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# Climate-Smart Agriculture Adoption and Farm Income Stability Under Extreme Weather Conditions

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**ABSTRACT**

*Farms are no longer facing a peripheral production risk due to extreme weather. It is direct income stabilization. The article employs a secondary qualitative review research design to assess the impacts of climate-smart agriculture (CSA) adoption on farm income stability in the face of heat, drought, flood and climatic variability. At the conceptual and secondary levels, the literature review is constructed based on the CSA, innovation diffusion and resilience, and the results intentionally employ another batch of 18 primary empirical studies. A thematic analysis finds that there are 4 cross-cutting patterns: bundled CSA practices are more consistently linked with both income and yield gains than single practices; extension, credit, cooperatives and digital advisory services determine adoption; resilience is more attributable when CSA attenuates income gains in shock years, not when it raises the average yield; and methodological claims are limited by cross-sectional data, selection bias and unequal access. The article contends that CSA is better suited to a risk-management portfolio than to a technology package.*

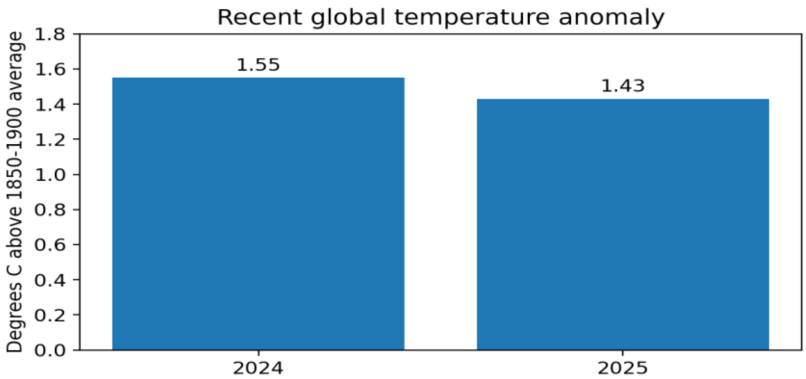
## Introduction

Stability of farm income is the nervous system of agribusiness, due to the simultaneous impact of climate shocks on production, labour potential, water supply and market predictability. WMO noted that 2024 was the hottest year, with temperatures ranging from 1.55°C above the 1850-1900 mean, but in 2025 temperatures rose to the 2nd- or 3rd-hottest, at 1.43-1.5°C above 1850-1900 (WMO, 2025, 2026). The FAO and WMO caution that the impact of extreme heat will endanger the livelihoods and health of over a billion individuals and result in approximately half a trillion lost working hours every year (FAO, 2026). The relevance of these statistics is that income volatility influences the purchase of inputs, debt repayment, the reliability of contracts and the decision to invest in rural areas in agribusiness management.

CSA is claimed to be a triple-win strategy that can contribute to higher productivity and income, adaptation and resilience, and, in some cases, minimize or eliminate emissions (FAO, 2013; Lipper et al., 2014). Nevertheless, the term may conceal significant variations among practices. Drought-tolerant seed, intercropping, zero tillage, irrigation, crop insurance, livestock breeds, agroforestry and digital advisories are not run on the same cost structures or risk pathways. The temperature context for the review appears in Figure 1. Extreme weather is not considered grounds as a background variable; in this case, other things remain constant, though.

The question in the article is: How can the adoption of CSA lead to stability in farm income in extreme weather conditions? The contribution is essential and not promotional. It juxtaposes good income results with limitations in approaches, access and execution. Also, it differentiates between average income gains and stability gains, since a technology that would increase yield in an average year may not secure income in a drought, flood or heat-stress year.

**Figure 1:** ***Recent global temperature anomaly as context for farm income risk***




Note. Data are from WMO State of the Global Climate reports for 2024 and 2025. Values are degrees C above the 1850-1900 average.

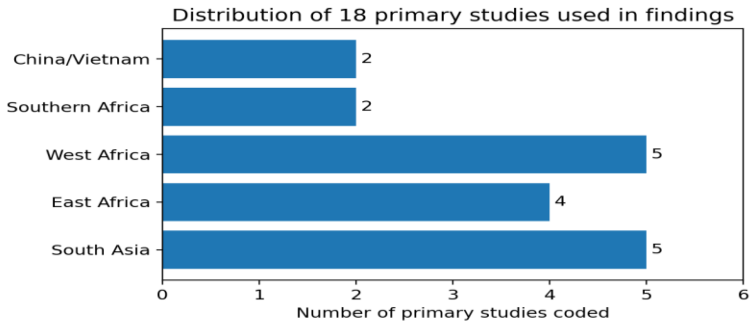
## Methodology: Secondary Review Design and Thematic Analysis

The secondary paper design is applied in this article. No new field data were collected. Secondary and conceptual sources, such as CSA sourcebooks, review papers and theory, were used to develop the literature review and theoretical framing. To adhere to the mandatory separation rule, papers involved in the literature review were not used as evidence in the findings section. The primary empirical studies form the basis of findings.

Search terms included climate-smart agriculture, adoption, farm income, income stability, drought, flood, extreme weather, yield, household welfare, and country names. To meet inclusion criteria, the research had to be peer-reviewed or a research institute's primary study, to explicitly focus on CSA or CSA-related practices, farm-level or household-level output and an output measure associated with income, yield, welfare, food security or resilience. Purely conceptual studies, such as systematic reviews or policy commentaries, were included in the background section but not in the results.

Thematic analysis was performed through five roles familiarisation with each of the studies; coding practices, methods, income outcomes and shock context; theme grouping; convergence and contradictory results comparison; critical interpretation against diffusion resilience and livelihoods theory. The 18 primary studies were spread regionally as indicated in Figure 2. Table 2 explains how the article avoids overlapping of theory sources and findings sources.

**Figure 2:** ***Regional and sectoral spread of primary studies coded for findings***




Note. Counts are based on the 18 primary empirical studies selected for the synthesis of findings. Studies were coded by dominant region or sector.

**Table 2:** ***Source separation rule used in the secondary design***

| **Article component** | **Sources used** | **Excluded from this component** |
|---|---|---|
| Literature review | CSA theory, innovation diffusion, resilience, sustainable livelihoods and recent review sources. | The 18 primary studies were coded for findings. |
| Findings | Primary studies using household surveys, programme evaluation, panel data or farm-level datasets. | Systematic reviews, sourcebooks and theory papers. |
| Discussion | Comparison between the primary review findings and theoretical or previous review claims. | No new uncoded empirical claims are introduced. |

## Literature Review

The literature identifies CSA as a response to three interrelated failures: inefficiency, excessive vulnerability to climate risks, and unsustainable resource use. The FAO (2013) settings of CSA focus on adaptation and mitigation, and income. Lipper et al. (2014) also note that CSA is not a predetermined list of technologies but a planning method that relates practices to local risks, institutions, and food security. This is important because income stability has been found to depend on the fit between a farm system and a practice. The drought-resistant seed can be used to cushion output during dry periods, and the advisory service can be used to cushion income by supporting better decision-making on timing. The process is not the same.

Diffusion of innovation theory can be used to explain the diffusion of income-positive practices that could still diffuse slowly. Rogers (2003) accentuates relative advantage, compatibility, complexity, trialability and observability. Relative advantage is more than the higher expected profit in CSA. The farmers have to balance initial expenditure, labour demand, delayed returns and performance under shocks. Feder et al. (1985) also state that risk, information, credit and farm size determine adoption. Low adoption can therefore be rational in cases where there is a lack of liquidity or the perceived benefits associated with climate can hardly be realized unless a massive episode is provoked.

The theory of resilience redirects the focus from average income to the capacity to absorb and recover from disruptions (Adger, 2006; Barrett & Constas, 2014). This is the focus of the current paper. The mean income of a farm family can be large, and stability can be weak due to drought killing one year of production or heat reducing labour days. The sustainable livelihoods approach holds that resilience can be developed through assets, institutions, and diversification, rather than through agronomic technology (Scoones, 1998).

Recent surveys claim that productivity, income growth and food security are typically linked to CSA, yet note mixed effects on adoption by gender, farm size, credit and location (Ma & Rahut, 2024; Zheng et al., 2024). Critical reading is required. Practices, crops and regions with markedly different agronomic and economic logics are frequently mixed in reviews. The current results thus challenge the hypothesis of the primary research: CSA stabilises farm income during extreme weather when it is embraced as a locally supported portfolio.

## Findings: Thematic Analysis of Primary Studies

The findings summarised in Table 3 are based on 18 major studies. The research works are not similar in both results, design or setting; thus, the synthesis does not turn into a mere vote-counting decision. Rather, in the coding, the approach compares how CSA practices change income pathways in the face of climate stress.

**Table 3:** ***Primary empirical studies used only in the findings***

| **Study/context** | **Design and data** | **Income or resilience evidence** | **Method critique** |
|---|---|---|---|
| Akter et al. (2022). Bangladesh | Flood-prone farm-level evidence on CSA adoption and yield or income. | Positive association with rice, wheat and maize yield and household income. | Strong shock context, but observational adoption still risks hidden selection. |
| Amadu et al. (2020). Malawi | CSA aid intervention and yield effects in southern Malawi. | Aid-linked CSA investment improved yield outcomes. | Valuable programme evaluation, but yield is not a full income-stability measure. |
| Agbenyo et al. (2022). Ghana | Cocoa farmer survey with endogenous treatment estimation. | CSA adoption increased farmer income, with crop insurance highlighted. | Good treatment framing, but cocoa-specific findings may not transfer to cereals. |
| Asante et al. (2024). Ghana | 3,197 maize farmers, multinomial endogenous switching regression. | Bundled adoption increased maize yield and net farm income more reliably than single practices. | Strong modelling of combinations, but cross-sectional data limits dynamic stability claims. |
| Aryal et al. (2018). India | Indo-Gangetic Plains survey on multiple CSA adoption. | Adoption is shaped by caste, education, plot traits, market distance and climate risks. | Explains adoption well, but income stability is indirect. |

| Study/context | Design and data | Income or resilience evidence | Method critique |
|---|---|---|---|
| Aryal et al. (2020). India | Household data on women's participation in technology decisions. | Women's participation influenced CSA adoption decisions. | Important equity lens, but empowerment measures are difficult to compare across households. |
| Kpadonou et al. (2017). West African Sahel | Joint adoption of soil and water conservation technologies. | Multiple on-farm conservation practices addressed dryland adaptation. | Strong dryland relevance, but income effects depend on local rainfall and labour costs. |
| Makate et al. (2019). Malawi and Zimbabwe | 1,172 farmers, multiple CSA innovations. | Multiple adoption improved productivity and income resilience. | Good cross-country evidence, but practice bundles complicate attribution. |
| Martey et al. (2021). Ghana | Cowpea adoption and welfare effects of training. | Training-supported adoption of climate-smart cowpea improved welfare outcomes. | Training effects may be inseparable from input and market support. |
| Ogada et al. (2020). Kenya | Nyando basin survey, matching and simultaneous equations. | CSA practices improved household income and asset accumulation pathways. | Useful livelihood pathway design, but the local basin context limits generalisation. |
| Radeny et al. (2022). Kenya | PSM and treatment models for stress-tolerant crops and livestock breeds. | Dietary diversity rose by 40% for crop varieties and 38% for breeds, while food insufficiency fell sharply. | Food security is linked to income stability, but not to a direct measure of income. |
| Samuel et al. (2024). India | 120 farmers, treated and control villages, difference-in-differences. | NICRA village income was over 40% higher, and drought-year income loss was reduced. | Direct shock-year evidence, though from a small purposive sample, weakens external validity. |
| Sang et al. (2024). China | 2020 China Rural Revitalization Survey, 2SRI and IV quantile regression. | Higher CSA intensity increased household income, net farm income and income diversity. | Strong heterogeneity analysis, but national survey categories may hide practice details. |
| Tabe-Ojong et al. (2023). West Africa | Cross-country evidence using endogenous switching methods. | CSA adoption improved food security and productivity in some practice bundles. | Cross-country design is valuable, but country institutions differ strongly. |

| Study/context | Design and data | Income or resilience evidence | Method critique |
|---|---|---|---|
| Tanti et al. (2024). India | 494 households, PSM and 2SLS in semi-arid Odisha. | Crop rotation and integrated soil management increased yield and income. | Endogeneity controls are strong, but the 2019-2020 data capture limited shock cycles. |
| Tesfaye et al. (2023). Ethiopia | 796 farmers in two climate-smart landscapes, PSM. | CSA improved food security in Doyogena and the average annual income in Basona. | Excellent site contrast, but it shows CSA is not one-size-fits-all. |
| Kehinde et al. (2024). Nigeria | 1,500 rice farmers, factor share equations. | Most CSA-potential practices were labour-intensive and affected input substitution. | Crucial cost critique: adoption may stabilise income only when labour bottlenecks are solved. |
| Mburu et al. (2024). Kenya | 665 dairy farmers, multinomial endogenous switching regression. | Combined climate-smart fodder and concentrates raised milk productivity, output and dairy income. | Strong livestock evidence, but feed markets and extension access condition benefits. |

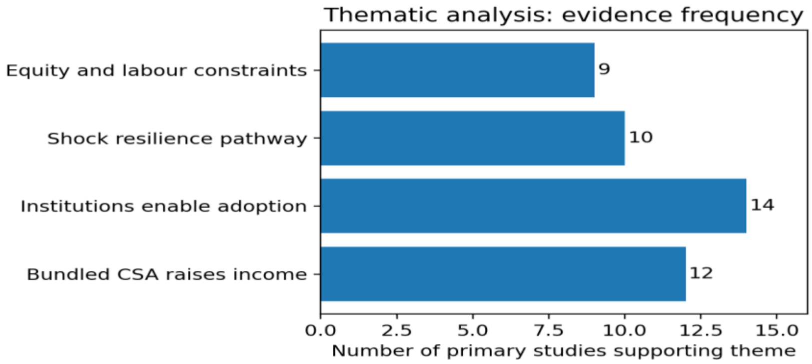
**Theme 1: Bundled CSA Gains**

The highest income gains are realized when CSA is bundled. The most reliable observation is that not every CSA practice is applicable everywhere, but packages do work better than non-practices. Asante et al. (2024) identified a large yield effect of drought-resistant seed with a combination of row planting and zero tillage, and the highest net farm income effect of zero tillage with row planting. Similar bundle logic appears in Makate et al. (2019), Tanti et al. (2024) and Mburu et al. (2024). This is a threat to simple extension messages that buy one practice as a universal solution.

**Theme 2: Institutional Enablers**

Technical potential translates into adoption within institutions. There is recurring education, extension, farmer organisations, digital advisories, credit and training in Aryal et al. (2018), Martey et al. (2021), Asante et al. (2024) and Tesfaye et al. (2023). This means that CSA is a product of the institution in some way. An otherwise untested technology could increase theoretical resilience but be unaffordable or improperly implemented. As seen in Figure 3, the most common theme when coded was enabling institutions.

**Figure 3:** ***Frequency of themes coded across the 18 primary studies***



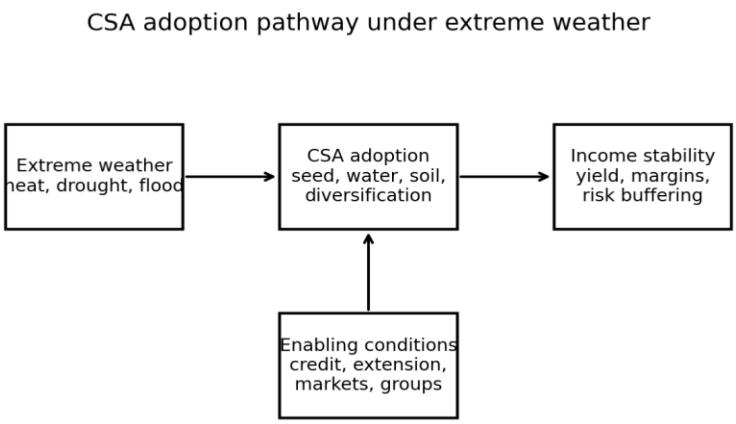

### Theme 3: Shock-Based Stability

Income stability can be better observed when shock conditions feature in studies. Samuel et al. (2024) provide rather unusual evidence, comparing treated and control villages during a drought: the average income of treated farmers was more than 40% higher, and the corresponding ratio of their property was 1.5 times higher. 54,717 drought-year income advantage. Other studies, such as Akter et al. (2022), Radeny et al. (2022), and Tabe-Ojong et al. (2023), relate CSA to either food security or production in unfavorable contexts. However, numerous studies continue to use average yield or income, which is not as strong evidence of stability as multi-season volatility.

### Theme 4: CSA Cost Barriers

Costs, labour and inequality can curtail stability benefits. Kehinde et al. (2024) discovered that a significant portion of the CSA-potential practices adopted by Nigerian rice farmers was labour-intensive. Aryal et al. (2020) and Tesfaye et al. (2023) demonstrate the cognitive conditioning to gendered decision-making and site-specific factors. Consequently, CSA can create discrepancies when more well-endowed farmers take first and receive the largest rewards. The results are in favor of CSA, though not as an automatic poverty-reduction agent.

**Figure 4:** ***Interpretive model linking CSA adoption to farm income stability***




Note. The model summarises the review findings and shows that enabling conditions mediate the relationship between CSA adoption and income stability.

## Discussion

The results substantiate the theory of CSA in general but narrow it down. According to FAO (2013) and Lipper et al. (2014), CSA is a pathway of productivity, adaptation and mitigation. The main studies confirm the productivity and income sides, although in most cases, adoption is approached as a portfolio. This is apparent in Ghana, India, Kenya and southern Africa, where a bundle of seed, tillage, soil management, feed and diversification are stronger in results than single activities are (Asante et al., 2024; Makate et al., 2019; Mburu et al., 2024; Tanti et al., 2024). The review hence concurs with the direction per the CSA concept of triple win, but questions any policy narrative that perceives CSA as a homogenous product.

Relative advantage is conditional, unlike the diffusion theory. Rogers (2003) would recommend adoption when the benefits are clear and compatible. However, Kehinde et al. (2024) demonstrate that labour intensity may decrease practical advantage, and Tesfaye et al. (2023) demonstrate that the same CSA agenda can increase food security in a single Ethiopia environment and income in a different one. This supports Feder et al. (1985), who claim that central to adoption are risk, information and liquidity. The current review further states that extreme weather alters the calculus of adoption: farmers might prefer practices not just because they increase mean returns, but also to insure against downside losses.

It also supports the resiliency literature, though it is only partially validated. Adger (2006) and Barrett and Constas (2014) describe resilience in terms of shock absorption, having welfare. A number of primary literature meet this requirement, particularly Samuel et al. (2024), which explicitly estimates the drought-year protection of income. Most studies, however, determine counterfactual income using cross-sectional matching or switching regressions, which do not capture actual seasonal volatility. These are powerful and helpful methods that nonetheless rely on assumptions about unobserved differences between adopters and non-adopters. The indication of the presence of stable income is, therefore, encouraging though not decisive.

Results also contrast with general reviews reporting positive CSA impacts (Ma & Rahut, 2024; Zheng et al., 2024). The current synthesis is more cautious due to primary findings indicating that benefit is mediated by institutions, labour, gender and local climate. To illustrate, adoption in Ghana and India is enhanced by farmer organisations and extension services, and labour bottlenecks in Nigeria have reduced the viability of labour-intensive practices (Asante et al., 2024; Kehinde et al., 2024). Thus, technologies should not be subsidised only by policy. It needs to mitigate the risk of adoption with climate information, credit, insurance, training and shared equipment.

## Conclusion and Implications

This article concludes that the adoption of CSA can enhance the stability of farm income during extreme weather, but the best illustration is the cohesive practices through institutional reinforcement. Whether or not there is income stability due to climate labels is not automatic. It relies on practices that minimize yield loss in the event of a shock, support revenue streams, and shield assets and accessibility for small, resource-limited farms.

As an agribusiness manager and policy maker, there are three implications. To begin with, CSA must be marketed as a crop, livestock, water and market-matched portfolio. Second, the support for adoption should include extensions, credit, digital advisory services, farmer organisations and labour-saving opportunities. Third, tracking needs to shift to measuring income variance and drought-year losses, in addition to average yield, recovery time and distributional impacts by gender and farm size. Panel data and experimental or quasi-experimental studies to observe farms before, during and after extreme events should be considered for further research.

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