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Evidence Review

Climate adaptation interventions in smallholder agriculture: What works and what doesn't?

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Abstract

This evidence review assesses various climate adaptation interventions aimed at enhancing the resilience and sustainability of smallholder agriculture. It evaluates the effectiveness of technological, informational, and financial interventions through a selection of high-quality studies. The review finds strong support for the positive impacts of interventions such as irrigation, improved seed varieties, and insurance. There is some suggestive evidence that Forecast-based Financing and cash transfers may be effective, while the evidence is still limited for interventions like Climate-Smart Agriculture and Early Warning Systems. Climate services and agricultural training programs show mixed results. These findings underscore the need for targeted research to optimize the design and implementation of adaptation strategies. This review, while offering a solid foundation for understanding different interventions' effectiveness, underscores the necessity for ongoing research to broaden the evidence base for less examined interventions, investigate synergies among various interventions, and enhance the knowledge of tailoring interventions to specific local contexts.

Main points

- Technological interventions such as irrigation and the use of improved seed varieties have shown consistent positive impacts on agricultural productivity, resilience to climate shocks, and income levels among smallholder farmers
- Financial mechanisms such as insurance (particularly index-based insurance) have generally shown positive effects on risk management and agricultural investment. Yet, demand for individual insurance among farmers has been consistently low.
- There is some indication that Forecast-based Financing and cash transfers can help protect households against climate shocks; however, the evidence base is sparse. Similarly, the evidence base for early warning systems and climate-smart agriculture interventions is very limited. This highlights the need for further research in this area.
- The evidence on interventions like climate information services and agricultural training programs is limited and shows mixed results, with some studies showing positive impacts on agricultural decision-making and productivity, while others indicate limited or no significant effects.
- Combining different types of interventions (e.g., insurance with agricultural inputs or technical assistance with training programs) tends to enhance the effectiveness of individual measures, suggesting that bundling multiple interventions may offer more substantial benefits than standalone ones.

1 Introduction

Climate change poses significant challenges to smallholder agriculture, making it crucial to identify effective adaptation strategies. This evidence review aims to shed light on policy-relevant interventions that can enhance resilience and sustainability among smallholders. It is motivated by the urgent need for informed decision-making in the face of increasingly unpredictable and extreme weather patterns, which disproportionately affect smallholder farmers.

The review is structured around three categories of interventions: technical, informational, and financial. Technical interventions include irrigation, new crop varieties, and improved seeds. Informational interventions encompass climate information services, training, and capacity building. Financial interventions cover insurance, Forecast-based Financing (FbF), and Cash Transfers. Additionally, the review explores the efficacy of bundled interventions that combine strategies across these categories. While this review focuses on these interventions, which are frequently implemented and directly relevant to rural communities, it should be noted that other categories of interventions, though relevant for climate adaptation, are not included. These include nature-based solutions like agroforestry and forest restoration, Payment for Ecosystem Services (PES) interventions, and infrastructure interventions beyond irrigation, such as flood control measures and renewable energy infrastructure. The scope of this review does not extend to a comprehensive examination of all possible climate adaptation interventions, and practitioners are encouraged to consider these and other complementary strategies in their climate adaptation efforts.

2 Methodology

This evidence review includes a selection of relevant and high-quality studies identified by the author. Quality assessment, although subjective, is based in part on the rigor of the research method—favoring experimental and quasi-experimental methods—and in part on the prestige of the publishing journal or outlet. Sources for studies include the 3ie Evidence Portal, Google Scholar, references in pre-existing papers, and the author's expertise. High-quality systematic or non-systematic literature reviews are also referenced when available. It is important to note that this evidence review does not constitute a systematic review and thus may miss some relevant studies.

3 Technological interventions

3.1 Irrigation

Irrigation interventions in the Global South aim to provide smallholder farmers with reliable access to water for agriculture, thus aiming to mitigate the effects of dry spells. The empirical literature assessing the impact of irrigation infrastructure is large; however, only a handful of studies are based on rigorous methods, such as RCTs.

Overall, the evidence suggests that providing access to irrigation has a positive impact on crop yields, crop diversification, resilience to climate shocks, and income. The most recent systematic review covering the impact of irrigation was done in 2013 and summarized the findings from 26 irrigation infrastructure studies (Knox et al. 2013). While this review concludes that the majority of irrigation projects in the referenced studies demonstrated positive impacts on agricultural productivity and poverty reduction, none of the cited studies are based on experimental methods, which necessitates caution when interpreting the results.

Beyond this review, the author has identified six studies that are deemed to be of high quality (Duflo and Pande 2007; Dillon 2011; Chakravorty et al. 2020; Jones et al. 2022; Dyer and Shapiro 2023; Fishman et al. 2023). Three of these studies are based on RCTs (Chakravorty et al. 2020; Dyer and Shapiro 2023; Fishman et al. 2023), while the other three are based on quasi-experimental methods that are deemed plausible in identifying causality. Irrigation technologies studied include household irrigation pumps (Dyer and Shapiro 2023), drip irrigation systems (Fishman et al. 2023), free access to water (Jones et al. 2022), provision of irrigation pipes (Chakravorty et al. 2020), small-scale irrigation systems (Dillon 2011), and a large-scale irrigation dam (Duflo and Pande 2007). Five of these studies demonstrate positive and significant impacts of these technologies on a variety of outcomes variables, including farm revenue and profits, consumption, and resilience to rainfall shocks (all except Chakravorty et al. 2020). For instance, a 2023 RCT in Kenya demonstrated that farmers provided with household pumps increased their net farm revenue by approximately 13% and sustained pump usage over two years (Dyer and Shapiro 2023). Another 2023 RCT in India showed that smallholders given drip irrigation systems shifted to more profitable crops, increased agricultural revenue, and transferred more groundwater to neighboring plots, primarily through cash sales (Fishman et al. 2023).

Given this strong evidence from several high-quality studies, this review concludes that there is substantial support for the positive impacts of irrigation investments.

3.2 New crop varieties and improved seeds

Improved seed varieties, often engineered to be more resilient to changing climate conditions and to increase yield, have been increasingly adopted as a crucial strategy in smallholder agriculture for climate adaptation. Similarly, new crop varieties may improve climate resilience. The most recent systematic review focusing on the impact of improved seeds was done in 2018 and covers 27 studies based on experimental or quasi-experimental impact evaluations of improved varieties but is limited to CGIAR-supported interventions (Garbero et al. 2018). The review found that these improved varieties increased income by 35 percent and increased expenditure by 14 percent in adopting households in rural areas;

however, it did not find any significant reductions in poverty. Another systematic review from 2015 (Stewart et al. 2015) identified six high-quality studies that have estimated the impact of new crop varieties, where five of these studies looked at orange-fleshed sweet potatoes (OFSP). Overall, these agricultural input innovations resulted in significant improvements in farmers' levels of food security as measured by nutritional indicators.

The review has also identified six additional RCTs that were published since these reviews came out (Emerick et al. 2016; Yamano et al. 2018; Ahmed et al. 2019; Bird et al. 2022; Bernard et al. 2023; Boucher et al. 2024). These covered several different types of improved varieties, including maize, rice, groundnuts, among others, and were conducted across several countries, including Kenya, India, Bangladesh, Tanzania, and Mozambique. The vast majority of these studies indicate positive effects of the improved varieties, including increases in profits and revenues, protection against downside risk, and lower incidence of pesticide exposure. Only one study finds that an improved variety (DT rice in India) is not more tolerant of drought than other rice varieties (Yamano et al. 2018). An example of a positive effect is Boucher et al. 2024, which shows that farmers who are offered a DT Maize variety in Tanzania and Mozambique suffer no dips in food security during a moderate drought, whereas control communities suffer relatively large losses during such droughts. Another study from India showed that the provision of a new flood-tolerant variety of rice increased the adoption of a more labor-intensive planting method, area cultivated, fertilizer usage, and credit utilization (Emerick et al. 2016).

Overall, these studies provide relatively strong evidence that improved seed varieties and new crop varieties (specifically OFSP) can have significant and positive impacts among smallholder farmers.

3.3 Climate-smart agriculture

Climate-Smart Agriculture (CSA) is a transformative approach aimed at enhancing agricultural productivity and sustainability in the context of climate change. It incorporates practices such as crop diversification, conservation agriculture, agroforestry, and precision farming, designed to increase income, bolster resilience, and reduce greenhouse gas emissions. Given the broad range of practices involved, it is difficult to make general statements about the effectiveness of CSA. In this sub-section, a few studies that have evaluated the impact of different types of CSA practices will be mentioned.

The author has not been able to identify any systematic reviews on the impact of CSA practices. Furthermore, experimental studies are scant—only two were identified (Bijarniya et al. 2020; Liverpool-Tasie et al. 2023)—and most of the available evidence stems from quasi-experimental methods. Recent research also highlights a paucity of rigorous evidence on the productivity effects directly attributable to the adoption of CSA technologies among farmers (Liverpool-Tasie et al. 2023).

Among the two RCTs that were conducted, one looked at the impact of introducing a local supplier of climate-smart urea super granules (USG) fertilizer and demonstration of its use and benefits to randomly selected villages in Nigeria (Liverpool-Tasie et al. 2023). The study reported a 24-percentage point increase in the adoption of USG fertilizer, while the utilization of prilled urea decreased by 17 percentage points. Similarly, an RCT in India examined the impact of various CSA practices, including zero-tillage, laser levelling, residue and water management, among others (Bijarniya et al. 2020). The results indicated that implementing this suite of climate-smart agriculture practices led to a more than 10% increase in system productivity and an almost 30% rise in farm profitability.

Beyond these RCTs, four impact evaluations using quasi-experimental methods have been identified, which are deemed to be of acceptable quality (Arslan et al. 2015; Michler et al. 2019; Amadu et al. 2020; Adam and Abdulai 2023). These studies show mixed impacts of CSA practices, but with mostly positive results. Specifically, a study conducted in Zimbabwe demonstrated that while Conservation Agriculture (CA) effectively mitigates the adverse impacts of rainfall deviations, its application in years of average rainfall yields no gain, and in some instances, even results in yield losses (Michler et al. 2019). Another research study in Zambia found that minimum soil disturbance and crop rotation had no significant impacts on yield outcomes (Arslan et al. 2015). However, legume intercropping significantly increased yields and reduced the likelihood of low yields, even under critical weather stress during the growing season.

While these studies offer some indication that CSA practices can have positive impacts, the author believes the existing evidence base is incomplete. Further research, particularly high-quality Randomized Control Trials (RCTs), is necessary to comprehensively understand the potential benefits of CSA practices.

4 Informational interventions

4.1 Climate information services

Climate information services (CIS) is the provision of short- and longer-term weather forecasts bundled with agricultural advice, which has the potential to help farmers make better agricultural decisions. There is currently only a limited number of rigorous studies evaluating the impacts of CIS, and all of them consider simple SMS- or voice-based messages with weather information and/or advice.

A literature review conducted in 2021 did not cite any impact studies and concluded that "…most of the existing climate service initiatives are still at their pilot phases, more rigorous impact evaluations are required to generate evidence on what works, how, when, for whom and at what cost" (Yegbemey and Egah 2021). Nonetheless, five high-quality studies were identified, where three are RCTs and two use quasi-experimental methods (Fafchamps and Minten 2012; Rosenzweig and Udry 2013; Rao et al. 2015; Camacho and Conover 2019; Yegbemey et al. 2023). The results of these studies are mixed. While four studies showed positive impacts on some variables, including either labor productivity and allocations, profits, or number of crops, they failed to demonstrate impacts on other outcome variables of interest (Rosenzweig and Udry 2013; Rao et al. 2015; Camacho and Conover 2019; Yegbemey et al. 2023). One study showed no significant impacts on any of the outcome variables of interest (Fafchamps and Minten 2012).

Hence, the evidence on the effect of climate services is inconclusive, and future research should focus on evaluating the impact of more comprehensive climate services programs that combine messages with training, user engagement, community dissemination, and access to enabling inputs.

4.2 Early warning systems

Early warning systems (EWS) play a crucial role in disaster risk reduction (DRR), enabling timely action to prevent loss and injury from impending climatic hazards. According to a 3ie Evidence Gap Map, which was last updated in 2022, there exist no interventions evaluating the impact of early warning systems (Yavuz et al. 2022). This is perhaps not surprising given that EWS are typically rolled out at a large scale at once, making it difficult to identify a suitable control group. However, one study assessing the impacts on an EWS has been identified. Akwango et al. (2017) used a simple regression approach to study the impact of the implementation of a drought early-warning system in one sub-region in Uganda. The study found that those participating in the EWS had lower incidence of food security and higher levels of nutrition. Given that an experimental approach was not used, selection issues might undermine the validity of these results. Another study was also identified which evaluated a set of community-level activities and programs in Nepal (Bishop 2014). These included DRR management training and the establishment of a flood EWS. While the study found positive impacts on resilience, the methodology for assessing causal impact has a high risk of bias.

In conclusion, the evidence base on the impact of Early Warning Systems (EWS) is notably sparse, highlighting a need for future research focus in this area.

4.3 Training

Training encompasses agricultural extension, farmer field schools (FFS), and other forms of educational and support activities aimed at providing farmers with essential skills and knowledge. Despite the myriad of agricultural training programs, this review focuses on those specifically addressing climate adaptation interventions or looking specifically at food security or resilience as outcomes.

The author is aware of one systematic review from 2015 that synthesizes the evidence from five agricultural training interventions (Stewart et al. 2015). While none of the included studies focus on climate adaptation practices or consider food security or resilience outcomes, the findings are nonetheless worth mentioning. Among these five studies, three find a positive effect on farmers' income while the other two fail to find any significant effects.
Beyond this review, five additional studies have been identified, where four look at the impact of training programs with a climate adaptation component (Dar et al. 2020; Pamuk et al. 2021; Martey et al. 2021; Bragança et al. 2022), and one study assesses the impact of a typical farmer field school program on food security (Larsen and Lilleør 2014). Three out of the four climate adaptation training studies show positive effects on CSA practices (Dar et al. 2020; Pamuk et al. 2021; Martey et al. 2021), while one study shows no impacts of the training component alone but significant impact when the training is combined with technical assistance (Bragança et al. 2022). The farmer field school study showed positive effects on food security but no effect on poverty (Larsen and Lilleør 2014).

Overall, the evidence on the impact of agricultural training programs is sparse, and results are mixed. The evidence base is further complicated by the fact that agricultural training programs are not standardized and rather tailored to the specific context. This also makes it difficult to use existing evidence in a new context.

5 Financial interventions

5.1 Insurance

Insurance can be a vital tool for managing risks and promoting economic stability in the face of climate risks. Index insurance, as opposed to traditional indemnity-based insurance, pays out benefits based on a predetermined index of loss, such as rainfall levels or crop yields in a specific region. This type of insurance may be especially beneficial for smallholder farmers who face significant agricultural risks, such as droughts or floods, which can lead to severe income volatility and food insecurity.

The empirical literature suggests that index insurance generally has a positive impact on resilience and has been found to boost the adoption of advanced production technologies, increase access to credit, and improve households' ability to cope with shocks. A systematic review conducted in 2016 identified nine experimental or quasi-experimental studies that have estimated the impact of insurance on household-level outcomes (Marr et al. 2016). The majority of these studies show positive effects, including reduced diversion of credit away from productive investments, higher investments in risky crops, and increases in total income. However, some of the included studies report on negative effects of insurance, including reduced wealth in good years and larger inequality. Furthermore, one study provides some evidence that insurance improves household welfare for some individual measures, but not for an aggregate measure of household welfare.

Since this review was published, an additional eleven high-quality RCTs have been identified that have assessed the impact of various insurance interventions (Kramer and Cole et al. 2017; Ceballos 2018; Janzen and Carter 2019; Hill et al. 2019; Ward et al. 2020; Ahmed et al. 2020; Bulte et al. 2020; Wong et al. 2020; Mishra et al. 2021; Stoeffler et al. 2022; Boucher et al. 2024). These interventions generally involve the provision of a weather-based or satellite-based index insurance product or in one case, a conditional indemnity insurance contract. Many of the interventions are also bundled with other products, such as improved seed varieties or unconditional cash transfers. These interventions have been implemented across several countries, including India, Ghana, Ethiopia, Tanzania, Bangladesh, and Kenya. Overall, the findings from these studies indicate that 1) insurance provides resilience in the face of shocks, 2) insured loans increase access to credit relative to uninsured loans, 3), insurance leads to increased usage of inputs, such as seeds and fertilizer, and uptake of climate-smart agriculture practices, 4) insurance reduces expensive coping strategies by making households less likely to sell assets following a shock.

For instance, one study highlighted that providing index insurance to smallholder farmers in Bangladesh encouraged an expansion of cultivated area and increased agricultural input expenditures during the monsoon season (Hill et al. 2019). In the wake of a shock, it propelled more intensive rice production in the subsequent dry season, with heightened use of irrigation and fertilizers, thereby yielding higher rice production overall. Another study covering both Tanzania and Mozambique illustrated that smallholders with insured seeds maintained, and even boosted, their investments in the subsequent season despite severe droughts, without suffering a loss in food security (Boucher et al. 2024). However, one study noted that providing free insurance did not yield improvements in input use, yield, or income (Ahmed et al. 2020).

Overall, the evidence base quite strongly suggests that insurance has positive benefits for smallholder farmers. However, impact varies depending on product design, local context, and how well the index correlates with actual losses experienced by the insured.

Despite these benefits among insured farmers, index insurance has been met with surprisingly low demand among smallholder farmers. A large number of studies have attempted to identify the causes of such low demand and have shown that lack of trust, limited financial literacy, affordability, and design issues related to basis risk (the mismatch between actual losses and payouts) are all factors that suppress demand.

5.2 Forecast-based financing and cash transfers

Forecast-based Financing (FbF) uses climate forecasts to trigger pre-emptive actions, minimizing climate hazard impacts. Cash transfers provide direct payments to aid risk management and recovery from climate shocks. Both strategies aim to enhance resilience and reduce climate change vulnerability.

The literature on the impact of both mechanisms on resilience and coping is small and incomplete, and no systemic reviews on this topic have been identified. While a large literature has demonstrated the substantial benefits of cash transfers and social protection programs on welfare, poverty reduction, and investments in human capital, there is limited evidence on FbF and the linkages between cash transfers and resilience.

Only two papers have been identified that study the impact of FbF assistance or anticipatory cash transfers, and neither makes use of experimental approaches. Pople et al. (2021) discovered that anticipatory cash transfers given to households predicted to face extreme floods in Bangladesh were primarily spent on food and water. Treated households were 36% less likely to endure a day without eating during the flood. Three months post-flood, these households reported significantly higher food consumption and wellbeing for both children and adults. In another study, Gros et al. (2022) demonstrated that one-off cash grants and in-kind veterinary kits provided to vulnerable herders based on forecasts of an extreme winter season in Mongolia led to reduced mortality and increased offspring survival for some livestock types. The study also emphasized the critical role of timing in FbF assistance.

Similarly, three papers studying the impact of cash transfers on resilience have been identified, where two of these studies utilize an RCT approach (Macours et al. 2012; Asfaw et al. 2017; Premand and Stoeffler 2020) Two of the three papers find that the cash transfers partially or fully mitigate the impacts of negative shocks (Asfaw et al. 2017; Premand and Stoeffler 2020). The third paper (Macours et al. 2012) found that the cash transfer alone did not offer protection against the negative effect of shocks, but that when bundled with either a vocational training package or a productive investment grant, interventions fully protected against drought shocks two years after the end of the intervention.

Overall, while the suggestive evidence is sparse, there is some indication that FbF and cash transfers can help protect households against climate shocks.

6 Bundled interventions

The previous sections discuss specific interventions that aim to improve resilience and food security in the face on climate shocks. Yet, many of these interventions may be ineffective or less effective when implemented by themselves. In fact, many of the studies discussed have bundled complementary interventions together or included a set of enabling programs as part of the package. There is still very limited research looking at the complementarities between different interventions, but below, we discuss a small selection of some of the bundles that have been considered in the literature.

First, a common bundle is credit and insurance. While one study found that insured loans decreased demand for credit (Gine and Yang 2009), another study showed that mandatory insurance increased access to credit (Mishra et al. 2021). Another common bundle is seeds and insurance. For example, three of the studies mentioned under the insurance section (Ward et al. 2020; Bulte et al. 2020; Boucher et al. 2024) have demonstrated the complementarities and benefits of bundling improved or certified seeds with index insurance. Other studies have shown synergies between agricultural credit and training (Moahid et al. 2021) and between index insurance and CSA practices (Kramer and Ceballos 2018).

There have also been several impact evaluations of so-called graduation programs which are multi-faceted programs aimed at helping households build resilience or escape poverty. However, given that these programs are often tailored to specific contexts and that it is challenging to isolate the contributions of and synergies between individual components, the evidence derived from these evaluations may not readily indicate the potential impact of such programs in other settings.

7 Conclusion

This evidence review has examined a range of interventions aimed at enhancing resilience among smallholder farmers in the face of climate change.

Strong evidence supports the positive impacts of technical interventions such as irrigation and improved seed varieties, as well as financial interventions like insurance. These strategies consistently show potential in bolstering productivity and promoting economic stability. Emerging evidence suggests that financial mechanisms like Forecast-based Financing and cash transfers can help protect households against climate shocks, although more research is needed. However, the evidence base is still limited for newer interventions, including Climate-Smart Agriculture practices and Early Warning Systems. Similarly, informational interventions like climate services and agricultural training programs show mixed results, highlighting the need for further investigation.

While this review provides a robust starting point for understanding the effectiveness of various interventions, it also highlights the need for continued research. Future work should aim to expand the evidence base for less-explored interventions, explore synergies between different intervention types, and deepen our understanding of how to tailor interventions to specific local contexts.

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