capitals are absent or constrained, information accumulates without being converted into income. The framework thus directs intervention design attention toward the missing capitals rather than toward improving information delivery — a reorientation with significant resource allocation implications.

5.2 Sustainable Land Management in Sub-Saharan Africa

Nkonya *et al.* (2018) ^[21] documented that sustainable land management (SLM) practices can offset climate-induced yield declines across sub-Saharan Africa. However, adoption rates remain persistently low despite demonstrated agronomic benefits. Applying the integrated framework reveals the capital barriers driving this adoption gap: SLM often requires significant upfront labour (human capital) and cash for inputs such as organic amendments and tree seedlings (financial capital); benefits — improved soil organic matter, reduced erosion, higher sustained yields — accrue over several years, creating a temporal mismatch between cost and benefit; and insecure tenure (institutional context) discourages investment in permanent improvements. The framework's institutional component explicitly identifies tenure security as a prerequisite for natural capital investment, and suggests that SLM programmes should be bundled with tenure regularisation, credit provision, and social protection that bridges the investment-return time lag.

5.3 Index-Based Insurance in East Africa

Carter *et al.* (2018) ^[4] evaluated index-based livestock insurance (IBLI) in Kenya and Ethiopia, finding that insurance improved ex-post coping capacity and enabled ex-ante productive investment. However, demand remained low in the absence of subsidies, and basis risk — the mismatch between index triggers and actual household losses — remained a structural limitation. The integrated framework illuminates why insurance, while building financial capital directly through post-shock payouts, requires human capital (financial literacy to understand and trust the product) and social capital (institutional trust and community-level uptake) to function effectively. It also highlights that insurance alone cannot drive systemic resilience: without complementary investments in natural capital (soil health, water management) and physical capital (storage, market access), insurance payouts are spent on survival consumption rather than productive investment. The framework recommends bundling insurance with extension, credit, and market linkage — a bundled approach increasingly supported by empirical evidence from South Asia and Africa.

5.4 Cash Transfers and Adaptive Capacity

Asfaw and Davis (2018) ^[2] demonstrated across multiple sub-Saharan African countries that cash transfer programmes increased household investment in agricultural inputs, livestock, and food security — all indicators of capital asset building. The integrated framework interprets these findings as evidence that direct financial capital injections, when predictable and sustained, enable households to accumulate complementary assets: better nutrition builds human capital; investment in draught animals builds physical capital; soil investment builds natural capital. Critically, the framework predicts that cash transfers produce the greatest resilience gains when aligned with climate information services and extension — precisely because financial capital injection without human capital development leaves households without the knowledge to convert cash into sustainable livelihood improvements. This prediction is consistent with the emerging literature on 'graduation programmes' that bundle social protection, livelihoods support, and savings promotion.

6. Discussion

6.1 Theoretical Contributions

The integrated CSA–SLA framework makes three theoretical contributions. First, it provides a systematic mechanism for diagnosing why CSA interventions succeed or fail, by tracing outcomes through capital asset conversion pathways rather than attributing success or failure to technology characteristics or farmer irrationality. Second, it shifts analytical focus from technology adoption to asset building, recognising that resilience is a property of whole livelihood systems — including their social, financial, and institutional dimensions — rather than of individual agricultural practices. Third, it explicitly incorporates institutional and political factors as mediators of the capital-to-outcome conversion, countering the technocratic bias that has been a persistent limitation of CSA literature (Taylor, 2018; Caron *et al.*, 2018) ^[28, 3].

The positioning of ICT as a cross-cutting enabling dimension adds a fourth contribution: it resolves a theoretical ambiguity in the ICT4Agriculture literature between ICT as an asset category and ICT as an enabling infrastructure. The integrated framework clarifies that ICT is best understood as the latter — a conditional enabler whose effectiveness is modulated by the five capital assets rather than an additional capital in its own right. This clarification has direct implications for how ICT programme effectiveness should be evaluated: not through uptake and awareness metrics alone, but through its effect on capital asset accumulation and the resulting livelihood outcomes.

6.2 Policy Implications

For policymakers, the framework implies several concrete shifts in strategy. Move from technology transfer to asset bundling: CSA interventions should combine agronomic practices with credit, training, insurance, and market linkages — addressing the capital prerequisites of adoption rather than promoting practices in isolation. Target the asset-poor: the most vulnerable households typically lack multiple capitals simultaneously; interventions that address only the most visible constraint while ignoring others will produce limited and fragile gains. Strengthen institutions for

asset conversion: without secure tenure, functional markets, and accountable extension services, accumulated capital assets cannot be converted into resilience outcomes. Use participatory asset diagnosis: asset pentagrams can be co-developed with communities to identify locally specific capital constraints and opportunities before intervention design. Monitor outcomes holistically: beyond yield and income metrics, programme evaluations should track changes in asset stocks, food security status, and subjective wellbeing across different household categories.

6.3 Research Agenda

The integrated framework generates several empirical research priorities. Longitudinal studies are needed to trace how asset portfolios change in response to CSA interventions and climate shocks over time — a gap in the current literature that relies heavily on cross-sectional designs. Comparative case studies that systematically apply the framework across contexts where CSA succeeds and fails would enable the identification of binding capital constraints and institutional mediators. Measurement innovation is required, particularly for social and human capital in agricultural settings, where existing metrics are poorly standardised. Political economy analysis of how power relations shape asset distribution and access — and how this shapes CSA programme outcomes — remains underrepresented. Finally, action research that tests bundled interventions co-designed with farmers and communities offers the most direct pathway to validating and refining the framework.

6.4 Limitations

The integrated framework has four significant limitations that should inform its application. It is descriptive rather than predictive: it does not specify functional or quantitative relationships between capital assets, and therefore cannot generate precise forecasts of intervention impact. Operationalising asset measurement remains challenging — particularly for social capital, where network quality and institutional trust resist straightforward quantification. The framework focuses primarily on household-level resilience and does not fully address landscape-level or system-level dynamics — including transboundary water management, value chain governance, and ecosystem service provision — that also shape smallholder climate vulnerability. Finally, the framework may be too analytically complex for rapid assessment in emergency or post-disaster contexts, where simplified diagnostic tools may be more practically appropriate.

7. Conclusion

Climate-Smart Agriculture has enormous potential to support smallholder resilience under accelerating climate change, but its current technology-centric operationalisation is insufficient. This paper has proposed an integrated framework combining CSA with the Sustainable Livelihoods Approach, and positioning ICT as a cross-cutting enabling mechanism within this integration. The framework places capital assets — human, social, natural, physical, and financial — at the centre of analysis, and explicitly incorporates the institutional and policy environment and livelihood strategy dimensions that

determine whether capital assets can be converted into genuine resilience outcomes.

Three insights stand out from this integration. First, the information-to-income gap widely observed in ICT-for-agriculture programmes is not a failure of information delivery but a failure of complementary capital assets — a diagnosis that redirects intervention design from communication to asset building. Second, the most capital-poor households face compound capital deficits that single-pillar CSA interventions cannot address; only integrated, multi-capital approaches have the analytical and practical reach to support genuine resilience for the most vulnerable. Third, institutional context — land tenure, market access, extension quality, social protection — is not a background condition but a first-order determinant of whether CSA interventions produce lasting livelihood improvements or remain isolated technology demonstrations.

We invite empirical testing and critical refinement of the framework across diverse smallholder contexts in South Asia, sub-Saharan Africa, and Latin America. The framework's primary value lies not in its theoretical elegance but in its operational utility: as a diagnostic tool for identifying binding capital constraints, a design guide for bundled interventions, and an evaluation framework for assessing multi-dimensional resilience outcomes. The goal is not a perfect framework but a more useful one — one that helps researchers, practitioners, and policymakers move closer to the shared objective of sustainable, climate-resilient livelihoods for the world's smallholder farmers.

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