MIDTERM FINDINGS FROM A CLUSTER RANDOMIZED TRIAL

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CLIMATE-SMART CROP INSURANCE TO PROMOTE ADOPTION OF STRESS-TOLERANT SEEDS

Midterm Findings from a Cluster Randomized Trial

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Background

Too often, smallholder farmers suffer severe financial consequences from extreme weather events, pests, and disease; and climate change will increase the frequency at which natural hazards occur. This poses a threat to livelihoods not only *ex post*, by reducing agricultural output and inducing farmers to sell their assets, keep children out of school or borrow at high rates; but also *ex ante*, by discouraging farmers from investing in high-return practices and technologies (Elbers *et al.*, 2007). Innovative solutions are needed to help marginalized farmers prepare for these natural hazards.

One solution, building upon decades of agricultural research for development, can be found in the breeding of crop varieties that are more tolerant to weather shocks, pests and disease. The resulting improvements in seed technology offer promising pathways to improve farmers' adaptive capacity, crowd in investments in agriculture, and thereby enhance agricultural productivity (Emerick *et al.*, 2016).

At the same time, stress tolerance is not a bullet-proof solution against all hazards. Farming is risky by nature, and improved stress-tolerant varieties will not shield farmers from more severe hazards, or from risks for which stress tolerance was not an explicit breeding objective. Drought-tolerant varieties are, for instance, not necessarily disease tolerant as well. Improving resilience in the face of climate change will require a more complete solution, in which farmers invest in stress-tolerant varieties to reduce their exposure to moderate, manageable risks, whilst accessing other types of solutions, including financial services, to protect their livelihoods from more severe and catastrophic production risks.

This project note describes the findings from a research program in Kenya that aims to design, implement, and evaluate more complete risk management solutions; in particular, a solution that promotes stress-tolerant crops and varieties using an innovative picture-based crop insurance (PBI) product. The note first describes this intervention and the study designed to measure its impacts, followed by an overview of key findings at midline. This will include insights on the scalability of picture-based claims settlement, opportunities for more gender-responsive program design, and demand for the insurance product. We conclude by describing key challenges faced whilst implementing these solutions and providing an outlook for the future.

Objectives and Intervention

The program was launched mid-2019 by ACRE Africa—a service provider that works with local insurers and agricultural value chains actors to provide holistic risk management solutions including insurance for smallholder farmers—in collaboration with the Kenya Agriculture and Livestock Research Organization (KALRO), and researchers from the International Food Policy Research Institute (IFPRI) and Wageningen University.

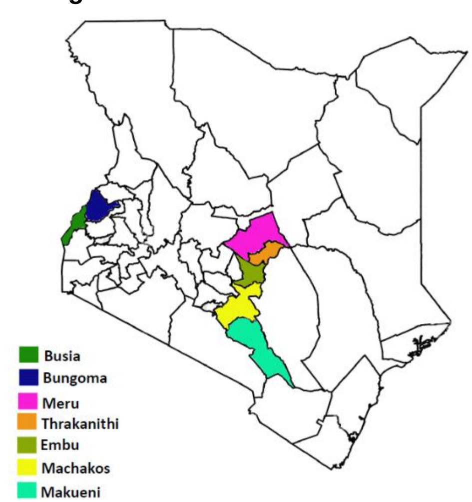
The main objective is to develop a scalable approach to improve smallholder farmers' risk management through an innovative picture-based crop insurance (PBI) solution and stress-tolerant varieties. PBI is used to reduce the basis risk—or inadequate correlation between insurance payouts and actual crop losses—that has plagued more common weather index insurance products (Clarke, 2016). Evidence from India shows that severe damage can be detected from smartphone images of crops (Ceballos et al., 2019).

PBI is likely complementary to stress-tolerant varieties. It could help recover farmers' investment in seeds of improved stress-tolerant varieties in the event of crop failure, as is the case for index insurance (Boucher et al., 2021). Further, farmers' use of stress-tolerant varieties could help reduce their risk exposure, lowering PBI premiums (Kramer and Ceballos, 2018). However, this needs to be tested, since compared to index-based insurance, PBI coverage may reduce incentives to invest in risk prevention and thus stress-tolerant varieties.

To inclusively deliver seeds and PBI, ACRE has trained a network of 181 champion farmers (of which 58% are female)—local opinion shapers who can influence agricultural practices and promote inclusion in their communities. Equipped with smartphones and ACRE-branded clothing, champions enroll interested farmers in insurance and take an inventory of local demand for seeds of different varieties. ACRE then places orders with regional seed distributors at negotiated prices, delivers seeds to locations convenient for both champions and farmers, and champions earn a commission per bag of seed sold. To facilitate crop monitoring, champions send in images of insured crops throughout the season via SeeItGrow, a smartphone app. These images form the basis for claims settlement: agricultural experts review the images for farmers with reported drought or rainfall damage, and insurance payouts are triggered when the experts confirm the damage.

The program is implemented in seven counties in Kenya (Figure 1): Embu, Meru and Tharaka Nithi in upper Eastern; Machakos and Makueni in lower Eastern; and Busia and Bungoma in Western. Target crops include maize, sorghum, green gram and beans. Combined, champions reached 36,506 farmers (of whom 61% are female), provided 5,907 insurance policies, resulting in 2,034 insurance payouts (with a relatively larger number of payouts for female clients), and they sold more than 600 packets of seed. Champions also collected close to 43,000 crop images for seasonal crop monitoring, which will be published online.

Figure 1. *Intervention Counties*



Experimental design

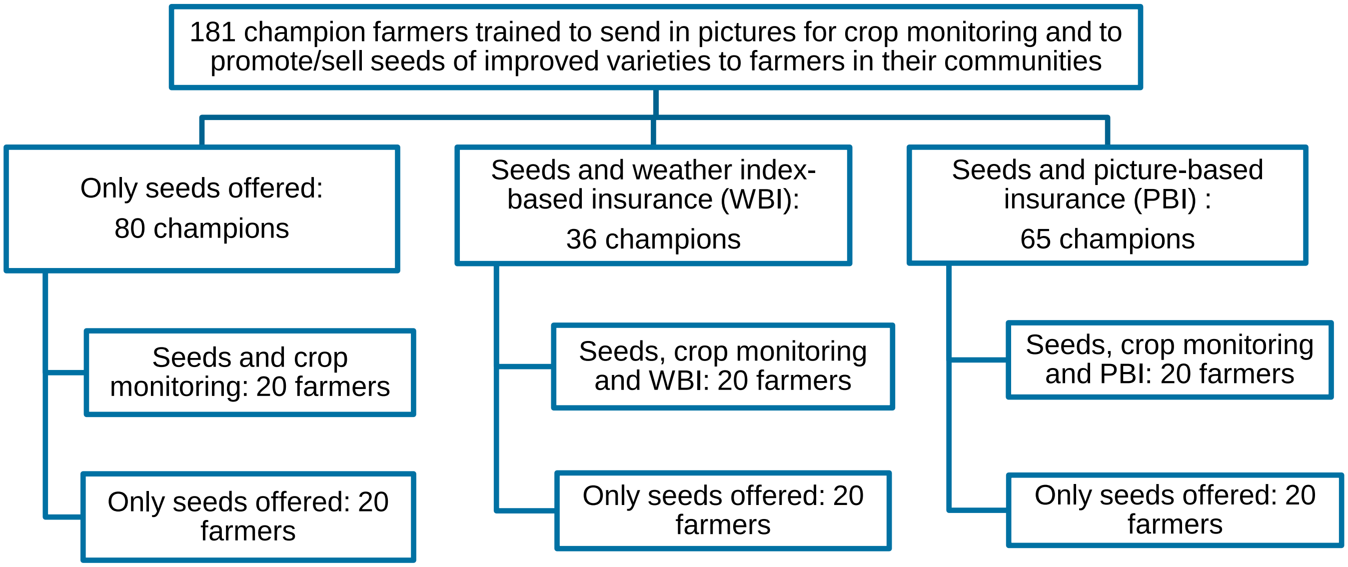


Figure 2: *Experimental design*

To analyze impacts of PBI on seed purchasing behavior, and in particular adoption of stress-tolerant varieties, we implement a cluster-randomized trial, randomizing champions into one of three treatment arms (Figure 2): i) a "seeds only" group, in which champions are marketing only the seeds, without providing insurance; ii) weather index-based insurance (WBI), in which champions are marketing seeds and also providing an insurance policy that insures farmers for abnormal levels of rainfall, measured from satellite data; and iii) picture-based insurance (PBI), in which champions market seeds by providing insurance coverage for damage if it is visible from a time series of georeferenced crop pictures. We cross-randomize whether a champion is marketing only seeds of improved but not stress-tolerant varieties, or also seeds of stress-tolerant varieties.

Thus far, due to resource constraints, champions monitored crops and provided insurance only to a subset of 20 randomly selected farmers, whilst marketing seeds to all registered farmers, including a sample of 20 farmers selected in a very similar way as the subset of 20 farmers with crop monitoring activities.

For these 40 farmers, the project collects various types of data, including: administrative data on production in the previous season and demand for inputs in the upcoming season, collected by champions at the start of every season; baseline data collected by the champions at the time of registration; a midline phone survey administered from March to August 2021 by trained enumerators from Innovations for Poverty Action (IPA); and an in-person endline survey that will be administered mid-2022. By comparing these data across treatment arms, the project aims to measure impacts on variables such as stress-tolerant variety adoption, insurance take-up, management practices, credit access, agricultural productivity, income, risk coping, and the ability to manage risk. In doing so, the program will analyse the extent to which the program delivers benefits equitably to women and men from different generations and social groups.

The following section will describe findings and lessons learned at midline, focusing on the scalability of picture-based loss assessments, gender gaps in empowerment and opportunities for more gender-responsive program design, and demand for insurance including PBI. See Kramer et al. (2021) for findings on the seed delivery model.

Findings at Midline

Loss assessments

Throughout the project, champion farmers collectively submitted more than 43,000 images, and delays in manual processing of these images yielded a first important insight: scaling of PBI requires automation of image processing. Even though at the time of claims settlement, experts reviewed only images of crops with reported drought- or rainfall-related damage, claims settlement was a time-consuming process.

To overcome this challenge, the project engaged Dvara E-Registry (DER), an agricultural fintech service provider in India, to assess the possibility of automating image processing through machine learning. DER agronomists first labeled 11,254 maize images in terms of three variables:

a) visible damage (focusing on damage causing a loss of at least 20%) and the type of damage,

b) extent of damage for the most commonly occurring type of damage, that is, drought; and

c) growth stage, as a variable determining the extent of crop damage in the event of a hazard.

Next, using 50% of these images, DER trained convolutional neural networks, a type of machine learning model often used in computer vision, to predict the three labels. They then estimated model accuracy using the remaining 50% of images and found that it is possible to automate image processing for claims settlement: their models accurately predicted visible drought damage in 89% of all smartphone images evaluated. The remaining images included 5.7% false negatives (images with visible drought damage for which the model did not predict drought), and 6% false positives (for which we erroneously predicted drought).

Another model, predicting the extent of drought damage, performed well too: the correlation between the actual extent of damage (as assessed by agronomists based on the pictures) and the predicted extent of damage (predicted by the machine learning model) was 0.86; and the absolute difference between actual and predicted damage remained small (Table 1).

Although these results indicate that automating image processing, particularly of drought detection, is possible, we also faced challenges. First, in terms of growth stage detection, the model achieved a lower accuracy of 0.75, as it proved difficult to distinguish late flowering from early maturity. Second, false positives in the drought prediction model were caused by discoloration of maize both when reaching the late maturity stage, and when affected by drought. The model had difficulty distinguishing plants that were turning yellow because of drought versus natural ripening (Figure 3). Third, training models that predict more types of damage beyond drought (such as pests, diseases, or excess rainfall) requires more data, given that non-drought damage was infrequent.

We conclude that image processing can be automated, particularly for drought detection, but a manual back-end process will need to remain in place whereby in case of doubt (for instance, when a farmer claims there was drought damage, but the model says otherwise, or when a farmer claims to have suffered damage from natural hazards other than drought). With automation in place for the majority of images, scaling PBI appears feasible.

Absolute deviation between actual and predicted extent of damage	0–10%	10–20%	20–30%	30–40%	40–50%	50–60%
Percentage of testing images (total: 5,627)	75.8%	10.4%	6.3%	3.8%	2%	1.7%

Table 1: *Absolute error in convolutional neural network trained to predict the extent of damage visible in crops.*

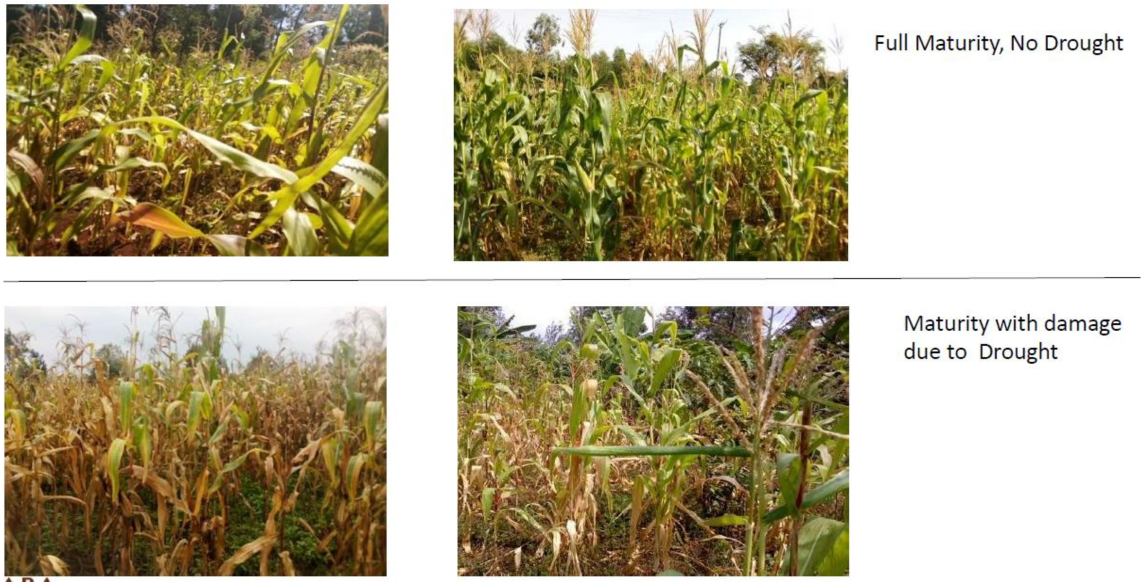


Figure 3: *Example of images with maize in maturity phase with and without drought.*

Gender equity and women's empowerment

An important program objective is to reach, benefit and empower women and men in an equitable way, and help address existing gender gaps in agriculture arising from differences in access to and agency over land, labor and other agricultural inputs, personal assets such as transportation and phones, finance, and markets. Improving women's risk management could directly help reduce these gaps for instance by de-risking their investments in agricultural inputs and enhancing access to finance. Program activities could also contribute through other channels. Promoting a new crop or variety could unlock access to new markets, as is the case for sorghum varieties used in brewing. By providing smartphones and training to champions, the program may enhance women's access to ICT if champions share their knowledge with others in their community. By raising the visibility of female champions in their communities, program activities could also debunk existing stereotypes of farming being a male activity, and change gender norms, which may create new opportunities for women.

To achieve these impacts, the program would want to make sure that it provides equal access to insurance and seeds for both women and men, instead of marketing these products in locations or through meetings accessible only to men. However, even by adopting such a gender-inclusive approach, women may not be able to benefit as much from program activities if they do not have access to land to expand their production, if they lack access to mobile money to receive insurance payouts, or if their spouse controls agricultural income as it is generated from land that he owns. A more equitable approach is gender-responsive and provides equal benefits for women and men; or could even be gender transformative and fix systemic inequities, increasing for instance women's access to and control over land. At a very minimum, the program should not harm women's empowerment or well-being, and this needs to be monitored.

For this reason, the midline phone survey included a module designed to construct the Project-level Women's Empowerment in Agriculture Index (Pro-WEAI). Pro-WEAI measures (gender gaps in) empowerment in three domains: intrinsic agency ('power within'; a person's internal voice, self-respect, or self-confidence), instrumental agency ('power to'; a person's ability to make decisions in their own best interest), and collective agency ('power with'; power from acting together with others to achieve a common goal). The instrument was administered in private for each registered farmer surveyed at baseline and his/her spouse.

Figure 4 summarizes survey findings on the extent to which different groups of women and men are disempowered, along with the indicators driving these results. Women are generally more disempowered than men and their total disempowerment does not vary strongly across groups. This is not the case for men: whereas male champions are by far the most empowered, followed by other male farmers, male spouses of female champions are among the most disempowered.

Disempowerment is primarily driven by a poor work balance, limited control over the use of income, and limited perceived autonomy in decision making. Women's perception that domestic violence is acceptable also contributes to their disempowerment. Gender-responsive programming will need to consider these factors, while it can pay less attention to the factors that contribute least to disempowerment—i.e., limited group membership, ownership of land and other assets, ability to visit important locations, and champions' access to and decisions on credit.

This suggests adopting the following gender-responsive strategies. First, to address concerns around control over the use of income, it is important to make payouts to beneficiaries directly, for instance into their personal mobile money accounts, and help beneficiaries without account register for one. Second, to reduce farmers' workload, the program could provide agricultural advisories that will help farmers save time, for instance by planting at the right time or adopting time-saving practices and technologies. Third, to address disempowerment arising from limited autonomy in decision-making and women's acceptance of domestic violence, the program could provide behavioural change communication through videos and engaging male role models, to advocate for increased autonomy in decision making and control over income among women.

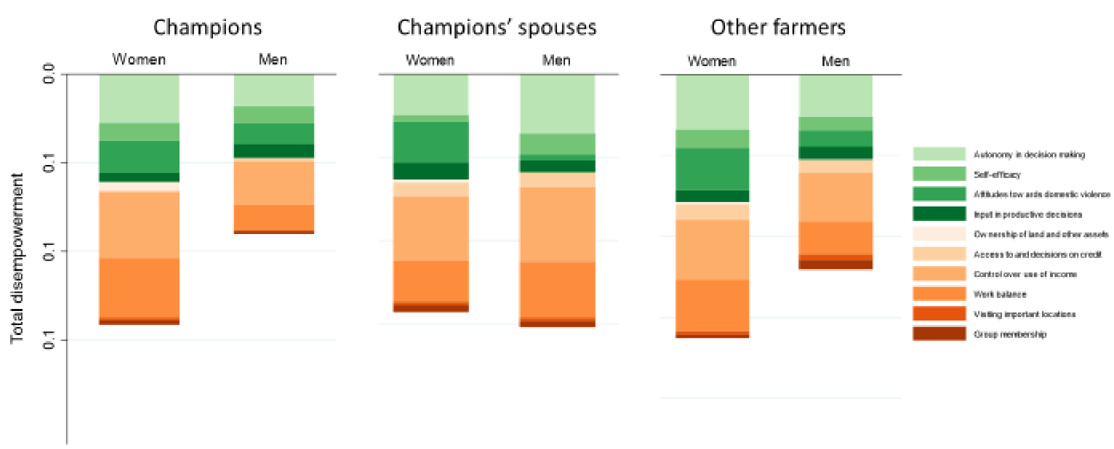


Figure 4: *Total disempowerment by gender and type of farmer (champions, their spouses, and other farmers).*

Take-up of insurance

The next analysis focuses on demand for insurance. In September 2021, prior to the short rains 2021/2022 season, champion farmers elicited incentivized measures of farmers' willingness to pay (WTP) for WBI and PBI.

This was done using incentivized auctions (Becker et al., 1964). Farmers were informed that they had the opportunity to purchase the insurance product at a discounted (and randomly selected) price, which was hidden under scratch ink on a card (like a lottery card). They were asked to write on the scratch card the maximum price they were willing to pay for insurance and could then scratch off the ink to reveal their discounted price. They could (and had to) purchase the product if and only if their stated WTP was equal to or higher than the randomly selected price. This gave farmers an incentive to reveal their true WTP: bidding a lower price could mean foregoing the opportunity of buying insurance at a discounted price still well below the farmer's actual WTP, whilst bidding a higher price could result in having to buy insurance at a higher premium than the farmer's true WTP. Farmers were given this explanation, practiced the mechanism, and then wrote down their real WTP.

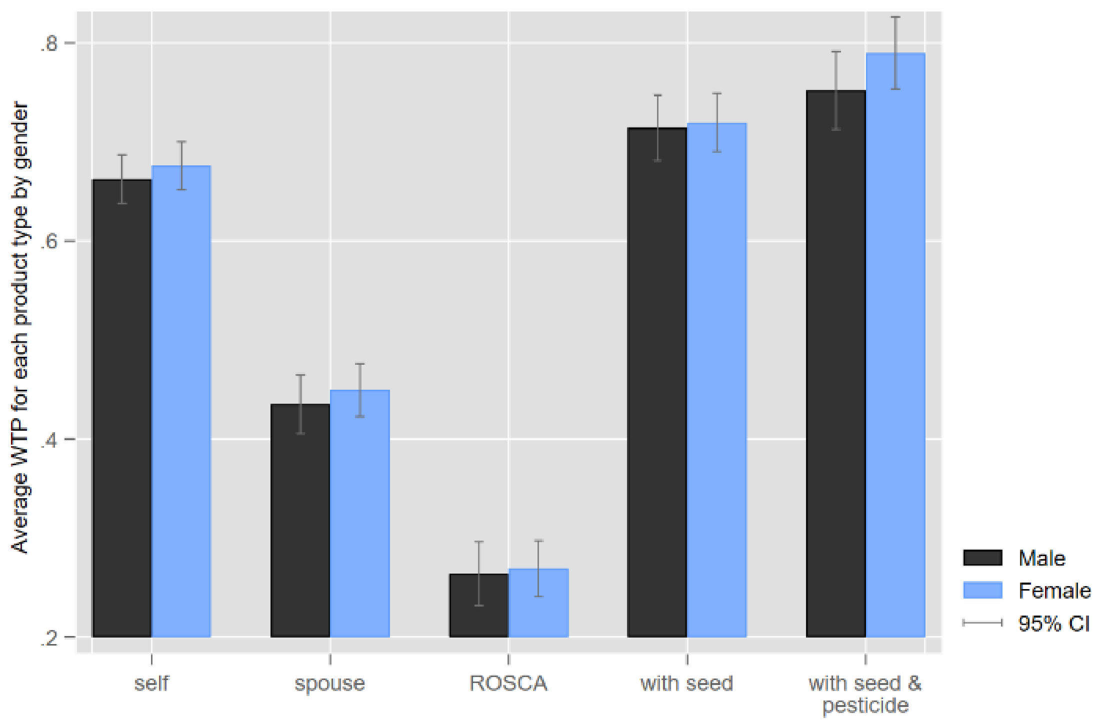


Figure 5: *Average WTP for different insurance products by gender*

Figure 5 shows the average WTP for different types of insurance products as a proportion of the actual premium (combining all respondents regardless of whether they are offered WBI or PBI).

Because not all respondents have a personal mobile money account, and gender findings illustrate that control over the use of income is a major contributor to disempowerment, we asked respondents to state their maximum WTP when the product would make payouts in i) their personal mobile money account (self), ii) their spouse's account, or iii) their savings group (ROSCA) account, as a potential solution for respondents without personal mobile money account and limited control over income if paid into their spouse's account. Farmers were indeed WTP most for a product making payouts directly into their account, instead of their spouse's account, consistent with the notion that they have limited control over the use of income if not paid to them directly; but demand for a product depositing into ROSCA accounts was even lower for both women and men. Thus, paying through ROSCAs would not be a viable solution, and instead, the solution might be to help farmers without mobile money account sign up for one.

We also varied whether the insurance product was bundled with seeds (or seeds and pesticides). Bundling enhances demand, which is important to consider in scaling the program.

The next question is whether PBI is associated with a higher WTP compared to WBI, as it aims to reduce basis risk and improve farmer trust. Figure 6 compares the WTP depending on whether farmers are offered PBI or WBI. PBI increases WTP for insurance if offered as a stand-alone product, but not if bundled with seeds. Perhaps the value of PBI reduces when bundled with seeds (of stress-tolerant varieties) since investing in high-quality seeds of stress-tolerant varieties reduces the chances of visible crop damage and thus insurance payouts. This is an important area for further research.

Another important area for program implementation is to improve knowledge and awareness. Although farmers had been receiving free insurance coverage through their champion farmers in prior seasons, the midline survey shows that many of them were unaware of the insurance products offered in their communities. Given this low awareness, it is perhaps also not surprising that receiving free insurance trials did not affect WTP. Limited awareness could be due to a lack of tangible outputs since insurance payouts were delayed due to the time taken for claims settlement, and by changes in farmers' phone numbers, which prevented ACRE from depositing payouts into mobile money accounts without additional verification.

In conclusion, although the average farmer is willing to pay less for insurance than commercial premium rates, farmers are willing to pay most for insurance if it makes payouts directly into their own mobile money account, especially when bundled with agricultural inputs such as seeds and pesticides. Being offered PBI instead of WBI improves demand, but not by much; arguably due to low awareness arising from implementation challenges that can be addressed. Combined, these findings provide important priorities for the final implementation phase of the project.

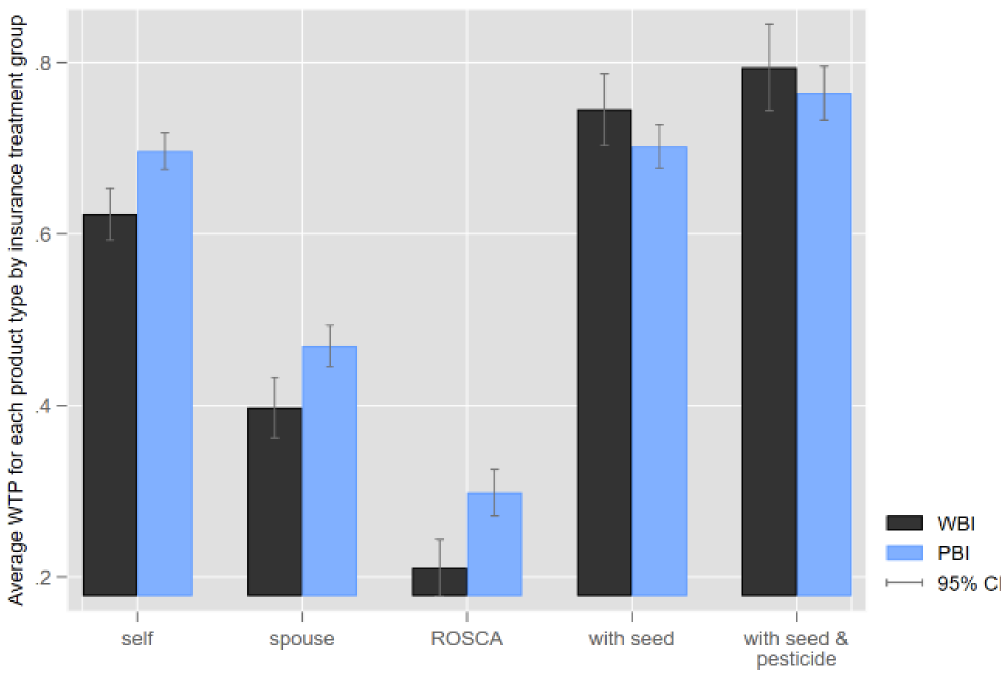


Figure 6: *Average WTP for each product type by treatment group*

Challenges and next steps

To improve agricultural risk management, ACRE and its partners have tested an innovative picture-based crop insurance (PBI) approach, which uses smartphone images of insured crops for claims settlement, combined with the promotion of stress-tolerant varieties of maize, sorghum and green gram seeds. This note presented insights from a midterm evaluation.

A first insight is that scaling the PBI approach requires automating image processing for claims settlement. We find that machine learning algorithms can help automate image processing since these algorithms can predict drought damage from smartphone images with high accuracy.

Scaling will also require sufficient demand for insurance. This poses a challenge since farmers are willing to pay less than actual premiums. Prospective clients are willing to pay most for insurance if payouts are deposited into their own mobile money accounts, and if bundled with seeds and pesticides. This offers two avenues to explore.

First, since prospective clients (and especially women) will not always have a personal account, the program could partner with a mobile money provider to sign up new clients for a personal account. This approach would be gender responsive given that a lack of control over the use of income is a major driver of women's disempowerment.

Second, the increased demand for insurance if bundled with inputs suggests the value of providing farmers with a more holistic solution in which champions do not only market insurance and potentially seeds but also other inputs. This would also provide champion farmers with opportunities to increase their revenue streams, as they can earn commission by selling agricultural inputs. However, thus far, ACRE has not been able to successfully scale its seed marketing approach (see Kramer et al., 2021), and a more sustainable solution could be to partner with other actors in the agricultural value chain that are specialized in the delivery of seeds and inputs, such as the One Acre Fund, Apollo Agriculture, or the Farm to Market Alliance (FtMA). As the research funding that has been used to finance seed delivery is ending in 2022, these will be important partnerships to explore for program sustainability.

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