Impacts of a digital credit-insurance bundle for landless farmers: Evidence from a cluster randomized trial in Odisha, India

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Abstract

Smallholder farmers often lack documented land rights to serve as collateral for formal loans, and their livelihoods are inextricably linked to increasingly variable weather conditions. Resulting credit and risk constraints prevent them from making potentially profitable investments in their farms. We implemented a randomized evaluation of the impacts of KhetScore, an innovative credit scoring methodology that uses digital technologies and in particular remote sensing to unlock credit and insurance for smallholders including landless farmers in Odisha, a state in eastern India. In our treatment group, where we offered loans and insurance based on the KhetScore methodology, farmers - and especially women - were more likely to purchase insurance, renew insurance coverage in subsequent years, and borrow from formal sources without substituting formal loans for informal loans. Despite increased borrowing, households in the treatment group faced less difficulty in repaying loans, suggesting that KhetScore loans, bundled with crop insurance, transferred risk and eased the burden of repayment. Moreover, the treatment increased agricultural revenues during the monsoon (kharif) season and reduced costs in the dry (rabi) season, enhancing profitability in both seasons. Positive and significant effects are found not only among baseline credit unconstrained farmers but also quantity rationed farmers, suggesting that KhetScore loans can help overcome supply-side credit constraints. Finally, women in the treatment group reported significantly higher levels of empowerment and mental health, manifested in increased participation in household decision-making and reduced feelings of stress, than women in the control group. In conclusion, digital technologies can contribute substantially to expansion in agricultural credit access, risk management, resilience, and well-being among marginalized landless farmers.

Keywords: credit; insurance; gender parity; impact evaluation; India.

JEL codes: D13, O13, O16, Q14.

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Introduction

To combat hunger, poverty, and global food security challenges, it is crucial to reduce risk, improve liquidity, and encourage investments in agricultural productivity. Because agriculture is inherently risky, small and marginal farmers often lack the funds to expand their operations or invest in profitable technologies and inputs. For smallholders with limited land holdings, formal financial services like credit and insurance are often considered cost-prohibitive due to high transaction and monitoring costs, along with limited available data on these farmers to identify the risks of insuring or lending to these farmers. For instance, not having documented land rights limits access to formal credit (Higgins et al., 2018), resulting in efficiency losses and potential entrapment in a low productivity equilibrium (Croppenstedt et al., 2013). Even when individuals may access to formal credit, credit markets can be in a disequilibrium in which lenders restrict potential borrowers' access to their desired level of borrowed funds to finance agricultural investments (Stiglitz and Weiss, 1981). In addition to such quantity (supply-side) credit rationing, risk averse borrowers may also voluntarily withdraw from the credit market even when qualifying for loans of a desired size, which is referred to as risk (demand-side) credit rationing (Boucher et al., 2008).

One way to potentially overcome credit rationing and expand investments in agriculture is through agricultural insurance. Yet, the challenges with agricultural insurance are well-known (e.g., Hazell et al., 1986; Binswanger-Mkhize, 2012; Carter et al., 2017; Kramer et al., 2022), namely high costs associated with monitoring and assessing losses, resulting in high administrative loads; informational asymmetries manifesting as both adverse selection and moral hazard; the highly covariate nature of production risks addressed by traditional crop insurance; and a mismatch between insurance demand (which is highest among wealthier farmers) and who would actually benefit from risk transfers (poor farmers without the ability to self-insure). Although index-based insurance programs promoted to address some of these challenges have their own shortcomings, they have recently been able to achieve large scales by leveraging digital technologies, such as remote sensing for predicting livestock mortality (Chantarat et al., 2013) and enhanced weather-based modelling for estimating food insecurity and humanitarian response costs, enabling risk pooling and drought insurance for countries (Kramer et al., 2020). However, to harness the full potential of digital technologies, it is essential to deepen our understanding of the extent to which these technologies enhance rural credit access, help smallholder farmers manage agricultural risks (Benami et al., 2021), and improve targeted populations' wellbeing and livelihoods.

This impact evaluation assesses how KhetScore—a novel credit scoring method that generates credit score through its use of remote sensing and crop analytics—can reduce transaction costs and overcome information asymmetries and documentation requirements in the provision of financial instruments for marginal farmers, and to what extent this, in turn, improves farmers' access to credit and insurance, investments in agriculture, incomes, food security and wellbeing. The evaluation pays particular attention to gender and baseline credit rationing status. Gender is important in the Indian context, since female farmers frequently lack documented land rights required by formal lenders as a condition for qualifying for a loan, and the KhetScore credit scoring methodology aims to precisely address this issue by producing a lens into the production and profitability potential of a plot of land regardless of who actually holds the title to the plot or the official credit score on file with credit bureaus. Further, KhetScore loans are bundled with insurance, which reduces both the need for collateral to secure a loan and the risk of collateral loss (since the insurance component could compensate the lender in the event of a catastrophic hazard that destroys a farmer's crop).

Thus, there is great potential for this kind of product to ease both supply-side rationing on the part of the lender and demand-side rationing on the part of the potential borrower.

We implemented a cluster randomized trial with about 1,800 potential KhetScore clients from 58 villages in the district of Jajpur in eastern Odisha. These 58 villages were randomized into a treatment arm (29 villages), where farmers were offered KhetScore loans bundled with insurance to protect them from the risk of crop failure, and a control arm (29 villages), where farmers were not offered loans based on the KhetScore credit scoring methodology but may have accessed other sources of credit. Both the KhetScore loans and crop insurance offered in the treatment arm leverage recent innovations in digital technology, by relying on satellite imagery and smartphone pictures for crop monitoring. Our aim, then, is to analyze how recent advances in remote sensing and crop analytics – reducing transaction costs and overcoming information asymmetries and documentation requirements in the provision of financial services for marginal farmers – improve farmers' access to credit and insurance, increase investments in agriculture, raise farm incomes, and enhance household members' wellbeing. The evaluation was designed to pay particular attention to gender, since women and other marginalized farmers are less likely to hold documented land rights, restricting their access to credit and insurance. KhetScore aims to precisely address those barriers that are pronounced most among women and other marginalized farmers. Indeed, at baseline, women expressed lower demand for credit, but they reported more often than men that introducing KhetScore and bundling with insurance would make them more likely to apply for loans; and that they would be interested in borrowing larger amounts (Kramer et al., 2021).

In this paper, we find beneficial impacts of offering farmers KhetScore loans bundled with insurance over a wide range of agricultural, gender parity, and mental health outcomes. In particular, the evaluation demonstrates the potential for this novel financial product to have potentially transformative effects on the rural economy by increasing financial literacy, increasing credit and insurance uptake, increasing farm profits, enhancing women's empowerment, and easing some of the mental health stresses that so often accompany near-subsistence agriculture.

The contributions of this paper are threefold. First, we demonstrate that this kind of credit and insurance bundle – and particularly one that determines an applicant's creditworthiness not based on traditional metrics, but based on a metric using emergent digital technologies to determine production and profit potential – has a beneficial impact on crowding in marginalized groups into financial markets and improving their overall experience with credit. This pertains both to individuals who might have been credit rationed at baseline, as well as women, who are typically excluded from credit markets because they often lack the documented land rights required by lenders as a condition for obtaining a loan. Not only do individuals from the treatment group who were members of these disadvantaged groups report taking up loans at an accelerated pace compared to their counterparts in the control villages, but they also reported an increase in borrowing from formal sources and a decrease in borrowing from informal sources, therein largely increasing the extent to which they are included in the formal financial sector. We also demonstrate that this kind of credit and insurance bundle comes with terms that borrowers find especially favorable, as there is a significant reduction in the proportion of borrowers who reported difficulties in repaying their loans, and these effects persist even among members of these groups who might otherwise face financial difficulties.

Second, we demonstrate that the product alleviates constraints that increase agricultural output. In particular, in evaluating local average treatment effects, we find that those farm households that received KhetScore loans bundled with insurance attained higher revenue

per acre and higher profit per acre than other households. Among those that borrowed funds, revenues per acre were over INR 7,800 higher than among farmers in the control group, and profits per acre were more than INR 9,000 higher than among farmers in the control group. The effects are largest among those farmers who were not credit rationed at the time of project baseline, but the beneficial impacts carry over to those farmers who were quantity rationed at baseline, implying that this product does alleviate supply-side constraints to borrowing that could enhance agricultural livelihoods.

Finally, we demonstrate that this innovative credit and insurance bundle has the potential to significantly improve women's empowerment. Although we find positive intention-to-treat effects across several different domains of women's empowerment, it is worth noting in particular that those women who were the primary clients with the loan and insurance bundle taken out in their name reported a significant increase in their contributions to household financial decisions, especially those related to the decision whether to borrow and the decision about how to use borrowed funds. Although women's contributions in these decision-making domains remain relatively low, these beneficial impacts hint at this products' potential to alter intrahousehold dynamics and improve gender parity in financial matters.

The remainder of this paper is structured as follows. The next section describes our evaluation methods, including the design and timeline of the evaluation, sampling and data collection methods, and our empirical specification. The next section describes findings of this impact evaluation, at both the aggregate level and for male versus female farmers. The final section concludes.

Section 2. Methods

2.1 Context and intervention

The study was conducted in Odisha, a state in eastern India, which covers over 1.56 million hectares of land, or 4.7% of India's total land mass. The state has four geographical regions: the Northern plateau, Central River basins, Eastern Hills, and Coastal Plains. This diversity creates a rich set of agro-climatic zones, including both low-lying coastal areas sharing a coastline with the Bay of Bengal, exposing the state to tropical cyclones and frequent prolonged floods, and rainfed uplands that suffer from moisture stress due to variability in rainfall. Farming in Odisha is hence a vulnerable activity exposed to many extreme weather risks. Almost every alternate year, a part of Odisha is hit by natural calamities.

Nevertheless, Odisha is one of the largest producers of food grain, and particularly paddy rice, with around 55 percent of the area under cultivation used for food grain production, and around 49% of the total workforce being dependent on agriculture. The state has two seasons: the summer monsoon (Kharif) season, during which farmers mainly produce paddy rice, and the winter (Rabi) season, during which most farmers leave their land fallow. However, the past few years have observed an increase in the share of Rabi production, and particularly of high-value crops like pulses and vegetables. A 49% increase in the area under irrigation has likely played a vital role in this development. Promoting investments in the cultivation of high-value crops during the Rabi season is considered an important channel to transform agricultural livelihoods in the state. Credit and insurance are key in this regard.

Odisha has a large concentration of marginalized landless farmers who fall outside the purview of state-sponsored credit and insurance schemes (including the Pradhan Mantri Fasal Bima

Yojana, or PMFBY), since they lack documented land rights that are required by these schemes. To address this challenge, Dvara E-Registry (DER) developed KhetScore, an innovation that uses digital technologies and particularly remote sensing to unlock digital credit and insurance for small and marginal farmers. To provide KhetScore loans, DER (i) digitizes information on a farmer's land parcels, regardless of whether a farmer owns, rents, or sharecrops the land, (ii) creates plot-level agricultural credit scores by estimating past and current productivity from satellite imagery, (iii) provides loans for farmers with sufficiently high credit scores, and, (iv) adds on crop insurance to de-risk these loans, using smartphone images for insurance claims settlement, to verify any crop damage that a farmer may have experienced due to extreme weather or other natural hazard.

KhetScore loans were designed around agricultural operations. Future loans were provided to farmers subject to timely repayment of prior loans and availability of funds, but farmers were granted a certain degree of flexibility in loan repayment, to maximize the chances that a farmer would be able to repay. In the rare case the farmer did not repay a loan, DER staff would work with the farmer for proper follow-up and counselling. Also, farmers could be granted additional time to repay the loan in case the reason/problem was genuine.

The impact evaluation around this innovative loan product was implemented in two blocks of Jajpur, a district in Odisha's low-lying coastal plains (Figure 1), where tropical cyclones and frequent prolonged floods form the main production risks in agriculture. In this district, agricultural activities are one of the primary sources of income, with paddy being the dominant crop grown. Irrigation is available in Jajpur due to the vicinity of the *Mahanadi*, the largest river of the state. This creates opportunities for farmers to expand production during the Rabi season, but credit and risk are often cited as a primary reason for not investing in crop production during this season. Although farmers in Jajpur have relatively higher levels of education and literacy than farmers in other districts, sharecropping and marginalization of tenant famers is still commonplace. Intercropping is not common in these districts, making it feasible to apply the KhetScore technology.

2.2 Design and timeline

We implemented a cluster randomized trial with about 1,800 potential KhetScore clients from 58 villages of 2 blocks in the district of Jajpur in eastern Odisha. We chose these specific blocks due to their significant population of small and marginalized farmers and the presence of Dvara E Registry's (our implementing partner) ongoing operations in these areas. DER covered all villages in these blocks, except for those deemed unfeasible for lending operations due to the high risk of flooding. Including these villages would have increased insurance costs and potentially jeopardized farmers' loan repayment abilities. Consequently, 58 villages in these two blocks were taken into the sample frame. All clients that had been recruited by DER through the farmer profiling meetings at the start of the impact evaluation serve as our sampling frame, and all farmers within this sampling frame were approached for baseline surveys. These 58 villages were randomized into a treatment arm (29 villages), where farmers were offered a digital credit product bundled with insurance to protect farmers from the downside risk of crop failure and a control arm (29 villages) where farmers were not offered loans based on the KhetScore credit scoring methodology but may have accessed other sources of credit. A timeline of the study is provided in Figure 2 below.

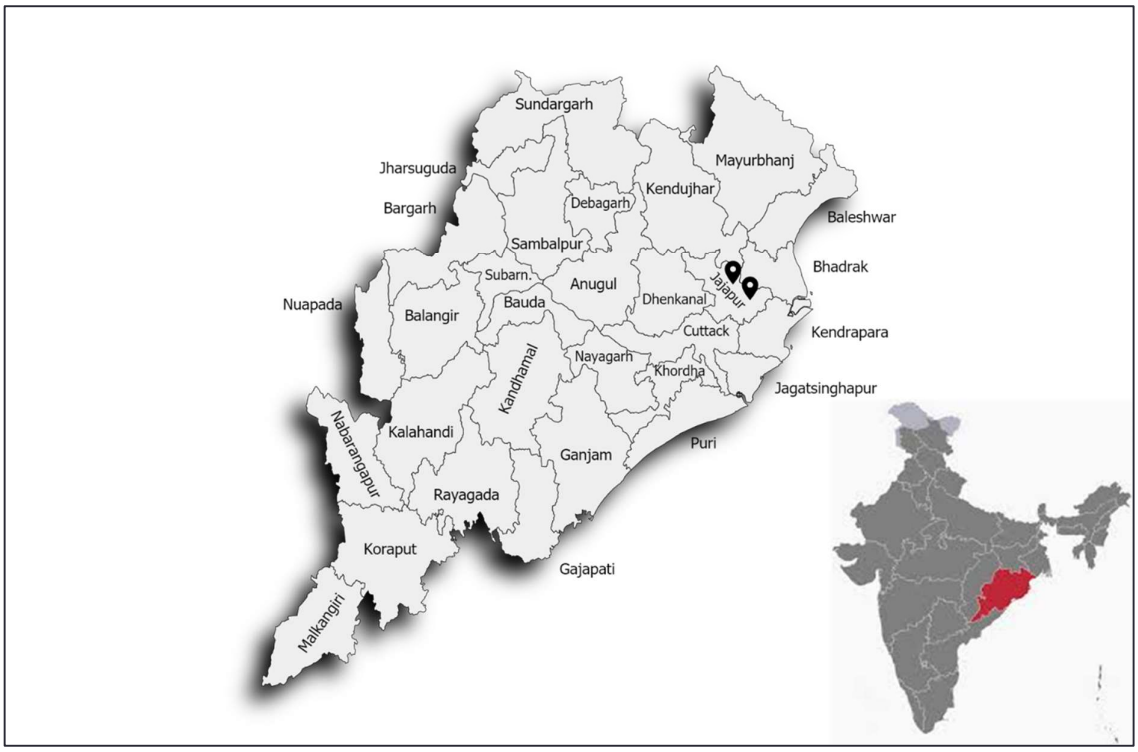

Figure 1. Map of Odisha, with study locations in Jajpur district

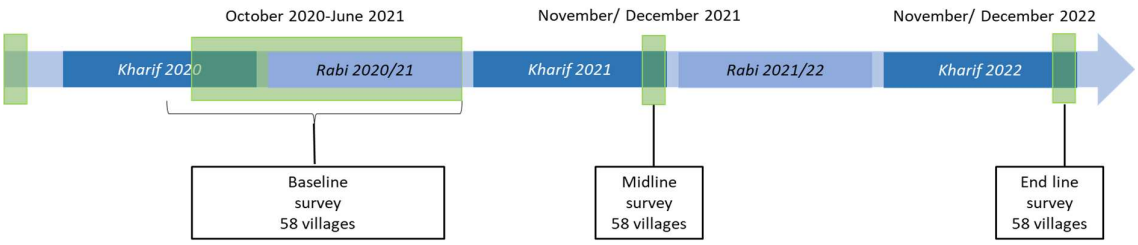

Figure 2. Study timeline

2.3 Sampling and data collection

Within each of the 58 study villages, thus including both treatment and control, DER organized so-called farmer profiling meetings and shared with the researchers a list of prospective clients who attended these meetings. At baseline (end of 2020, early 2021), we invited the full list of 1,872 farmers identified through the farmer profiling meetings for a phone survey (in-person data collection was not possible due to COVID-19 related restrictions on mobility in the targeted study district). Based on power calculations, we aimed to survey at least 1,800 farmers at baseline. Assuming a 3% percent attrition rate from baseline to endline, this meant recruiting at least 1,854 clients through product meetings. Due to non-response at baseline, we were able to survey 1,810 households, which was close to the number that we had targeted based on our power calculations.

The quantitative endline survey was conducted in November/December 2022, and we were able to administer this survey in person, given that pandemic-related restrictions on mobility had been lifted. We aimed to re-survey all clients that had been surveyed at baseline, as well as one other family member of the opposite sex (usually the client's spouse, and typically a co-signer for loans issued by DER). The sampling frame hence included 1,810 clients, of whom 1,621 were surveyed. We were able to identify and interview another family member for 1,294 of those 1,621 clients, for a total sample of 2,915 individuals. Reasons for why a client could not be interviewed are provided in Table 1 below.

Both baseline and endline surveys included modules to collect information about the respondent's demographics, household income, financial inclusion, credit practices, women's empowerment, insurance take-up and renewal, awareness and perceptions of insurance, income from insured crops, and women's mental health. Questions related to insurance take-up and renewal, awareness and perceptions of insurance, and income from insured crops, were asked to the primary client only. Questions about women's mental health, were asked only to the female member of the household.[1] Other questions (related to demographics, household income, financial inclusion, and credit practices) were asked to both respondents in each household.

2.4 Empirical strategy

To estimate intent-to-treat (ITT) effects, we use analysis of covariance (ANCOVA) estimators, in which endline values of dependent variables (outcomes) are regressed on a dummy variable indicating whether the farmer was in the treatment group, controlling for baseline values of the dependent variable and other variables for which experimental groups statistically differed at the time the study was initiated, and block fixed effects to account for stratification, with standard errors adjusted for the clustered nature of the experimental design (i.e., by village, since randomization into treatment and control groups was done at the village level). Our base econometric specification will be the following:

$$Y_{ib,1} = \alpha + \beta Y_{ib,0} + \delta_1 T_{ib} + \sum_{j=1}^{J} \theta_j \mathbf{x}_{ijb,0} + \varepsilon_{ib} \quad (1)$$

where $Y_{ib,t}$ is the measure of outcome Y for individual i from block b in period $t \in \{0,1\}$, with $t = 0$ and $t = 1$ indicating baseline and endline, respectively; $\mathbf{x}_{ijb,0}$ is a vector of covariates to control for variables on which randomization was stratified and for imbalances between households in the treatment versus control at the time of the baseline (which includes whether the household cultivated in the rabi season, whether they had taken a credit, and profits per acre), as well as a number of demographic controls from the endline survey (caste, literacy, age terciles, and gender of the primary client); ε_{ib} is an identically distributed disturbance assumed to be independently distributed across villages, but correlated among members from the same village; T_{ib} is a binary variable equal to 1 if individual i from village b was from a village randomly selected as part of the treatment arm. This base specification will allow for

[1] In our registered pre-analysis plan (study ID RIDIE-STUDY-ID-6110cd09b6003), we also indicated that we would evaluate the impact of the program on household food consumption and women's dietary diversity. These outcomes were included at the request of the project donor, who track such measures among all funded projects. We have not included these outcomes in the impact evaluation presented in this manuscript, both because there were no meaningful impacts observed, but also because there is not an obvious causal mechanism by which we would have expected there to be observed impacts.

us to estimate the average effect of the program in treatment villages (i.e., these are intention to treat effects). In addition to this base specification, we will be interested in examining heterogeneous effects by (i) gender and (ii) baseline credit rationing status.[2] To do so, we will modify equation (1) and estimate one of the following regressions:

$$Y_{ib,1} = \alpha + \beta Y_{ib,0} + \gamma Female_{ib} + \delta_1 T_{ib} + \delta_2 T_{ib} \times Female_{ib} + \sum_{j=1}^{J} \theta_j \mathbf{x}_{ijb,0} + \varepsilon_{ib} \quad (2)$$

or

$$Y_{ib,1} = \alpha + \beta Y_{ib,0} + \gamma_1 QR_{ib} + \gamma_2 RR_{ib} + \delta_1 T_{ib} + \delta_2 T_{ib} \times QR_{ib} + \delta_3 T_{ib} \times RR_{ib} + \sum_{j=1}^{J} \theta_j \mathbf{x}_{ijb,0} + \varepsilon_{ib} \quad (3)$$

where, in equation (2), $Female_{ib}$ is a binary variable equal to 1 if individual i from village b was a female (and 0 otherwise), and in equation (3), QR_{ib} and RR_{ib} are binary variables equal to 1 if individual i from village b was quantity rationed or risk rationed, respectively, at the time of project baseline. In equation (2), $Female_{ib}$ is interacted with T_{ib} to test whether the program had differential effects on male (δ_1) and female respondents ($\delta_1 + \delta_2$) within the treatment group. In equation (3) QR_{ib} and RR_{ib} are each interacted with T_{ib}, allowing us to test whether the program had differential effects on un-rationed individuals (δ_1), quantity rationed individuals ($\delta_1 + \delta_2$), or risk rationed individuals ($\delta_1 + \delta_3$) within the treatment group.

For outcome measures related to women's mental health, we only have data on female respondents (since these questions were only asked of female respondents). Further, these outcome measures were specified differently at the time of baseline and endline data collection, so there are no comparable baseline measures for these outcomes that could be included in an ANCOVA regression. Since no other variable can proxy for the outcome measure at baseline, the regression equation would be modified by dropping $Y_{ib,0}$, and the estimator is reduced to a single-difference estimator comparing simple (conditional) differences between treated and control samples. We can still estimate effects separately for women in households where the primary client is male (i.e., the female is the "other household member") versus female (i.e., the female is the "client") and estimate a variation of equation (2). In particular, this regression specification will take the form

$$Y_{ib,1} = \alpha + \gamma Other_{ib} + \delta_1 T_{ib} + \delta_2 T_{ib} \times Other_{ib} + \sum_{j=1}^{J} \theta_j \mathbf{x}_{ijb,0} + \varepsilon_{ib} \quad (4)$$

where all terms are as they were introduced before, though specifically pertaining to female respondents, and $Other_{ib}$ is a binary indicator equal to 1 if the respondent was classified as

[2] In our registered pre-analysis plan, we did not specify that we would explore heterogeneous impacts on the basis of baseline credit rationing status. This was a dimension of heterogeneity that was subsequently included based on conversations with participants in a research seminar given by one of the authors.

the “other household member” – implying she was not a Dvara E-registry client. So, the intention-to-treat effect among Dvara’s female clients is captured by δ_1, and the spillover intention-to-treat effects from Dvara’s client to his female household member is captured by $\delta_1 + \delta_2$.

As mentioned, estimating equations **Error! Reference source not found.**-(4) yield intention-to-treat (ITT) effects, which provide an estimate of the overall impact of the KhetScore credit-scoring methodology and the credit + insurance products based on these scores among households in the villages randomly selected for inclusion in the treatment group. Assuming there is a positive correlation between actually *taking* KhetScore loans and the various outcomes of interest, these ITT effects will be a downward-biased measure of the beneficial impacts of these credit products. Nevertheless, these provide a conservative estimate of the overall program impacts and may be of greater interest to policymakers interested in the economywide impacts of such a program, rather than just the effects on those members of the sample who were able to take KhetScore loans.

Section 3. Findings

3.1. Descriptive statistics

Table 2 provides descriptive statistics of the full sample of 2,915 clients and other family members surveyed at endline. About half, or 51.9 percent of respondents, was female. The average respondent is about 44 years of age, and close to one third belong to a scheduled caste or tribe. About three thirds know how to read and write, with 71 percent having completed at least primary education, and 32 percent having completed at least secondary education. The majority of households’ income falls below INR 90,000 per year, or INR 247 day, which puts a 2-member household below the poverty line of US$ 2 per day. About 30 percent having an income between INR 90,000 and INR 120,000 per year, and only 15 percent having an income of more than INR 120,000 per year. Virtually all respondents cultivated during the most recent Kharif season, whereas fewer households (73 percent) cultivated during the most recent Rabi season.

We collected data on credit-related variables for all respondents. Borrowing, and especially from formal sector sources, is not very common. Only 23 and 11 percent of households took a loan from an informal or formal source, respectively. The average loan was sanctioned 7.5 months ago, at which time the household had borrowed on average INR 28,304, at an interest rate of 13 percent. Households still owed on average 55 percent of that loan at the time of the endline survey, but in total, they had on average 10.5 months to repay the loan, meaning that they only had an average of 3 months remaining to mobilize the funds needed to repay. Indeed, a sizable 41 percent of households with loans reported that they were facing difficulties repaying their loans, and 82 percent said that there would be consequences associated with not paying the loan on time. Less than one fifth has other outstanding non-agricultural loans, and among these households, the average debt from non-agricultural loans is INR 19,938.

A next set of variables relates to insurance knowledge and take-up. Less than half of all primary clients have ever heard of insurance. Among those who are aware of insurance, a large majority (85.5 percent) has heard of the PMFBY, whereas fewer (62 percent) have heard of PBI. Very few households have heard of the Restructured Weather-based Crop Insurance

Scheme (RWBCIS) or other insurance products. As a more nuanced measure of awareness, we also construct an "insurance knowledge score", based on the number of correct responses to a series of six true/false questions regarding general terms and conditions of crop insurance. The average respondent provided the correct answer to 3.5 of the following six questions: *I have to pay (a premium) to be covered by crop insurance* (TRUE); *the insurance premium is typically a small fraction of the maximum insurance payout* (TRUE); *insurance promises to pay compensation every season* (FALSE); *insurance compensates for any amount of loss I may face for any reason* (FALSE); *if I don't have any damage, the insurance company gives back my premium* (FALSE); and *insurance promises to pay compensation to me even if the price for my crop falls* (FALSE). Despite low awareness rates, more than half of all respondents (59 percent) took up insurance in the study period, and among them, close to two thirds (64 percent) renewed their coverage.

A next set of descriptive statistics relates to agricultural outcomes during the kharif 2022 and rabi 2021-2022 seasons. Whereas nearly all farmers cultivated during the kharif season, this was not the case for the rabi season, during which only 73 percent of farmers decided to plant, creating an opportunity for KhetScore loans to expand production at the extensive margin. The average area cultivated among those who planted paddy was on average lower during the rabi season, yet, total production and thus also productivity, were higher, perhaps because only farmers with access to irrigation, who potentially have higher productivity, select into cultivating during rabi. However, the cost of production during rabi is higher, and crops fetch lower prices, as observed from the total revenue per acre. As a result, whilst profits are positive during the kharif season, during the rabi season, farmers are making a loss even before we include the opportunity cost of their own labor. Increasing profitability would be an important priority for KhetScore loans.

We also asked all respondents about their contributions to household decision making and the extent to which they have control over household assets. About 44 to 45 percent of respondents indicated that they contributed to the decision whether to borrow, and to the decision how to use any borrowed money. Close to three quarters have input in livelihood decisions, and 70 percent of respondents perceives to have a certain degree of control over the use of income. Finally, most respondents are considered adequately empowered in terms of their asset ownership, with close to 90 percent owning either land or at least three assets, which is how the Women's Empowerment in Agriculture Index defines its asset ownership indicator. It is important to note, though, that this sample includes both male and female respondents, and that each of these indicators of empowerment are significantly lower for women than for men. We are therefore primarily interested in the question whether KhetScore loans improves gender parity, by increasing the proportion of women having control over these important aspects of life.

Female survey respondents also completed consumption and mental health modules (in households where the female respondent could not be interviewed, we completed the consumption module with the male respondent, to still collect consumption indicators). We measured a Food Consumption Score (FCS), which is based on the frequency at which different food groups are consumed in the past 7 days (with scores in the range 0-21 being considered poor, 21.5-35 borderline, and greater than 35 being acceptable); the Minimum Dietary Diversity for Women (MDD-W) index, which is based on dietary diversity in the past 24 hours (and women need to have consumed at least 5 out of 10 food groups in order for

their diets to be considered sufficiently diverse); and a four-item stress indicator as an indicator for mental health.[3] Although household-level consumption indicators are at adequate levels, women's dietary diversity is poor; women consume on average only 3.8 out of the 10 food groups included in that indicator. The perceived stress indicator averages 1.7, indicating that responses are more skewed towards experiencing stressors "never" and "sometimes" (a score of 1 and 2, respectively) than to "often" or "very often" (scores of 4 or 5, respectively).

[include description of what credit and risk rationed is.]

3.2. Balance across treatments

Table 3 summarizes the data collected at baseline (Panels A and B), as well as time-invariant characteristics collected at endline (Panel C), by treatment arm. The last column provides the *p*-value from a test for significant differences between treatment and control, with clustering of standard errors at the village level. We find that overall, variables are well balanced across treatment and control, with only a few variables showing significant differences at the 10 percent level, as one would expect when testing multiple hypotheses. Overall, randomization resulted in two comparable samples.

Variables that are imbalanced at baseline include the percentage of farmers that were growing crops in the most recent Rabi season (81 percent in the control group versus 65 percent in the treatment group) and the percentage of farmers purchasing goods and services on credit in the past 12 months (43 percent in the control group versus 55 percent in the treatment group). Farmers in the treatment group also have significantly lower stress levels and earn higher profits at baseline. At endline, farmers in the control group are more likely to belong to a scheduled caste or tribe instead of general or other backward castes, and we observe imbalances in the proportion of participants that can read or write. We will control for these differences in our impact estimates.

3.3. Impacts of KhetScore loans

Table 4 presents the results on the impacts of the program on outcomes pertaining to insurance, including financial literacy (specifically awareness of crop insurance and some of its terms and conditions), insurance uptake, and insurance renewal over the course of the project. Looking at Panel A, among 1,621 primary DER clients, we find strong evidence that the program increased the uptake and renewal of crop insurance. In column (1), we see that assignment to treatment increased the likelihood that a respondent took up insurance at least once during the study period by more than 60 percentage points, from 28 percent in the control group to 90 percent in treatment villages. Further, being assigned to the treatment group increased the likelihood that farmers who had purchased insurance would renew their coverage. Indeed, we find that farmers in the treatment group who had previously purchased

[3] An individual's perceived stress is based on their responses to the following four questions: 1. How often have you felt you were unable to control the important things in your life? 2. How often have you felt confident about your ability to handle your personal problems? 3. How often have you felt confident that things were going your way? 4. How often have you felt difficulties were piling up so high that you could not overcome them? Answers were coded according to a Likert scale ranging from "never" (1) to "very often" (5). Important to note, however, is that a response of "very often" to questions 1 and 4 indicate higher degrees of perceived stress, while a response of "very often" to questions 2 and 3 indicate lower degrees of perceived stress. We construct a composite measure of perceived stress by first re-coding the scores for questions 2 and 3 so that a higher score indicates a higher degree of stress, and then take the average score over the four questions.

crop insurance were 30 percentage points more likely to renew their coverage than the 40 percent of DER clients renewing their coverage in the control group (column 2). Additionally, there is evidence that the program increased familiarity with crop insurance and an understanding of how crop insurance works. The program had an overall positive and statistically significant effect on clients' awareness of crop insurance, with clients in the treatment group being 15.5 percentage points more likely than those in the control group to have ever heard of crop insurance in (column 3). We also measured the extent to which clients who considered themselves aware of crop insurance understand the nuances via an insurance knowledge score. DER clients in the treatment group correctly answered 1.32 more crop insurance questions out of six than those in the control group, who on average have 3 correct answers (column 4). This suggests that not only did the treated farmers have higher general awareness of crop insurance but also they had more knowledge on its specific terms and conditions compared to their control village counterparts. Turning to Panel B, results reveal that treatment effects among baseline credit unconstrained, quantity rationed, and risk rationed DER clients are somewhat comparable. Moving on to Panel C, results in columns 2 and 3 suggest that significant effects on insurance renewal and awareness are only found among female DER clients, while large and significant effects on insurance knowledge score are found among male DER clients only.

Table 5 reports the results of being assigned to KhetScore treatment group on credit uptake. In assessing the impact of the program on credit uptake, we consider the full sample, primary DER clients and non-client family members separately, because family members' borrowing behavior could have been affected by the DER clients in their household. Looking at Panel A, in the full sample, individuals in the treatment group were more than 10 percentage points more likely to have taken a loan than those in the control group (column 1). There is evidence that the KhetScore loan is effective in encouraging borrowing from formal sources given that only about half of this effect is attributable to switching from informal credit sources to formal credit sources: in the full sample, individuals in the treatment group are 23 percent more likely to borrow from formal sources but only 13 percent less likely to borrow from informal sources compared to the control group (columns 4 and 7). However, it should be noted that this sizable net increase in formal credit uptake can only observed among non-client family members (by comparing column 6 to column 9) but not among DER clients (by comparing column 5 to column 8). A potential explanation for this could be that taking out the KhetScore loan mainly shifted DER clients from borrowing from informal sources to borrowing from formal sources, while non-client family members who had not been in the credit market previously benefited from shared information and newly entered the formal credit market. We next turn to column 10, where we examine the extent to which respondents indicated that they faced difficulties in repaying their loans, because merely increasing borrowing could be detrimental if it led to increased indebtedness and a pattern of circular borrowing (borrowing from one lender to repay a loan originally taken from another lender). At the onset, it is worth noting that only those respondents who indicated that they had taken a loan from any source were invited to respond to this question. Somewhat amazingly, households in the treatment group were more than 40 percentage points less likely to report that they faced some difficulty in repaying their loans. Roughly 70 percent of respondents in the control group indicated that they faced some difficulty in repaying their loans, compared with only about 30 percent in the treatment group, suggesting that the loans offered as part of this program had particularly favorable terms. While not specific to the credit-scoring methodology per se, it should be noted that the loans that were offered as part of this project required repayments in instalments rather than in a

single lump sum, which is often the case for agricultural loans, or rather than weekly instalments, which often applies to microfinance loans. Anecdotal evidence suggests that borrowers especially liked this feature of the loans, though some borrowers may have had to work off-farm to be able to pay off the first two or three instalments, which are due during the season before the harvest. This did not, evidently, have a detrimental effect on how they perceived their abilities to repay their loans.

Panel B of Table 5 presents results that indicate the KhetScore program has similar treatment effects among farmers that are credit unconstrained, quantity rationed, and risk rationed at baseline. On the other hand, findings in Panel C show that the treatment effects of KhetScore loans on credit uptake outcomes are primarily found among women rather than men. While women in the full sample are 26 percent more likely to borrow loans, 34 percent more likely to borrow from formal sources, and 47 percent less likely to find themselves struggling to repay loans compared to their control group counterparts, treatment effects on these outcomes among men are either the opposite (but small in magnitude) or not significantly different from zero. These findings strongly suggest that the KhetScore product especially benefits marginal female farmers through expanding access to formal credit and insuring against risk of debt. In sum, results in Table 4 and 5 indicate a strong potential for KhetScore loans to have transformative effects on smallholder finance through improving financial literacy, expanding access to credit, enhancing agricultural risk management skills, and alleviating the burden of loan repayment under natural hazard-related crop loss.

In Table 6, we present the results on the effects of the program on a series of agricultural outcomes. In Panel A, we consider the effects of the program on the likelihood of farmers to cultivate during kharif 2022 (column 1) and rabi 2021-22 (column 2). Although cultivating during the kharif season is nearly ubiquitous (94 percent in the control group), we find evidence that treatment assignment increased the likelihood that farmers would cultivate during kharif 2022 by about 2 percentage points. During kharif 2022, revenues per acre in the treatment group were about INR 2,000 greater than those in the control group (column 5), without the treatment affecting the total area of cultivated land (column 3). During rabi 2021-2022, treatment households increased their cultivated area by nearly 0.5 acres (column 4), though the total cost of production per acre fell by INR 3,400, perhaps as treatment farmers generated economies of scale (column 8). Additionally, during the rabi season treatment farmers experienced a 16-percentage point increase in the return on agricultural investments (column 10). In columns 11 and 12, there is compelling evidence that treatment households had significantly higher agricultural profits, with kharif profits nearly double those in the control group, and rabi profits offsetting losses that farmers in the control group experienced.[4]

The results in Table 6 are intention-to-treat (ITT) effects, so may understate the effects among those households that actually borrowed money as part of the project. To estimate these

[4] During both seasons, the program increased seeds purchases and hiring of female labour (the latter statistically significant only for kharif 2022, due to less precise estimates in the rabi season), which suggests that respondents are using some of their loans to hire labour, and free up time for themselves to allocate to other activities. At the same time, in both seasons, treatment farmers spent less on renting in additional land for cultivation, and only in the kharif season, on hiring machinery. There is also some evidence that households in the treatment group allocated less personal labour to agricultural production during kharif 2022. If we were to include the opportunity cost of the primary DER client's labour in the cost of production, profits and returns on investments, then this reduction in one's own labour supply would manifest itself in a significant decrease in the costs of production, a significant increase in the return of investment, and an even greater increase in profits during kharif.

effects, we would need to modify equations (1)-(3) so that the treatment indicator (T_i) would be a binary variable indicating that the household actually took a loan, rather than simply indicating that the household resided in a village that was randomly selected as one in which Dvara E-registry would offer KhetScore loans. The decision to actually take a loan is endogenous, so we follow standard practice and instrument for loan take up with a binary variable equal to one if the household resided in a village that was randomly assigned to be offered KhetScore loans. The resulting local average treatment effects (LATEs) represent the average treatment effects among the subsample of the population who always comply with their assignment (i.e., among those individuals in randomly assigned treatment villages who actually took up loans). Local average treatment effects for agricultural outcomes in Kharif 2022 are reported in Table 7. These results are qualitatively similar to those reported in Table 6, but, as is typical, they are of considerably larger magnitude, suggesting that the beneficial effects of KhetScore loans in increasing farm revenues and profits are primarily experienced among those who directly benefited from the loans. In Panel A column 3, in particular, we observe that farmers who took a KhetScore loan earned revenues nearly INR 7,800 more per acre than they would have otherwise. Similarly, profits per acre were nearly INR 10,000 higher than they would have been had these farmers not borrowed these funds (Panel A column 6). The effects are largest among those farmers who were not credit rationed at the time of project baseline, but the beneficial impacts carry over to those farmers who were quantity rationed at baseline, implying that this product does alleviate supply-side constraints to borrowing that could enhance agricultural livelihoods (Panel B).

In Table 8, we present results on the effect of being assigned to KhetScore loan treatment group on gender parity outcomes, especially intra-household gender dynamics among DER clients and non-client family members through exploiting whether they (1) contribute to household borrowing decisions, (2) contribute to household decisions about how to spend borrowed money, (3) give input on household livelihood decisions, (4) exercise control over uses of income, and (5) own land and/or any three assets. Results from our model in Panel B reveal that sizable and statistically significant improvements in the above five empowerment indicators among treatment households are primarily observed among women, though there is considerable heterogeneity in whether the significant effects are driven by female DER clients or non-client female household members. In particular, we find that female DER clients in the treatment group reported being able to contribute more to household decisions around borrowing and the use of borrowed funds, while female household members reported an increase in their input into household livelihood activities and their control over household income. As for the last outcome, asset ownership, we observe that male DER clients and more so female family members in the treatment group are more likely to own land or assets. These significant effects observed among female family members could be simply due to the male DER's clients already giving input into household livelihood activities, exercising meaningful control over income and owning a number of assets, such that being in the KhetScore treatment group did not "move the needle" to a measurable degree among them. Overall, results in Table 8 provide strong evidence for the effectiveness of the KhetScore loan in empowering women and improving intra-household gender relations.

Finally, we consider the effect of the program on several women's mental health outcomes, which are effectively measures of individuals' perceived stress. We report the effects of the program on different measures of perceived stress in Table 9. In this table, the row label "Treatment" refers to women in the treatment group, though we also disambiguate the effects on DER's female clients vs. the other family member surveyed by incorporating an interaction

term “Treatment x Other family member”. It is worth noting that, in general, these other family members report higher levels of stress, suggesting more mental health problems among this sample. In column (1), we consider the effects of the program on the composite stress measure described above. We find that the program had a beneficial effect on reducing stress levels, but only among the other female household members that were not directly targeted by DER. Compared to a control group mean of 2.785, these other female household members’ composite stress score was reduced by 0.55 points, indicating a significantly lower overall stress level. We also find that the program had beneficial impacts in reducing stress in three out of the four indicators considered, though again these effects are limited to the other female household members, and do not materialize among DER’s female clients. In particular, we find that the program decreased the frequency with which women felt control over important things in their life (column 2), increased the frequency of feeling confident in their ability to handle personal problems (column 3), and the frequency with which women felt that difficulties were piling up so high that they could not overcome them (column 5). In terms of feeling control over the important things in life, the measured effect is round 10 percent of the average score among women in the control group. As for confidence in ability to handle personal problems, the effect is 13 percent of the average in the control group. In the case of feeling difficulties piling up, the effect is an even more pronounced 1.2-point reduction, which is greater than 40 percent of the average score among the control group, signifying a substantial reduction in women feeling overwhelmed. The treatment effects on the indicator in column 4 is not statistically different from zero at conventional levels, but the positive sign is consistent with the program having a beneficial effect on reducing stress levels.

In sum, the results from the program are highly encouraging. They suggest that the program has wide-ranging beneficial impacts for women, in terms of increasing access and utilization of credit, improving their ability to contribute to household decision-making, their control over income and assets, and reducing their overall levels of stress, thereby improving well-being.

3.4. Cost analysis

To determine the costs of the intervention, we focused on the costs of implementing loans and insurance using KhetScore relative to conventional methods for providing financial services, but holding the distribution channel constant, since DER leverages existing lending and insurance operations of financial service providers. We distinguish between the fixed costs of the research and development around KhetScore, and the marginal costs of providing the digital credit and insurance products. DER is still finalizing its estimates of implementation costs, but the best available estimates of implementation costs are based on baseline projections, and are provided in Table 10.

The total one-off R&D costs associated with launching the KhetScore program are close to USD 60,000. The fixed cost of operating the loan operations, including project management, staff travel, field office costs, app maintenance and communication material, are another approximately USD 20,000. These costs would not be sustainable in a program with 450 farmers taking out loans, and even when enrolling a similar number of farmers in the control group, the costs of $21.07 would be too high for a sustainable operation as they would significantly increase interest rates if factored into the projected interest that farmers pay. The presence of a field office would become more sustainable if DER would be able to expand into more blocks and villages within these blocks and lend to more farmers per village.

Moreover, the variable costs that DER incurs in every agricultural season per farmer (thus, costs that are increasing in the number of farmers that it is trying to reach) are currently too high for the intervention to be sustainable, but also these figures could improve as the program reaches scale. Currently, these costs add up to close to USD 100, of which 43.5% are borne by the farmer. DER field staff constitutes the main cost driver in this category, and it will be important for DER to identify ways in which these costs can be reduced. Some of these costs are likely of a fixed nature, and as the program would go to scale, each field agent would cover a larger number of farmers, reducing the per-farmer cost.

Finally, it is worth noting that for the impact evaluation, we needed to keep scale limited, to keep operations focused on targeted clients in the treatment group and avoid contamination of the control group. But as the impact evaluation is coming to an end, DER can reach a larger scale, and bring down both average fixed costs, and variable costs, to make for a more financially viable – and highly impactful – intervention.

4. Conclusion

In this impact evaluation, we found that KhetScore loans have a wide range of significant and meaningful impacts that benefit participants in our study area. We find evidence of a significant increase in the uptake (62 percent higher than the control) and renewal (28 percent higher than the control) of agricultural insurance, and an overall increase in familiarity with the terms and conditions of crop insurance. The program also increased overall utilization of credit, especially among women. Much of the overall increase comes from an expansion in formal credit uptake (by about 23 percentage points on average, and by more than 34 percent among women) and not merely from a shift to formal credit from informal credit. In addition, households in the treatment group were more than 40 percentage points less likely to report facing difficulty in repaying their loans, indicating that the KhetScore loan and insurance bundle had particularly favorable terms.

Local average treatment effect estimates for the 2022 monsoon season (kharif) found that revenues per acre among treated farmers were over INR 7,800 higher, and profits per acre were more than INR 9,000 higher than among farmers in the control group. During the 2021-2022 dry season (rabi), intention-to-treat effects suggest that treatment households increased their cultivated area by nearly 0.5 acres, though the total cost of production per acre fell by INR 3,400, perhaps as treatment farmers generated economies of scale. There is evidence that treatment households had significantly higher agricultural profits, with kharif profits nearly doubling those in the control group, and rabi profits offsetting losses that farmers in the control group experienced.

We also observe important impacts on women's empowerment and mental health. Compared to the control group, women in the treatment group were 16 percentage points more likely to report making contributions to household decisions regarding borrowing, 13 percentage points more likely to make contributions to household decisions about how to use borrowed money, 21 percentage points more likely to report providing input into household livelihood decisions, and 22 percentage points more likely to report having control over the use of income. We also find that the program had a beneficial effect on reducing stress levels, but only among female household members who co-signed the loans rather than female DER clients. These findings also underscore the value of surveying not only the (typically male) head of the household, but also other household members, since the impacts of an intervention may differ across members of a household.

In this regard, it is worth noting that at baseline, women reported more often than men that the introduction of KhetScore loan bundled with insurance would make them more likely to apply for loans and that they would be interested in borrowing larger amounts. Indeed, over the course of this impact evaluation, we find beneficial impacts over a wide range of agricultural and gender parity outcomes. In particular, this impact evaluation highlights the potential of this innovative financial product in bringing about transformative changes in rural economies by enhancing financial literacy, expanding access to credit and insurance services, boosting agricultural investment and production, promoting women's empowerment, and alleviating some of the psychological stresses often associated with subsistence farming.

Our findings suggest that the KhetScore credit-scoring methodology, notably its ability to reduce transaction costs for both borrowers and lenders, serves to mitigate credit rationing while simultaneously broadening and enhancing the inclusivity of rural finance. In particular, KhetScore's elimination of paperwork prerequisites, specifically the need for land titles, extends access to formal credit to a previously underserved group of potential borrowers. Furthermore, the incorporation of crop insurance may alleviate collateral requirements, addressing both risk-related and quantity-related constraints in formal borrowing. These results provide valuable insights for policymakers interested in expanding access to credit and insurance for sharecroppers and tenant farmers who lack documented land rights.

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Table 1 Attrition and reasons for non-response at endline

	Main client	Family member
Total	1810	1810
Number of interviews completed	1621	1294
Nonresponse reason - death	36	39
Nonresponse reason – Moved away	125	100
Nonresponse reason – Not farming	9	53
Did not consent to be interviewed	19	127
Could not be reached	0	197

Table 2 Descriptive statistics for the full endline sample

	Full sample		
	Mean	Std.	N
Respondent is a female	0.519	0.500	2915
Age of the respondent	43.63	8.867	2915
Belongs to Schedule caste/Schedule tribe	0.318	0.466	2915
Can read and write	0.747	0.435	2915
Completed at least primary education	0.714	0.452	2915
Completed at least secondary education	0.319	0.466	2915
Household income			
- Low (below ₹ 90,000 p/year)	0.559	0.497	2915
- Medium (₹ 90,000 - ₹ 120,000 p/year)	0.29	0.456	2915
- High (above ₹ 120,000 p/year)	0.146	0.354	2915
Credit			
Took up credit in last 12 months	0.339	0.473	2915
Took loan from a formal source	0.229	0.420	2915
Took loan from an informal source	0.110	0.317	2915
How many months ago the loan was sanctioned	7.49	4.065	987
Total loan amount	28,305	14295	987
Interest rate	13.12	1.461	987
Outstanding loan	15,523	10791	987
Number of months to repay the loan	10.48	5.618	987
Facing difficulty in repaying the loan	0.410	0.493	987
There are consequence for not paying the loan on time	0.824	0.381	987
Respondent currently having non agriculture loan outstanding	0.177	0.382	2915
Outstanding loan of respondent having current non-agri loan	19,938	11681	516
Insurance			
Heard of crop insurance	0.424	0.494	1621
- Aware of PMFBY existing in village	0.856	0.351	687
- Aware of RWBCIS existing in village	0.006	0.076	687
- Aware of PBI existing in village	0.620	0.486	687
- Aware of other insurance products existing in village	0.003	0.054	687
Knowledge score on insurance	3.489	1.244	687
Insurance uptake: took insurance at least once	0.586	0.493	1621
Insurance renewal: if took up insurance, took insurance twice	0.635	0.482	950
Agriculture - Kharif 2022 (summer) season			
Cultivated in the season	0.959	0.198	1621
Total production (in quintals)	16.00	16.343	1468
Total productivity	9.21	7.580	1468
Total land cultivated	2.08	0.826	1468
Revenue per acre - in INR 10,000	1.36	0.928	1468
Cost of production per acre - in INR 10,000	1.15	1.021	1468
Profit per acre - in INR 10,000	0.24	1.009	1468
Return on investment per acre - in INR 10,000	0.36	1.249	1468
Agriculture - Rabi 2021-22 (winter) season			
Cultivated in the season	0.729	0.445	1621
Total production (in quintals)	25.40	18.976	992
Total productivity	13.44	5.217	992
Total land cultivated	1.92	1.069	992
Revenue per acre - in INR 10,000	1.30	0.858	992
Cost of production per acre - in INR 10,000	1.33	0.826	992
Profit per acre - in INR 10,000	-0.19	2.291	992
Return on investment per acre - in INR 10,000	0.07	0.674	992
Household decision making			
Contributes to household borrowing decisions	0.441	0.497	2915
Contributes to household decisions - how to use borrowed money	0.446	0.497	2915
Input in livelihood decisions	0.743	0.437	2915
Control over use of income	0.701	0.458	2915
Asset ownership	0.880	0.325	2915
Consumption and women's mental health			
Household Food consumption score	81.42	29.921	2915
Minimum Dietary Diversity-Women	3.840	2.017	2915
Women's mental health	1.684	1.355	1512
Credit rationing status			
Quantity rationed	0.447	0.497	2956
Risk rationed	0.324	0.468	2956
Credit unconstrained	0.228	0.420	2956

Table 3 Descriptive statistics by treatment

	Control			Treatment			
	N	Mean	Std.	N	Mean	Std.	p-value
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A. Baseline characteristics – Full sample							
Female	1516	0.524	0.500	1440	0.492	0.500	0.2650
Age	1516	43.31	8.89	1438	42.41	8.75	0.3298
Can read and write	1516	0.854	0.353	1440	0.876	0.330	0.5114
Completed at least primary school	1516	0.792	0.406	1440	0.731	0.443	0.1726
Completed at least secondary school	1516	0.282	0.450	1440	0.288	0.453	0.8869
Household income							
- Low (below ₹ 90,000 per year)	1516	0.528	0.499	1440	0.540	0.499	0.8759
- Medium (₹ 90,000 - 120,000 p/year)	1516	0.280	0.449	1440	0.271	0.445	0.8067
- High (above ₹ 120,000 per year)	1516	0.191	0.394	1440	0.190	0.392	0.9653
Cultivated in last Kharif*	1333	0.905	0.293	1287	0.912	0.283	0.8224
Cultivated in last Rabi	1499	0.809	0.394	1432	0.645	0.479	0.0058
Purchased on credit in past 12 months	1516	0.431	0.495	1440	0.551	0.498	0.0420
Borrowed money in past 12 months	1516	0.254	0.435	1440	0.260	0.439	0.8989
Desired loan size for last season	1514	35878	15514	1440	36431	15772	0.7297
WTP to insure loan of ₹20,000	1516	0.014	0.009	1440	0.014	0.008	0.1470
Panel B. Baseline survey by primary client							
Total cultivated land (in acres)	716	2.011	1.127	651	2.093	1.227	0.6387
- Small farmer (0-2.5 acres)	716	0.770	0.421	651	0.728	0.445	0.4330
- Marginal farmer (2.5-5 acres)	716	0.212	0.409	651	0.247	0.432	0.4656
Medium farmer 5-10 acres	716	0.018	0.134	651	0.025	0.155	0.5348
Cultivated paddy	716	0.996	0.065	651	0.992	0.087	0.4186
Cultivated lentil	716	0.006	0.075	651	0.051	0.220	0.1270
Cultivated vegetables	716	0.006	0.075	651	0.026	0.160	0.3059
Crop was damaged	716	0.272	0.445	651	0.249	0.433	0.6955
Ever had crop insurance	798	0.026	0.160	722	0.039	0.193	0.3678
Now having crop insurance	798	0.011	0.106	722	0.018	0.133	0.3774
Received pay-out from crop insurance	798	0.008	0.086	722	0.011	0.105	0.5299
Women's Dietary Diversity (MDD-W)	798	3.97	1.50	722	3.93	1.56	0.8060
Household Dietary Diversity (HDDS)	798	7.58	1.31	722	7.56	1.41	0.8983
Food Consumption Score (FCS)	798	81.09	24.55	722	81.22	27.11	0.9761
Stress indicator	350	3.448	0.360	250	3.347	0.418	0.1395
Total revenue per acre for all crops	716	21387	13069	651	24628	16453	0.1531
Total land cultivated for all crops	716	2.011	1.127	651	2.093	1.227	0.6387
Cost of production excl. own labor	716	13783	5916	651	13737	7380	0.9712
Profit from all crops excl. own labor	716	7604	13023	651	10891	14040	0.0254
Panel C. Endline demographics – Full sample							
Female	1473	0.50	0.500	1442	0.54	0.499	0.308
Age	1473	43.38	9.144	1442	43.88	8.570	0.388
Scheduled caste or tribe	1473	0.40	0.491	1442	0.23	0.422	0.001
Can read and write	1473	0.72	0.448	1442	0.77	0.419	0.047
Completed at least primary education	1473	0.72	0.451	1442	0.71	0.453	0.928
Completed at least secondary education	1473	0.31	0.463	1442	0.33	0.470	0.641
Credit rationing status							
Quantity rationed	1518	0.400	0.490	1438	0.497	0.500	0.008
Risk rationed	1518	0.335	0.472	1438	0.314	0.464	0.658
Credit unconstrained	1518	0.265	0.441	1438	0.190	0.392	0.048

Notes: p-values are derived from a regression in which we regress the variable of interest on a variable indicating treatment, with standard errors clustered by village (our unit of randomization). We test whether the coefficient on Treatment is different from zero and report the *p*-value associated with the *t*-test statistic here.

Table 4 Treatment effects on insurance take-up and familiarity with insurance (ITT)

	Insurance uptake	Insurance renewal	Heard of insurance	Knowledge score
	(1)	(2)	(3)	(4)
Panel A				
Treatment	0.617***	0.282***	0.155***	0.498***
	(0.044)	(0.068)	(0.040)	(0.153)
R^2	0.407	0.111	0.159	0.185
Panel B				
Treatment	0.661***	0.345***	0.184***	0.358
	(0.057)	(0.100)	(0.069)	(0.274)
Quantity rationed	0.038	0.055	0.034	0.125
	(0.028)	(0.088)	(0.052)	(0.187)
Risk rationed	0.069	0.127	0.060	0.107
	(0.044)	(0.120)	(0.059)	(0.266)
Treatment x Quantity rationed	-0.020	-0.055	-0.017	0.062
	(0.044)	(0.101)	(0.066)	(0.265)
Treatment x Risk rationed	-0.067	-0.148	-0.030	0.217
	(0.051)	(0.133)	(0.080)	(0.349)
R^2	0.430	0.098	0.162	0.196
Total effect | Quantity rationed	0.641***	0.290***	0.167***	0.420***
p-value	<1e-10	5.86e-05	7.77e-04	0.003
Total effect | Risk rationed	0.594***	0.197	0.155**	0.575
p-value	<1e-10	0.143	0.018	0.148
Panel C				
Treatment	0.630***	0.073	0.023	0.521***
	(0.046)	(0.079)	(0.052)	(0.116)
Female	-0.021	-0.453***	-0.171***	0.461
	(0.064)	(0.075)	(0.046)	(0.348)
Treatment x Female	-0.029	0.497***	0.289***	-0.063
	(0.074)	(0.089)	(0.072)	(0.372)
R^2	0.407	0.157	0.180	0.185
Total effect | Female	0.601***	0.570***	0.312***	0.458
p-value	<2e-16	<2e-16	4.92e-08	0.201
Observations	1,621	950	1,621	687
Control group mean	0.280	0.394	0.308	3.047

Notes: Standard errors in parentheses clustered by village. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. The first three dependent variables are binary, the fourth, "knowledge score" takes integer values 0-6, is the number of correct answers to six crop insurance statements. Control variables include dummy variables for block, age terciles, gender, literacy, caste, pre-existing operations in the village, baseline cultivation in the Rabi season, took credit at baseline, and profits at baseline. The model in columns (1) and (2) controls for baseline insurance uptake.

Table 5 Treatment effects on credit uptake (ITT)

	Took up credit in past 12 months			Credit from formal source			Credit from informal source			Difficulty in repayment
	All	Client	Other	All	Client	Other	All	Client	Other	All
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Panel A										
Treatment	0.107***	0.028	0.190***	0.228***	0.209***	0.240***	-0.128***	-0.189***	-0.056***	-0.412***
	(0.029)	(0.035)	(0.033)	(0.025)	(0.032)	(0.029)	(0.021)	(0.027)	(0.020)	(0.046)
R^2	0.072	0.131	0.113	0.133	0.149	0.207	0.068	0.115	0.047	0.340
Panel B										
Treatment	0.083*	0.064	0.125*	0.234***	0.242***	0.231***	-0.151***	-0.178***	-0.106***	-0.448***
	(0.044)	(0.053)	(0.064)	(0.041)	(0.054)	(0.060)	(0.032)	(0.033)	(0.041)	(0.073)
Quantity rationed	0.065**	0.054*	-0.024	0.046**	0.034	-0.005	0.021	0.023	-0.019	0.020
	(0.026)	(0.032)	(0.053)	(0.020)	(0.022)	(0.041)	(0.025)	(0.030)	(0.035)	(0.068)
Risk rationed	0.065**	0.054*	-0.024	0.046**	0.034	-0.005	0.021	0.023	-0.019	0.020
	(0.026)	(0.032)	(0.053)	(0.020)	(0.022)	(0.041)	(0.025)	(0.030)	(0.035)	(0.068)
Treatment x Quantity rationed	-0.023	-0.039	0.031	-0.026	-0.038	-0.006	-3e-04	-0.005	0.036	-0.002
	(0.052)	(0.060)	(0.089)	(0.053)	(0.062)	(0.084)	(0.026)	(0.036)	(0.039)	(0.090)
Treatment x Risk rationed	0.026	-0.031	0.050	-0.0003	-0.027	-0.0004	0.010	-0.030	0.045	0.005
	(0.058)	(0.059)	(0.101)	(0.052)	(0.066)	(0.090)	(0.047)	(0.057)	(0.048)	(0.102)
R^2	0.080	0.143	0.094	0.134	0.163	0.179	0.077	0.118	0.059	0.350
Total effect | Quantity rationed	0.059	0.025	0.155**	0.209***	0.033***	0.225***	-0.151***	-0.183***	-0.070	-0.450***
p-value	0.284	0.802	0.045	7.13e-10	9.6e-10	2.1e-04	1.18e-06	3.77e-08	0.190	4.71e-10
Total effect | Risk rationed	0.109**	0.032	0.175**	0.234***	0.215***	0.230***	-0.141***	-0.207***	-0.061	-0.443***
p-value	0.027	0.694	0.029	1.3e-08	1.22e-04	1.63e-04	1.27e-04	1.92e-05	0.116	3.19e-09
Panel C										
Treatment	-0.133***	-0.188***	-0.058	-0.046*	0.002	-0.105***	-0.089***	-0.206***	0.059	-0.019
	(0.031)	(0.049)	(0.043)	(0.024)	(0.039)	(0.038)	(0.027)	(0.050)	(0.038)	(0.076)
Female	-0.133***	-0.188***	-0.058	-0.046*	0.002	-0.105***	-0.089***	-0.206***	0.059	-0.019
	(0.031)	(0.049)	(0.043)	(0.024)	(0.039)	(0.038)	(0.027)	(0.050)	(0.038)	(0.076)
Treatment x Female	0.311***	0.237***	0.372***	0.225***	0.091	0.383***	0.090***	0.161***	-0.020	-0.111
	(0.037)	(0.067)	(0.062)	(0.035)	(0.066)	(0.057)	(0.029)	(0.053)	(0.039)	(0.083)
R^2	0.311***	0.237***	0.372***	0.225***	0.091	0.383***	0.090***	0.161***	-0.020	-0.111
Total effect | Female	0.259***	0.157***	0.348***	0.337***	0.259***	0.403***	-0.084***	-0.102***	-0.064**	-0.472***
p-value	<2e-16	4.87e-4	2.22e-16	<2e-16	2.21e-09	<2e-16	7.46e-04	0.003	0.037	9.5e-14
Observations	2,915	1,621	1,294	2,915	1,621	1,294	2,915	1,621	1,294	987
Control group mean	0.275	0.353	0.176	0.111	0.140	0.076	0.171	0.223	0.105	0.709

Table 6 Treatment effects on agricultural outcomes

	Cultivated paddy (binary)		Area cultivated (in acre)		Revenue p/acre (in 10,000 INR)		Cost per acre (in 10,000 INR)		Return on investment		Profit per acre (in 10,000 INR)	
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A												
Treatment	0.022*	0.005	-0.001	0.479***	0.197***	0.043	-0.020	-0.340***	0.019	0.161**	0.231***	1.329***
	(0.013)	(0.040)	(0.066)	(0.094)	(0.066)	(0.113)	(0.070)	(0.065)	(0.069)	(0.062)	(0.068)	(0.237)
R-squared	0.026	0.061	0.016	0.104	0.045	0.041	0.010	0.121	0.012	0.057	0.039	0.061
Panel B - By Gender												
Treatment	0.027	-0.015	0.047	0.407***	0.240***	-0.008	0.012	-0.243***	-0.078	0.155***	0.220**	1.419***
	(0.019)	(0.042)	(0.086)	(0.121)	(0.076)	(0.123)	(0.115)	(0.068)	(0.089)	(0.054)	(0.109)	(0.260)
Female	0.043**	-0.117*	0.032	0.202*	-0.043	0.092	-0.006	0.306***	-0.159	-0.007	-0.055	0.743*
	(0.017)	(0.060)	(0.093)	(0.105)	(0.079)	(0.136)	(0.074)	(0.111)	(0.118)	(0.114)	(0.078)	(0.417)
Treatment x Female	-0.011	0.043	-0.105	0.192	-0.095	0.137	-0.069	-0.259**	0.200	0.016	0.023	-0.241
	(0.020)	(0.070)	(0.125)	(0.176)	(0.109)	(0.163)	(0.121)	(0.119)	(0.137)	(0.126)	(0.119)	(0.456)
R-squared	0.027	0.062	0.017	0.106	0.045	0.042	0.010	0.126	0.014	0.057	0.039	0.061
Observations	1621	1621	1468	992	1468	992	1468	992	1468	992	1468	992
Control group mean	0.944	0.729	2.084	1.916	1.248	1.299	1.146	1.329	0.364	0.069	0.237	-1.284

Notes: Standard errors in parentheses clustered by village. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Cost per acre, return on investment, and profit per acre all estimated excluding own labor. Control variables include dummy variables for block, age terciles, gender, literacy, caste, pre-existing operations in the village, baseline cultivation in the Rabi season, took credit at baseline, and profits at baseline.

Table 7 Treatment effects on agricultural outcomes in kharif 2022 (LATE)

	Cultivated paddy (binary)	Area cultivated (in acre)	Revenue per acre (in 10,000 INR)	Cost per acre (in 10,000 INR)	Return on investment	Profit per acre (in 10,000 INR)
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A						
Treated	0.093*	-0.004	0.779***	-0.073	0.073	0.931***
	(0.054)	(0.262)	(0.254)	(0.272)	(0.272)	(0.279)
R^2	0.009	0.015	0.005	0.007	0.011	-0.030
Panel B						
Treated	0.294	-0.107	1.415*	-0.672	-0.010	1.761***
	(0.190)	(0.638)	(0.783)	(0.540)	(0.802)	(0.680)
Quantity rationed	0.025	0.048	0.128	0.069	0.070	-0.001
	(0.024)	(0.085)	(0.098)	(0.120)	(0.143)	(0.116)
Risk rationed	0.016	-0.086	0.136	0.065	-0.001	0.020
	(0.033)	(0.063)	(0.087)	(0.080)	(0.173)	(0.079)
Treated x Quantity rationed	-0.219	-0.120	-0.563	0.719	-0.124	-0.815
	(0.170)	(0.607)	(0.787)	(0.704)	(0.816)	(0.781)
Treated x Risk rationed	-0.225	0.254	-0.953	0.502	0.255	-0.985
	(0.199)	(0.611)	(0.726)	(0.515)	(0.885)	(0.670)
R^2	2e-04	0.014	-0.001	0.005	0.010	-0.038
Total effect | Quantity rationed	0.075	-0.228	0.852**	0.047	-0.134	0.946*
p-value	0.432	0.794	0.005	0.993	0.936	0.077
Total effect | Risk rationed	0.069	0.147	0.462	-0.170	0.245	0.776***
p-value	0.610	0.817	0.267	0.694	0.798	0.002
Panel C						
Treated	0.121	0.189	0.988***	0.050	-0.291	0.926**
	(0.084)	(0.339)	(0.265)	(0.459)	(0.368)	(0.436)
Female	0.043**	0.040	-0.049	0.001	-0.177	-0.076
	(0.019)	(0.100)	(0.089)	(0.080)	(0.127)	(0.082)
Treated x Female	-0.055	-0.387	-0.420	-0.248	0.731	0.009
	(0.082)	(0.455)	(0.388)	(0.459)	(0.532)	(0.443)
R^2	0.010	0.015	0.013	0.007	-0.005	-0.030
Total effect | Female	0.065	-0.198	0.568	-0.198	0.440	0.935***
p-value	0.153	0.581	0.116	0.337	0.268	1.99e-04
Observations	1,621	1,468	1,468	1,468	1,468	1,468
Control group mean	0.944	2.076	1.248	1.131	0.375	0.125

Notes: Standard errors in parentheses clustered by village. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Cost per acre, return on investment, and profit per acre all estimated excluding own labor. Control variables include dummy variables for block, age terciles, gender, literacy, caste, pre-existing operations in the village, baseline cultivation in the Rabi season, took credit at baseline, and profits at baseline. The model in column (2) controls for number of acres cultivated at baseline. The model in column (3)-(6) controls for paddy revenue per acre at baseline.

Table 8 Treatment effects on gender parity outcomes (ITT)

	Contributes to household borrowing decisions			Contributes to decisions how to use borrowed money			Input in livelihood decisions			Control over use of income			Asset ownership		
	All	Client	Other	All	Client	Other	All	Client	Other	All	Client	Other	All	Client	Other
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Panel A															
Treatment	0.073***	0.136***	-0.012	0.062***	0.120***	-0.014	0.096***	0.010	0.193***	0.137***	0.063*	0.216***	0.114***	0.035*	0.211***
	(0.023)	(0.030)	(0.031)	(0.020)	(0.030)	(0.028)	(0.029)	(0.037)	(0.043)	(0.034)	(0.037)	(0.044)	(0.017)	(0.021)	(0.029)
R^2	0.372	0.304	0.461	0.394	0.316	0.507	0.106	0.089	0.126	0.097	0.088	0.114	0.106	0.032	0.203
Panel B															
Treatment	-0.016	0.017	-0.067	-0.009	0.008	-0.028	-0.027	-0.029	-0.060	0.046	0.055	-0.004	0.044***	0.045**	0.021
	(0.034)	(0.039)	(0.058)	(0.035)	(0.042)	(0.057)	(0.040)	(0.049)	(0.056)	(0.045)	(0.053)	(0.058)	(0.015)	(0.017)	(0.028)
Female	-0.525***	-0.521***	-0.521***	-0.533***	-0.523***	-0.516***	-0.288***	-0.214***	-0.391***	-0.228***	-0.155***	-0.346***	-0.145***	-0.064**	-0.241***
	(0.025)	(0.035)	(0.043)	(0.025)	(0.041)	(0.043)	(0.032)	(0.044)	(0.054)	(0.028)	(0.053)	(0.050)	(0.019)	(0.032)	(0.036)
Treatment x Female	0.174***	0.261***	0.095	0.139***	0.244***	0.024	0.242***	0.085	0.439***	0.178***	0.016	0.381***	0.137***	-0.022	0.330***
	(0.050)	(0.071)	(0.065)	(0.053)	(0.083)	(0.060)	(0.042)	(0.064)	(0.068)	(0.039)	(0.070)	(0.067)	(0.024)	(0.041)	(0.040)
R^2	0.379	0.320	0.463	0.399	0.331	0.507	0.125	0.092	0.177	0.106	0.088	0.151	0.117	0.032	0.253
Total effect | Female	0.158***	0.278***	0.028	0.131***	0.252***	-0.004	0.214***	0.057	0.379***	0.224***	0.072	0.377***	0.181***	0.023	0.351***
p-value	1.89e-06	2.42e-07	0.384	4.24e-05	4.55e-05	0.857	6.08e-11	0.253	8.17e-14	8.76e-12	0.134	1.41e-12	1.38e-12	0.557	<2e-16
Observations	2,915	1,621	1,294	2,915	1,621	1,294	2,915	1,621	1,294	2,915	1,621	1,294	2,915	1,621	1,294
Control group mean	0.403	0.427	0.373	0.414	0.450	0.368	0.697	0.803	0.562	0.632	0.716	0.525	0.828	0.893	0.744

Notes: Standard errors in parentheses clustered by village. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. All dependent variables are binary. Control variables include dummy variables for block, age terciles, gender, literacy, caste, pre-existing operations in the village, baseline cultivation in the Rabi season, took credit at baseline, profits at baseline and empowerment score.

Table 9 Treatment effects on women's mental health outcomes (ITT)

	Composite stress score	Unable to control important things in life (frequency)	Confidence in ability to handle personal problems (frequency)	Felt that things were going her way (frequency)	Felt that difficulties were piling up (frequency)
	(1)	(2)	(3)	(4)	(5)
Treatment	-0.028	0.095	0.187	0.101	0.121
	(0.079)	(0.149)	(0.153)	(0.136)	(0.159)
Other family member	0.262***	0.373***	-0.193	-0.345*	0.435**
	(0.101)	(0.143)	(0.181)	(0.184)	(0.185)
Treatment x Other family member	-0.525***	-0.401**	0.291	0.049	-1.327***
	(0.116)	(0.159)	(0.201)	(0.195)	(0.194)
R^2	0.146	0.073	0.084	0.073	0.151
Total effect | Other family member	-0.553***	-0.306***	0.478***	0.150	-1.205***
p-value	4.93e-12	4.71e-04	0.001	0.279	<2e-16
Observations	1,512	1,512	1,512	1,512	1,512
Control group mean	2.785	3.126	3.659	3.332	3.007

Notes: Standard errors in parentheses clustered by village. Responses to questions in columns (2)-(5) are based on a Likert scale ranging from 1 (Never) to 5 (Very often). Composite stress score is the average of the responses to questions in columns (2)-(5), recoded so that higher scores indicate higher levels of stress. Control variables include dummy variables for block, family member, age terciles, literacy, caste, pre-existing operations in the village, baseline cultivation in the Rabi season, took credit at baseline, profits at baseline, and baseline stress score/indicator.

Table 10. Implementation cost

	Cost per unit	Nr of unit	Total cost	
			INR	USD
Research & Development (one-off cost)				
Personnel			1,463,060	19,665
Office/facilities			690,000	9,274
IT services			243,994	3,279
Data collection/licensing			1,670,086	22,447
Guarantee fund for initial de-risking of KhetScore	10% per INR 28,850 loan	104 farmers	300,000	4,032
Other overheads			225,000	3,024
Total one-off R&D cost			***4,367,140***	***58,697***
Fixed cost per season				
Project management			367,481	4,939
Staff travel			36,627	492
Field office costs			690,000	9,274
App/portal maintenance			248,400	3,339
Communication material			68,626	922
Total cost			***1,411,135***	***18,966***
Variable cost per farmer				
Interest for 6-month loan	9% of loan	26,129	2,352	31.61
Insurance	3% of loan	26,129	784	10.54
KhetScore reports	n/a	n/a	500	6.72
DER field staff	n/a	n/a	3,173	42.65
Staff transport, allowance	n/a	n/a	308	4.14
Printing, stationeries	n/a	n/a	96	1.29
Total cost per farmer			***7,213***	***96.95***

USD = INR 74.40