Photo credit: Michael Major/Crop Trust

# SPIA Briefing Note: Climate Change Mitigation and Adaptation

Standing Panel on Impact Assessment

November 2024

Smallholder farmers in the Global South face unique challenges due to climate change, with increasing temperatures, erratic rainfall, and extreme weather events significantly impacting their livelihoods. These farmers, who often rely on rain-fed agriculture, are particularly vulnerable to climate variability, which exacerbates soil degradation, water scarcity, and crop failure. Researchers across CGIAR have long been developing and testing innovations that aim to help smallholder farmers adapt to climate change, be it through the prism of breeding innovations, or from the standpoint of new agronomic and natural resource management practices. Since at least the inception of the Climate Change, Adaptation and Food Security (CCAFS) CGIAR Research Program (2009-2021), CGIAR has also sought to design and test integrated bundles of biophysical and social or policy innovations related to climate change adaptation and mitigation.

Breeding new crop varieties for tolerance to drought, submergence, heat, or salinity (together referred to as “stress tolerance”) is a core CGIAR approach to climate change adaptation. Through the SPIA Country Study portfolio we are learning about the dissemination and adoption of these stress tolerant varieties in key geographies. We take plant samples from farmers’ fields and DNA fingerprint them to identify the varieties that farmers are growing. For example, in Ethiopia in 2018/19, we estimated that 23.7% of maize-growing households were growing CGIAR-related **drought-tolerant maize varieties** (SPIA Ethiopia Country Study, 2020). When we re-sampled in 2021/22, following a three-year period of repeated droughts, COVID-19 and a protracted civil conflict, we found that this number had increased to 39.6% of maize-growing households, representing an estimated 2.6 million households (SPIA Ethiopia Country Study, 2024). In Ethiopia, the government is arguably the central player fostering agricultural development, so we might characterize this story of successful rapid diffusion of drought-tolerant maize varieties as being largely supply-driven.

Absent a strong supply push from the state as in Ethiopia, farmers are likely to seek out and adopt new innovations only if they are convinced of their benefits. The study by Boucher et al (2024) shows the challenges associated with learning about the properties of new crop varieties. Stress tolerant varieties will only demonstrate their benefits in response to quite specific extreme weather events. The authors test whether this scaling challenge can be addressed by bundling stress-tolerant seed varieties with insurance that covers climate-related damages that the seeds do not protect against. Through a randomized controlled trial in Mozambique and Tanzania, they evaluate a combined offer of drought-tolerant maize seeds and a satellite-based index insurance product. They find that compared to drought-tolerant seeds alone, this bundled innovation protects crop yields against mid-season drought and also mitigates the long-term drop in productivity that drought typically causes. Importantly, this innovation influenced the reach of the product as well, but in a nuanced fashion -- farmers who experienced a drought shock and observed the protection provided by the bundled intervention were more likely to increase their investment in these innovations in subsequent years. By contrast, farmers who did not experience a shock were less likely to invest in these climate risk management innovations.

**Submergence tolerance in rice** has emerged as a key trait of CGIAR interest, particularly following the results of the seminal study by Emerick et al (2016). Their randomized control trial in India examined the impacts of Swarna *Sub1*, a rice variety developed by IRRI by using marker-assisted backcrossing of the *Sub1* gene into the popular Indian variety Swarna. The study demonstrates that the presence of the *Sub1* gene has a positive impact not only through preventing yield losses during flooding, but also through additional farm investments in normal years when farmers know that they are protected through the *Sub1* trait.

Several recent evidence streams provide additional insight and nuance. Michler et al (2024) used three waves of household panel data to examine the impact of stress-tolerant varieties at a larger scale (and for Bangladesh rather than India). To compensate for the relative unavailability of data, the authors relied on machine learning and Earth Observation data to construct detailed maps of both rice area and floods, which were then merged with administrative data about dissemination of submergence tolerant rice varieties. They were unable to replicate the positive results reported by Emerick et al (2016). Possible reasons include insufficient adoption, or insufficient instances of flooding of exactly the right type, to detect a positive signal.[1]

Kretzschmar et al (2018) carried out DNA fingerprinting of farmers' rice seeds in Bangladesh in 2014, finding that the two submergence tolerant rice varieties (BRRI Dhan 51 and BRRI Dhan 52)[2] bred for the *Aman* season were being grown by a modest 6.6% of farmers (BRRI Dhan 51 at 1.4% and BRRI Dhan 52 at 5.2%). Ten years later, the SPIA Bangladesh Country Study (2024)'s farmer recall data[3] find a similar estimate of 6.7% for the *Aman* season 2023.[4] Despite concerns about farmers' accuracy at identifying the exact crop variety, taken at face value this suggests that the spread of submergence tolerant varieties has stalled in Bangladesh. These modest levels of adoption provide a simple explanation for the inability to detect benefits of *Sub1* with aggregated remote sensing data.

In the Vietnam country study, we were able to collect DNA fingerprinting data at a large scale to identify the presence of the *Sub1* gene. Alleles associated with *Sub1* were found in 1.3% of the sample (equivalent to approx. 100,000 households), but importantly, only in rice samples whose genetic heritage could not be identified. Since the *Sub1* gene was originally discovered in a landrace, this suggests that the modest presence of submergence tolerant rice in Vietnam is unrelated to the breeding program.

Taken together, these somewhat sobering findings on submergence tolerance raise questions about the long-term impacts of the breeding efforts, absent either a bundled approach to roll-out, or a major supply-side push from government.

The agronomic practice of **Alternate Wetting and Drying (AWD)** of rice paddies has the potential to significantly reduce GHG emissions from rice. It has been a centerpiece of CGIAR research efforts in climate mitigation. For example, in 2011, CCAFS (2011) forecast that AWD "looks set to be rolled out across 3.2 million hectares in Vietnam". Over the past decade, eight Vietnamese governmental decrees have promoted AWD implementation, and since 2016, AWD has been recognized as central to the country's Nationally Determined Contributions (NDC) under the Paris agreement.

Despite this, scaling the approach has been a challenge. In the SPIA Vietnam Country Study (2024) we estimate between 3.3% (if we consider two dry downs of five or more days) and 5.4% (if we consider one dry down) of rice-growing households adopt

[1] It is very challenging to detect the impacts of innovations like submergence tolerance when working with the Earth Observation products that were available for 2010 onwards (when the rice varieties were being rolled out). This data constraint is an additional possible explanation for the null result.

[2] The international names for these varieties are Swarna_Sub1 and BR11_Sub1.

[3] We could only carry out DNA fingerprinting of rice during the *Boro* 2024 season, which is mostly irrigated and for which stress tolerance is a less relevant focus.

[4] The two varieties had switched positions in relative popularity almost perfectly (BRRI Dhan 51 at 5.5%, BRRI Dhan 52 at 1.2%).

AWD[5]. The corresponding estimated reach of AWD in Vietnam is between 249,300 households (two dry downs) and 408,700 households (only one dry-down). In the SPIA Bangladesh Country Study (2024), over 25% (corresponding to an upper bound estimate of approximately 2.8 million households) of rice-growing households report drying their rice plots between irrigation cycles during the *Boro* season. Importantly however, 33.9% of these plots belonged to households reporting water shortages in the past three *Boro* seasons – suggesting the fields had dried naturally and not through intentional AWD application. Moreover, less than 1% of farmers in Bangladesh were adopting AWD with the intended method of using a perforated PVC pipe. This may indicate that the correct estimate of AWD adoption in a water-abundant context is even smaller.

Indeed, Chakravorty et al (2023) show that when irrigation water is abundant, large-scale adoption of AWD is hampered by a lack of private incentives. In their village-level randomized trial in Bangladesh, training about AWD along with provision of perforated pipes had no significant effects on water use and farm-level profits on average. Instead, measurable water savings occurred only in villages where farmers pay a volumetric (marginal) price for water. In a follow-up study, farmers who were randomly selected to receive debit cards that converted their billing from per-acre to per-hour of water use adopted AWD at higher rates. This shows the potential for innovations that align private incentives with the public good.

Another example of policy-related innovations to address climate change comes from work on **climate-smart mapping and adaptation planning** (CS-MAPS), featured in the SPIA Vietnam Country Study (2024). During the period 2016–2021, CCAFS researchers developed and tested a participatory approach that integrated scientific evidence about climate risks with local knowledge about relevant land use and infrastructure to develop adaptive interventions.

In 2023, SPIA collected these scenario maps for all 41 provinces across four regions in Vietnam that have created location-, risk-, and season-specific climate change adaptation plans. A phone survey of provincial officials and qualitative content analysis of the annual/ seasonal agricultural plans they developed, helped to understand how CS-MAPs influence the government's recommendations to farmers when extreme weather is predicted. Our analysis using the VHLSS data from the Mekong River Delta suggests that in an extreme year, 27.4% of the rice-growing households (representing 171561 households) chose a planting date aligned with extreme-year planting date recommended for their district by the CS-MAP.

**Index-based livestock insurance (IBLI)**[6] supports pastoralists' adaptation to climate change. Barrett et al (2023) examine the long-term effects of a randomized roll-out of IBLI in pastoral areas of Northern Kenya and Southern Ethiopia. The roll-out involved the distribution of discount coupons to help pay the insurance premium to 1,439 pastoralists across Marsabit County in Kenya (2009) and Borana Zone in Ethiopia (2012). Some ten years after the original study the authors find that adoption of IBLI had increased the share of large animals herded at the expense of small animals (particularly goats). While there was no observable change in the total value of productive assets, they find large, albeit imprecisely estimated, increases in income from livestock and crops. Remarkably, this shift in the households' production strategy is closely linked to an observed major increase in household members' education levels. As small animals, traditionally herded by children, are displaced by larger animals, child labor becomes less productive at the margin which provides a further incentive for households to send their children to school.

Across the portfolio of innovations reviewed in this brief, a recurring theme is the value of having multiple waves of data on the same innovation collected over time to help understand the dynamics of change. The studies also highlight the importance of experimental impact evaluations in both studying complex combinations of innovations and in creating space to uncover unanticipated causal pathways.

---

[5] The AWD practice recommends that farmers dry the surface of their fields, and only reirrigate when the water level drops 15 cm below the surface. The water level can be monitored using a simple plastic pipe bedded in the soil. SPIA's country studies both in Vietnam and Bangladesh find minimal adoption of this plastic pipe. However, AWD advocates argue that the use of this pipe is not a necessary condition for adoption of AWD, as experienced farmers learn to judge the patterns of drying on the soil surface without it. Hence the focus on collecting data about actual patterns of drying.

[6] IBLI is also the focus of the study by Wilcox et al (2024), featured in the environmental impacts brief, showing that there are no observed negative environmental impacts on rangeland health from the IBLI roll-out.

## References


*Barrett, C. B., Jensen, N., Morsink, K., Noritomo, Y., Son, H. H., Banerjee, R., & Teufel, N. (2024). Long-run Effects of Catastrophic Drought Insurance. October 2024. Retrieved from https://barrett.dyson.cornell.edu/files/papers/Long_term_effects_of_IBLI%20submitted%2026%20Oct%202024.pdf.

Boucher, S. R., Carter, M. R., Flatnes, J. E., Lybbert, T. J., Malacarne, J. G., Mareyna, P. P., & Paul, L. A. (2024). Bundling Genetic and Financial Technologies for More Resilient and Productive Small-Scale Farmers in Africa. The Economic Journal, 134(662), 2321–2350. https://doi.org/10.1093/ej/ueae012

CCAFS. (2014). Putting Alternate Wetting and Drying (AWD) on the Map, Globally and Nationally. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Retrieved from https://ccafs.cgiar.org/outcomes/putting-alternate-wetting-and-drying-awd-map-globally-and-nationally

Chakravorty, U., Dar, M. H., & Emerick, K. (2023). Inefficient Water Pricing and Incentives for Conservation. American Economic Journal: Applied Economics, 15(1), 319–350. DOI: 10.1257/app.20210011

Emerick, K., de Janvry, A., Sadoulet, E., & Dar, M. H. (2016). Technological Innovations, Downside Risk, and the Modernization of Agriculture. American Economic Review, 106(6), 1537–1561.

*Kosmowski, F., Alemu, S., Mallia, P., Stevenson, J., Macours, K. (2020). *Shining a Brighter Light*: *Comprehensive Evidence on Adoption and Diffusion of CGIAR-Related Innovations in Ethiopia.* Rome: Standing Panel on Impact Assessment (SPIA).

Kretzschmar, T., Mbanjo, E. G. N., Magalit, G. A., Dwiyanti, M. S., Habib, M. A., Diaz, M. G., Hernandez, J., Huelgas, Z., Malabayabas, M. L., Das, S. K., & Yamano, T. (2018). DNA fingerprinting at farm level maps rice biodiversity across Bangladesh and reveals regional varietal preferences. Scientific Reports, 8(1), 14920.

*Michler, J. D., Rafi, D. A. A., Giezendanner, J., Josephson, A., Pede, V. O., & Tellman, E. (2024). Impact Evaluations in Data Poor Settings: The Case of Stress-Tolerant Rice Varieties in Bangladesh. https://doi.org/10.48550/arXiv.2409.02201

*SPIA Vietnam Country Study (2024)

*SPIA Bangladesh Country Study (2024)

*SPIA Ethiopia Country Study (2024)

*Wilcox, S. W., Barrett, C. B., Jensen, N. D., Clark, P., Fava, F., Kahiu, N., Soto, G. E., & Sun, Y. (2024). The Environmental Impacts of Microfinance: Index-Based Livestock Insurance and East African Rangelands. Presentation at the SPIA Fest pre-conference to the International Conference of Agricultural Economists (ICAE), 2 August 2024.


*study conducted under the 2019-2024 workplan