# Eliciting Supplier Cooperation for Value Chain Decarbonization:

# A Field Experiment with Smallholder Farmers in India

Sukti Ghosh
INSEAD
sukti.ghosh@insead.edu

Jasjit Singh
INSEAD
jasjit.singh@insead.edu

April 18, 2024

**Acknowledgments**. We are grateful to the firm that partnered our research for providing access and support. We thank Arzi Adbi, Laurence Capron, Lucia Del Carpio, Devanshee Shukla, Vibha Gaba, Maria Guadalupe, Yun Hou, Rupali Kaul, Hyunjin Kim, Ilze Kivleniece, Matthew Lee, Jiao Luo, Lite Nartey, Kate Odziemkowska, Phanish Puranam, Victoria Sevcenko, Chiara Spina, Anna Szerb, Lin Tian, Bengisu Urlu, Bala Vissa, Phebo Wibbens and Xiaoteng Wu for helpful inputs. This research has also benefited from feedback at the AOM and SMS annual meetings, the NMSRC Doctoral Conference, and seminar presentations at INSEAD. We also acknowledge the financial support from INSEAD's Kurt Björklund Research Fund. Any errors remain our own.

# ABSTRACT

Firms are increasingly under pressure to reduce greenhouse gas (GHG) emissions not just within their operations but across their value chains. However, value chain decarbonization is typically not a priority for suppliers, and aligning their goals through formal contracts is often also impractical. This study examines the effectiveness of a firm employing relational strategies as a way to address this dual challenge. In a research collaboration with a Fortune 500 firm seeking to reduce GHG emissions in its agricultural supply chain in India, we designed a field experiment to examine the effectiveness of combining decarbonization training for the firm's supplier farmers with personalized agricultural support to boost the economic value that they derived from their relationship with the firm. Specifically, we examined two interventions that differed in the nature and extent of this personalized support: a lower investment intervention that provided personalized support only for the crop the supplier farmers grew specifically for the firm's value chain, and a higher investment intervention that additionally provided personalized support for broader agricultural practices relevant for the other crops the farmers grew. Relative to a control group that was only exposed to decarbonization training and not given any personalized support, both interventions improved the farmers' adoption of the firm-recommended climate-friendly practices. The higher investment intervention produced greater environmental impact in terms of emissions reduction per farmer as well as emissions reduction per dollar invested, while also leading to better business outcomes in terms of expected retention of farmers in the sourcing program.

**Keywords**: Sustainability; Decarbonization Strategy; Nonmarket Strategy; Emerging Markets; Field Experiment

## 1. INTRODUCTION

Helping address society’s grand challenges often requires firms to coordinate collective action across stakeholders (George et al. 2016, Lumpkin and Bacq 2019, McGahan 2021). Mitigating climate crisis, one of the greatest challenges facing humanity (Richardson et al. 2023), is no exception. Firms are under pressure to reduce greenhouse gas (GHG) emissions that they are responsible for, as business-related activities are a critical contributor to global warming (Cenci et al. 2023, Dietz et al. 2018). One source of this pressure is the ongoing or expected tightening of environment-related regulations directly in response to the climate crisis (Rennert et al. 2022, Rockström et al. 2017). An expectation that firms ought to demonstrate more social responsibility has more generally also been on the rise for other prominent stakeholders of the firms, including customers (Aghion et al. 2023, Bertini et al. 2022), employees (Bode and Singh 2018, Burbano 2016), communities (Dorobantu and Odziemkowska 2017, Henisz et al. 2014), and investors (Cheng et al. 2014, Flammer et al. 2021). As a result, more and more firms are integrating societal priorities into their business strategies (Burbano et al. 2023), including pledging to specific goals for reducing their GHG emissions and designing strategic decarbonization programs to achieve them (Lenox and Duff 2021, York et al. 2018).

Meeting societal expectations on decarbonization increasingly requires firms to pursue GHG emission reduction not only within their operations but across their value chains. However, a large fraction of the value chain emissions can be beyond a firm’s direct control (Blanco et al. 2016), and coordinating with and achieving the cooperation of value chain partners like suppliers therefore becomes very important (Hardy and Sandys 2022, Hsu and Rauber 2021). This challenge is accentuated by emissions reduction often not being a priority for suppliers, a barrier especially critical in contexts where relying purely on formal contracts for aligning goals is difficult (Hoskisson et al. 2000, Marquis and Raynard, 2015, Marquis and Qian 2014). In particular, primary producers or small suppliers struggling with economic survival in emerging economies might understandably have different priorities, and getting them to prioritize climate impact by employing contractual solutions is also usually impractical. Nevertheless, as such suppliers often contribute significantly in aggregate towards a firm's overall value chain GHG emissions, eliciting their cooperation is critical.

We examine the effectiveness of one potential solution to the challenge of engaging value chain partners without using contractual solutions: relying on relational strategies (Elfenbein and Zenger 2014, Gibbons and Henderson 2012, Henisz 2023, Teodorovicz et al. 2023). In their study of a U.S. logistics company employing a relational strategy to influence driver behavior in a different context, Blader et al. (2015) summarize a significant literature suggesting that "competitively significant managerial practices rely for their effectiveness on the performance of actions that cannot be specified in advance or contractually verified ex post." Extending this argument to the specific issue of engaging a firm's suppliers in its decarbonization strategy in an emerging economy context, we examine how the extent and nature of a firm's investments in enhancing the value suppliers perceive from their relationship with the firm might affect their cooperation with the firm's value chain decarbonization efforts. In other words, we empirically investigate whether and how much extending the firm's focus beyond just its decarbonization goals to also integrating considerations of the overall well-being of its suppliers might affect the likelihood of the suppliers adopting the more climate-friendly production practices the firm would like to move them towards.[1]

We carry out our research in the context of a firm's agricultural supply chain in India. The setting is motivated by the fact that, in the agriculture sector the average land per farming household in emerging economies is less than five hectares, yet smallholder-dominated regions contribute more than half of the global production for several major food crops (Samberg et al. 2016). We partnered with a Fortune 500 firm in the food and beverage industry whose value chain in India involves sourcing a crop – referred to here as "Crop X" – that is critical for the production process of its final products.[2] The firm had already been running a strategic sourcing program involving a standardized

---

[1] Our study has parallels to McGahan and Pongeluppe (2023), who examine Natura engaging with its suppliers to make progress on rainforest preservation in the Amazon. However, our specific context, hypotheses and analysis are distinct, as we use a field experiment for evaluating effectiveness of two interventions employing relational strategies to try to get smallholder farmers in a firm's agricultural value chain in India to adopt more climate-friendly practices.

[2] Since our partner firm is one of the few major firms with deep engagement in this specific crop's supply chain in India, we do not mention the name of the specific crop in this study in order to protect the firm's identity.

process of supporting supplier farmers to grow Crop X in line with the firm's quality requirements. Given the recent aspiration of the firm to pursue decarbonization, the firm was now keen to additionally also move the farmers towards certain climate-friendly agricultural practices. The setting thus provided us a unique opportunity to design and test potential interventions that could elicit supplier cooperation for implementing a major global firm's value chain decarbonization strategy.

Our formal research design relies on a field experiment, an approach ideally suited for econometric estimation of causal effects (Chatterji et al. 2016, Spicer et al. 2021), and increasingly being employed to examine various impacts specifically of corporate initiatives engaging with societal issues (Durand and Huysentruyt 2022, Portocarrero and Burbano 2023, Singh et al. 2019). However, our investigation started with in-depth interviews to first understand the perspective of the supplier farmers. Our first observation was that the farmers were generally aware of neither the role of GHG emissions in climate change nor how their activities contributed to such emissions. However, they did care about localized climate-related issues directly affecting their economic welfare - such as achieving climate resilience or preserving soil health. A large fraction of the farmers had small land holdings and came from low-income segments, and their most pressing concerns were their agricultural productivity and economic well-being. Our interviews revealed considerable barriers to their adoption of new agricultural practices due to a perception of uncertain returns and a lack of specific resources required for their implementation. Further, the farmers had significant unmet agricultural needs that they felt could be better addressed by the firm, notably through personalized agricultural advice tailored to each farmer's specific context. In particular, the farmers hoped to get access to personalized crop-specific support within the firm's value chain (i.e., for growing Crop X) as well as personalized agricultural support relevant even for their other crops (i.e., beyond Crop X).

Our field interviews also suggested that employing relational strategies for the firm to boost the value the supplier farmers derived from working with the firm could be helpful for achieving their cooperation with the firm's decarbonization efforts as well. In other words, rather than only providing farmers knowledge of climate-friendly agricultural practices through training, it could be more effective to bundle this training with personalized support services that also addressed their unmet agricultural needs and hence strengthened their relationship with the firm. Provision of personalized value-chain-specific support (for Crop X) and further addition of broader agricultural support (for all crops) were two directions that therefore seemed worth testing as relational strategies to employ.

We used insights from our field interviews to design two interventions wherein training in climate-friendly agricultural practices (the only component of a "base program" we use as a control) would be bundled with personalized agricultural support that the farmers would find contextually valuable. These interventions differed in the extent and nature of the personalized support to be bundled with the base program: (i) Intervention A, which only added personalized crop-specific advisory services in the form of a free soil-testing service and accompanying support (restricted to Crop X, and thus still an investment within the firm's value chain); (ii) Intervention B, which included everything in Intervention A but also added broader agricultural advisory services provided during a visit by an expert agronomist covering all crops a farmer grew, thus making it an investment that extended beyond just the activities the farmer carried out within the firm's value chain.

Our next step was to design a field experiment to examine the impact of Interventions A and B relative to the base program. The intervention was carried out for each of the 2,605 supplier farmers that had signed up for the sourcing program for the upcoming year, but the randomization was carried out at the level of the village to minimize contamination within a village. Our main analysis relies on two kinds of primary outcomes: business outcomes and environmental outcomes. The two business outcomes – the intention of a farmer to continue growing Crop X for the firm the following season and the extent of land they intended to allocate to Crop X the following season – relate to expected farmer retention, a key metric tracked by the firm as a leading indicator of feasible scaling up of the firm's sourcing program in India. The two environmental outcomes – the extent of tillage of land and of the extent of inorganic fertilizers used – relate to a farmer's adoption of the firm-recommended climate-friendly agricultural practices known to influence the GHG emissions in the value chain.

Our results indicate that Intervention A generated greater impact than the base program for our primary environmental outcomes but not our primary business outcomes, while Intervention B generated greater impact than both the base program and Intervention A for both kinds of outcomes. In terms of the farmers' intention to continue with the firm next season, Intervention B led to an 8.17% increase over the base program, while the impact of Intervention A was indistinguishable from that of the base program. For the farmers' intended land allocation for Crop X in the following season, Intervention B led to a 38.78% increase over the base program, while the impact of Intervention A was indistinguishable from that of the base program. Regarding the environmentally harmful practice of excessive land tillage, Intervention B led to an 8.16% decrease in tillage over the base program, while Intervention A was indistinguishable from the base program. Finally, in terms of reducing excessive inorganic fertilizer use, Intervention B led to a 6.75% decrease in the use of inorganic fertilizer, while Intervention A led to a smaller decrease of 3.20%. Reduced tillage and reduced inorganic fertilizer use also led to both Intervention A and Intervention B producing significant cost savings for the farmer, the savings being greater for Intervention B than for Intervention A.

Having established that the intervention with greater investment per farmer in personalized support that extended beyond the value chain (Intervention B) did have the greatest impact in terms of associated emissions reduction per farmer, we next analyze the more nuanced question of whether it was also the best choice in terms of emissions reduction achieved *per dollar* invested. In a cost-benefit analysis that accounted for not only the emissions reduction but also the cost entailed, Intervention B still turns out to be the most cost-effective intervention for meeting the firm's GHG emissions reduction goals. In other words, even in terms of environmental impact achieved *per dollar*, Intervention B is better than both Intervention A and the base program. Put differently, making investment in personalization for specific support within the value chain *as well as* broader support beyond the value chain is worth the extra cost for eliciting supplier cooperation for decarbonization.

While we expect there to be limits to generalizability of our specific findings, our study is certainly serves as an illustration that significant investment in a relational strategy to engage value chain partners in a firm’s decarbonization strategy *can* be worthwhile. Our paper represents one of the few large-scale empirical studies (and, to our knowledge, the first field experiment) in management to examine the impact of a real corporate value chain decarbonization initiative, in line with calls for scholars studying corporate sustainability to engage more in “business-academic cooperation in designing and learning from field experiments” (Spicer et al. 2021). Our findings demonstrate that, even in the absence of formal contracts, meaningful progress towards value chain decarbonization can be made by investing in relational strategies to boost the value derived by the value chain partners. Our analysis goes beyond simply estimating the impacts of the experimental interventions to also carrying out a cost-benefit analysis that quantifies their cost effectiveness. We hope that this study motivates further research on effective corporate strategies to mitigate negative environmental externalities, especially by leading collaborative efforts across stakeholders.

## 2. VALUE CHAIN DECARBONIZATION

### 2.1. The corporate imperative for value chain decarbonization

It is scientifically established that GHG emissions attributable to human activity are a driver of rise in the earth’s temperature, thereby increasing the risk of severe climate-related consequences like rise in sea levels, floods, droughts, and extreme weather events (Intergovernmental Panel on Climate Change 2022). This has prompted urgent calls for limiting further GHG emissions to contain climate change, including the Paris Climate Agreement of 2015 urging global action to limit global warming to under 2° Celsius (and as close to 1.5° as possible) relative to pre-industrial levels. However, scientists have noted that progress towards reducing global emissions is still not rapid enough (Rockström et al. 2017, Richardson et al. 2023, Wright and Nyberg 2017). Given that business-related activities are an important source of global emissions (Cenci et al. 2023, Dietz et al. 2018), firms are increasingly being asked to do more to reduce the GHG emissions they are responsible for.

Businesses have for long faced pressure to address the various negative environmental externalities related to their value chain activities (Jira and Toffel 2013, Reid and Toffel 2009). However, in the past, it has been common for firms to circumvent such pressures through strategic responses like moving pollution-intensive activities to more lenient jurisdictions (Berry et al. 2021, Li and Zhou 2017), outsourcing such activities to others in their value chain (Alberini and Austin 2002, Barney et al.1992, Becker and Henderson 2000), or shifting them to subsidiary firms in order to limit their liability (Lee and Bansal 2024, Prechel and Zheng 2012). With increased global awareness of and sensitivity towards environmental issues, such strategies are becoming less practical, and firms are having to take responsibility for genuinely addressing the environmental impacts arising across their entire value chain (Cenci et al. 2023, Fankhauser et al. 2022). Such pressures have escalated with the diffusion of emission measurement standards like the GHG protocol (which classifies emissions from a firm's value chain partners as its "Scope 3 emissions") and emission reduction standards like the SBTi (Science Based Target Initiative, which helps firms pursue science-based "net zero" strategies).[3] In response, forward-looking firms are increasingly setting ambitious emission-reduction targets and formulating decarbonization strategies to reduce emissions both within their boundaries and throughout the value chain (Bjørn et al. 2022, Sautner et al. 2023).

The impact of reducing emissions anywhere in the world is global, providing unique opportunities for pursuing mitigation wherever it is most cost-effective (Glennerster and Jayachandran 2023). Large multinational firms are in principle particularly well positioned to help reduce global GHG emissions, as they can redesign their supply chains to be more climate-friendly, such as by sourcing more inputs locally rather than importing them (thereby also improving supply resilience). They also command significant resources and knowledge of low-carbon technologies, and thanks to their global reach are well positioned to change the behavior of millions of smaller suppliers worldwide towards more climate-friendly practices (Steenbergen and Saurav 2023). However, these unique opportunities also come with unique challenges that need to be overcome.

## 2.2. Achieving value chain decarbonization using a relational strategy

---

[3] The GHG Protocol uses the term "Scope 1 emissions" for direct emissions from a firm's activities; "Scope 2 emissions" for emissions associated with its acquired electricity, steam, heat or cooling; and "Scope 3 emissions" for emissions from its value chain partners (https://ghgprotocol.org/). Scope 3 emissions are the hardest to manage and yet often represent a large majority of a firm's total emissions (Stenzel and Waichman 2023, Tidy et al. 2016).

Eliciting cooperation of relevant stakeholders is known to be a key challenge for firms tackling any societal issue (Bridoux and Stoelhorst 2016, McGahan 2021), and there is no reason to expect that the issue of decarbonization would be an exception. Decarbonizing the value chain often involves cooperation of partners like small suppliers or primary producers that are individually not in a position to prioritize emission mitigation, yet are collectively responsible for a large fraction of the emissions. Engaging with such partners involves overcoming a dual challenge: their insufficient awareness as well as prioritization of climate-related issues, and an insufficient alignment of their interests with the firm's goals (Koh et al. 2023). These challenges are further aggravated for firms with complex cross-border value chains that involve numerous varied stakeholders (Verbeke 2021). At the same time, it is also a unique opportunity: by integrating decarbonization strategy with sustainability strategy on the social dimension, firms can also have a significant social impact, especially for low-income segments of the global population (Howard-Grenville et al. 2014, McGahan and Pongeluppe 2023).

Engaging small suppliers, especially those located in emerging economies, requires several unique considerations. Such suppliers are more likely to lack relevant knowledge and resources to lead decarbonization initiatives, making it critical to provide them with intensive support for developing their capabilities (Gatignon and Capron, 2023, McGahan and Pongeluppe 2023). Further, the trade-off between protecting the environment versus ensuring their economic well-being can be especially stark for such suppliers, making it important for decarbonization initiatives to also consider local livelihoods (Jayachandran 2023, Samii et al. 2014). The issue is accentuated by the fact that contractual solutions are often impractical due to limited legal recourse or enforcement, making it paramount to find other ways to engage the suppliers (Jack et al. 2022, Jack and Jayachandran 2019).

One potential solution to manage the above challenge is to invest in relational strategies, which can be especially effective in situations when formal contracts are impractical (Dorobantu et al. 2017, Marquis and Raynard 2015). Such strategies help overcome limitations in relying only on formal governance mechanisms to align incentives (Henisz 2023), and may even involve looking beyond the specific exchange relationship to generate benefits for the partner that extend beyond the value chain (Lazzarini et al. 2020). One channel through which such strategies operate is by establishing or deepening the relationship through a focus on joint value creation (Gibbons and Henderson 2012). A related channel is a commitment-based mechanism involving the development of a positive view and reciprocity (Fehr and Gächter 2000, Poppo and Zenger 2002, Teodorovicz et al. 2023). Both economic considerations and social mechanisms can underpin the value derived from relational strategies (Elfenbein and Zenger, 2014). Consistent with the theory, recent studies have found that firms do often improve their business outcomes by investing in relational strategies (Gatignon and Capron 2023, Teodorovicz et al. 2023). Extended to our context, we posit that the nature and extent of investments made by the firm as part of a relational strategy can offer a potential solution for firms to effectively engage their suppliers in their value chain decarbonization strategy.

## 3. RESEARCH CONTEXT AND HYPOTHESES

### 3.1. Empirical setting: A firm's agricultural supply chain in India

Our research setting is the agricultural supply chain in India for a Fortune 500 firm in the food and beverage industry. Before the start of our research collaboration, the firm had already been running a local sourcing program in India, which involved procurement of crop ("Crop X") from independent smallholder farmers. The goal of our research collaboration was to help design and test potential extensions to this sourcing program to also promote more climate-friendly agricultural practices among the supplier farmers. Although the impact of climate change is expected to fall disproportionately on such farmers, their efforts to mitigate their agriculture-related GHG emissions are generally limited. The first reason is inadequate institutional infrastructure, including insufficient access to requisite knowledge and tools for this (Cole and Fernando 2021, Jack 2013). A second reason is that farmers are naturally more concerned about their (typically modest) livelihoods than climate change, and are worried that adopting unfamiliar practices might even make their lives worse. The goal of our research was thus to examine how these barriers could be appropriately overcome.

### 3.2. The firm's original sourcing program for Crop X

Before going into our proposed interventions, it is useful to describe the original sourcing program in detail. Cultivating Crop X in line with the stringent quality standards of the firm entailed the farmer adopting specific seed varieties, land preparation activities and sowing as well as harvest timing. If a farmer's produce failed to meet the firm's quality parameters, the prospect of finding an alternative buyer and securing a good price was uncertain, which could deter farmers from working with the firm in the first place or from devoting enough land to Crop X. This risk could not be addressed through formal contractual means as the limitations of the legal infrastructure, marginal landholdings and ambiguity in land ownership made this impractical. The firm's sourcing program tried to overcome this challenge by investing in ensuring that farmers were both able and willing to grow Crop X at the desired scale and quality.[4] Given the firm's interest in expanding the volume of Crop X sourced in India, a key performance indicator for the program was therefore farmer retention, i.e., getting farmers to continue from one year to the next and allocate a significant part of the land to grow Crop X.

The farmers were given access to certified seeds, information on best practices, a digitized quality check on the crop produced, and informal assurances that the firm would buy Crop X at a price commensurate with the investment the farmers made to ensure its quality. The program was implemented through the firm's field officers, who carried out regular visits to assure the farmers that growing Crop X for firm was an attractive option. Figure 1 summarizes the organizational structure of the program, which was implemented in northern India in the states of Haryana and Rajasthan. Within these states, the firm's network spanned 16 geographic centers (corresponding to "Agricultural Produce and Livestock Market Committee" locations as per the nomenclature of the Indian government). Farmers accessed inputs and sold their produce at the center closest to them, with the firm's field officer at each center serving as their main point of contact.

---

[4] The program borrowed elements from past government and development programs seeking to boost farmer productivity through in-person support, though often with mixed success (Birner and Anderson 2007, Glendenning et al. 2010). Insufficient institutional capacity, dispersed populations and limited infrastructure had made it hard for such so-called "extension services" to be delivered in a reliable and timely manner (Glendenning et al. 2010). Another challenge had been that the knowledge provided was often too generic to address context-specific issues or too technical for the illiterate or semi-literate farmers to use (Cole and Fernando 2021). Further, the practices had often been tested in controlled conditions very different from farmers' actual contexts, introducing uncertainty about the benefits of adoption (Suri 2011).

[Insert Figure 1 here]

### 3.3. Insights from pre-experiment field interviews

Before proposing potential extensions to meet the firm's decarbonization goals, we carried out interviews to understand how the original program was perceived. This involved 43 semi-structured interviews with farmers (from 15 villages across seven centers), seven with field officers (from the same seven centers), and seven with managers (two state-level managers also serving as agronomists, one R&D manager, and four program managers). The interviews took place in April-May 2022 and October-November 2022. Each lasted 45-90 minutes and was either in English or a local dialect (with field staff translating where necessary). Table 1 provides illustrative quotes from the interviews.

[Insert Table 1 here]

In several interviews (e.g., interview [1] in Table 1), the farmers informed us that they found the regular one-to-one visits of the field officers (usually once a month during the cultivation season) beneficial for receiving timely information on issues relevant at the different stages of growing Crop X. The farmers viewed their relationship with the firm as a long-term partnership that was mutually beneficial, showing particular appreciation for the frequent visits by field staff managing the engagement (e.g., interviews [2] and [3] in Table 1). However, the interviews also revealed farmer needs that were not currently addressed by the program.

The first set of unmet needs related to issues unique to a farmer's context and priorities as available information was often too generic (e.g., interviews [4] and [5] in Table 1). There was a latent need for more personalized advisory based on a farmer's agricultural routines, choice of fertilizers, and the uniqueness of the soil.[5] Access to personalized advisory based on a timely and reliable soil testing service was mentioned several times as a specific service that the farmers would find particularly useful as an extension to the original program. Although soil-testing services were, in principle, provided by the government in some locations, they did not always reach farmers in time

---

[5] The importance of considering a farmer's local context has been previously documented by prior work on adoption and effectiveness of agricultural technologies and practices (Abdul Latif Jameel Poverty Action Lab (J-PAL) 2023, Suri 2011). In particular, access to scientific tools like soil tests, combined with farmer-friendly information-sharing to help interpret the results from such tests, has been documented as a particularly impactful service (Cole and Sharma 2017).

for them to implement appropriate actions. The information provided in the soil test report was often too technical to be useful for a large majority of the farmers who were illiterate or semi-literate.

The second set of unaddressed farmer needs related to the firm providing support that would cover not just Crop X but also other crops a farmer grew, a point that came through in our interviews with the farmers themselves (e.g., interviews [6] and [7] in Table 1) as well as with the firm's employees (e.g., interview [8]). This included the need for more comprehensive advice on agriculture-related matters, such as weather patterns, crop diseases and pests, and access to inputs like good-quality seeds, even for crops other than Crop X. Based on their positive experience with the existing program, the farmers hoped that the firm might also provide access to expert agricultural knowledge and tools beyond that which its field staff (specialized in Crop X alone) were equipped to provide.

We also asked farmers about their understanding of and attitude towards environmental issues. They generally had little awareness of global environmental debates like climate change, but were sensitive to directly relevant local environmental issues – such as soil health, water availability, weather unpredictability, and new kinds of pests and diseases. They seemed somewhat open to adopting climate-friendly practices, but only if doing so did not involve compromising their productivity and economic well-being (e.g., interview [9] in Table 1).

On the whole, our field interviews suggested that farmer adoption of climate-friendly practices would be easier if the firm strengthened the relationship by extending the original program to include not just information and training about climate-friendly practices but also more personalized and context-relevant agricultural services that created immediate economic value for the farmers.[6]

### 3.4. Proposed program extensions and formal hypotheses

Subsequent to our field interviews, we started exploring potential ways of extending the original sourcing program to reduce two kinds of GHG emissions from the farmers' agricultural activities–carbon dioxide ($CO_2$) and nitrous oxide ($N_2O$). The simplest way of achieving this was to design a

---

[6] Our pre-experiment survey also included some questions beyond those used in the formal analyses in the paper. The responses to these questions reinforce the findings from our pre-experiment interviews, such as the observation the farmers appreciated the field officer visits and general advisory but were keen to get more personalized advisory.

“base program” that involved extending the original sourcing program only in terms of adding information and training about relevant climate-friendly practices. This base program was intended to serve as the control condition for our subsequent field experiment design.

Prior research shows that resource-limited, knowledge-poor farmers often carry out sub-optimal agricultural practices (Cui et al. 2018, Ritchie 2024), including carrying out too much land tillage (Bhan and Behera, 2014, Erenstein et al. 2008, Rahman et al. 2021) and using too much inorganic fertilizer (Cole and Sharma 2017, Dar et al. 2023, Duflo et al. 2011, Islam and Beg 2021). These challenges are especially pronounced among smallholder farmers (Cui et al. 2018), and internal data from our partner firm confirmed this to be the case also among their supplier farmers. The base program would therefore involve the field officers providing farmers basic training in climate-friendly agricultural practices to address these. In line with scientific recommendations from agronomy (Haddaway et al. 2016, Han et al. 2016, Menegat et al. 2022, Pratibha et al. 2019), this would involve two levers: reducing tillage of land (i.e., the number of times the farmers turn the soil) and reducing inorganic fertilizer usage (i.e., cutting farmers’ use of inorganic fertilizers and partly substituting these with organic fertilizers). Table 2 provides further details on the scientific link between these firm-recommended practices and GHG emissions reduction.

[Insert Table 2 here]

Based on our field interviews, we expected that the farmers’ cooperation in adopting the firm-recommended climate-friendly agricultural practices would be enhanced if the firm also invested in relational strategies that took the farmer’s unmet needs and priorities into account. The next step was therefore to design two interventions (which we call “Intervention A” and “Intervention B”) that went beyond the base program to create more immediate and visible value for the farmers by also addressing some of these unmet needs. Our field interviews had revealed that one form of support the farmers were keen to get was personalized advisory for growing Crop X based on a timely and reliable soil-testing service. Other than the incremental cost of the soil test, adding this service to the program was not hard; the firm already had ties with external parties who could provide the test, and its field officers could personalize their support for a farmer based on the test results for the specific farmer. This therefore formed the basis of our Intervention A, which included everything in the base program and added the free soil-testing service and associated personalized advisory related to Crop X.

Our field interviews also suggested an unmet need for personalized agricultural advisory beyond Crop X. As per the firm's records, the average land a farmer allocated for Crop X cultivation was 1.54 hectares, with a large fraction of their overall average land holding of 4.74 hectares being used for growing other crops. Although the field officers were only qualified to support Crop X, the firm was open to leveraging the agronomist expertise available internally: it was feasible to provide limited personalized advisory beyond Crop X in the form of a visit by one of the firm's agronomists, who could provide customized guidance based on a farmer's conditions and priorities. This idea formed the basis of Intervention B, which included everything in Intervention A plus one visit per farmer by an expert agronomist. Intervention B thus involved investing beyond the Crop X value chain, in the hope that this could pay off additionally through greater reciprocity from the farmers.

To summarize, the base program extended the original sourcing program by adding training around climate-friendly practices. Intervention A further added *personalized crop-specific agricultural advisory services* in the form of a free soil-testing service and accompanying advisory for growing Crop X. Intervention B involved even greater personalization through *personalized crop-specific as well as broader agricultural advisory*, which included support beyond Crop X. Our expectation was that the personalized support in Intervention A or B would enhance the value derived by the supplier farmers and their reciprocity towards the firm, which in turn would improve their retention in the program as well as willingness to adopt the recommended climate-friendly practices. The above arguments underpin our two sets of formal hypotheses that we pre-registered.[7]

Our first set of hypotheses pertains to a business outcome ("retention") that captures the farmers' inclination to continue to participate in the firm's program in the future:

---

[7] Our pre-registration can be accessed at https://osf.io/uce82/?view_only=1ec229570692467ca76892470ab85084 (anonymized version). We report our pre-registered analyses and additional post hoc analyses in separate sections to have a "clear demarcation between preregistered and post hoc results" (Levine et al. 2023).

*Hypothesis 1a. When the firm provides inducement to its supplier farmers in the form of personalized crop-specific advisory (Intervention A), farmer* ***retention*** *in the program will be greater than when they do not receive this inducement (Base Program).*

*Hypothesis 2a. When the firm provides inducement to its supplier farmers in the form of personalized crop-specific as well as broader advisory (Intervention B), farmer* ***retention*** *in the program will be greater than when they do not receive this inducement (Base Program).*

*Hypothesis 3a. When the firm provides inducement to its supplier farmers in the form of personalized crop-specific as well as broader advisory (Intervention B), farmer* ***retention*** *in the program will be greater than when the inducement is only in the form of personalized crop-specific advisory (Intervention A).*

Our second set of hypotheses pertains to an environmental outcome ("adoption") that captures the farmers' adoption of the climate-friendly agricultural practices recommended by the firm:

*Hypothesis 1b. When the firm provides inducement to its supplier farmers in the form of personalized crop-specific advisory (Intervention A), farmer* ***adoption*** *of the climate-friendly practices will be greater than when they do not receive this inducement (Base Program).*

*Hypothesis 2b. When the firm provides inducement to its supplier farmers in the form of personalized crop-specific as well as broader advisory (Intervention B), farmer* ***adoption*** *of the climate-friendly practices will be greater than when they do not receive this inducement (Base Program).*

*Hypothesis 3b. When the firm provides inducement to its supplier farmers in the form of personalized crop-specific as well as broader advisory (Intervention B), farmer* ***adoption*** *of the climate-friendly practices will be greater than when the inducement is only in the form of personalized crop-specific advisory (Intervention A).*

## 4. FIELD EXPERIMENT DESIGN AND EXECUTION

### 4.1. Sample construction, randomization approach and data collection

Our sample consists of the 2,605 supplier farmers who signed up for the Crop X sourcing program for the 2022-2023 season. Following prior field experiments related to the adoption of agricultural practices among farmers in emerging economies (Barrett et al. 2018, Cole and Fernando 2021), we carried out randomization at the village level.[8] Given that each of the 362 villages our sample farmers lived in belongs to one of 16 centers (see Figure 1), we adopted a stratified randomization strategy wherein the villages within each center were divided roughly equally into three groups. As depicted in Figure 2, this led to 127 villages being assigned to the base program, 120 to Intervention A, and 115 to Intervention B. Figure 3a depicts the 16 centers on a map, and Figure 3b provides a detailed distribution of the 362 villages across the 16 centers and across our three experimental conditions.

[Insert Figures 2, 3a and 3b here]

Our field experiment was implemented from December 2022 to April 2023. We also had access to proprietary data on farmer characteristics, their activity records and their transactions with the firm. We merged these data with village-level socio-economic indicators (Asher et al. 2021) as well as two rounds of in-person survey data: baseline data collected pre-experiment (November-December 2022) and endline data collected post-experiment (July-August 2023). To ensure high response rate and mitigate concerns about desirability bias driving our results, our endline survey was administered one-on-one by a third party that made no reference to our interventions and framed it as a data collection exercise just to understand the farmers' experience in working with the firm.

## 4.2. Variable definition

To help test Hypotheses 1a, 2a and 3a, we define two business-related outcome variables that capture information related to the farmer's intended retention in the firm's program. The first is *Continuation*, a binary indicator of the farmer's intention to continue next year (coded as 1 if the farmer intended to stay in the program, and 0 otherwise). The second is *Land allocated*, the farmer's land allocation for Crop X for the following year's program (measured in hectares and set to 0 if the farmer did not

---

[8] It seemed impractical to carry out different interventions for farmers in the same village. Even if this were doable, there was a significant risk of spillovers as farmers in a village generally knew each other and were often in touch.

intend to continue). Unlike *Continuation*, which is only measured post-experiment, *Land allocated* is also measured for the current year.

To help test Hypotheses 1b, 2b and 3b, we define two environment-related outcome variables that capture a farmer's adoption of the climate-friendly practices the firm recommends (see Table 2). The first is *Tillage,* which measures the extent of soil turning practiced by the farmer (a count variable). The second is *Inorganic fertilizer*, which measures the intensity of inorganic fertilizer by taking the average of the two kinds of inorganic fertilizers –DAP and urea– that the farmers in this setting used per unit of land (in kilograms per hectare).[9] Both *Tillage* and *Inorganic fertilizer* were measured pre-experiment as well as post-experiment using in-person farmer surveys.

Given the random assignment, it is not critical for us to consider control variables. Nevertheless, to improve estimation efficiency we employ village-level and farmer-level controls in our regression analysis. Table 3a details our village-level controls: *Total population, Village area, Literacy rate*, *Rural poverty rate*, *Agriculture main income*, *Daily hours power* and *Night light*. Table 3b does the same for our farmer-level controls: *Age, Household size, No formal education*, *Only primary education*, *Land area*, *Land ownership* and *Agriculture primary source of income*.

### 4.3. Summary statistics and balance check

As Table 3a shows, the average village in our sample has 3,064 people, 844 hectares of land, a literacy rate of 63%, a poverty rate of 18%, agriculture as the main source of income 44% of residents rely on, and access to electricity not all day but about 18 hours per day. The summary statistics provided in Table 3b yield further insight into the farmer population: average farmer age is 42, 19% have primary education or less, they work on 4.74 hectares of land on average, 84% own the land, and 88% rely on agriculture as their primary source of income. Their average household size is seven people.

[Insert Tables 3a and 3b here]

As our unit of randomization is the village, the balance check is also required at the village level. Comparing averages of the village-level characteristics for the experimental groups (Table 3a)

---

[9] Table 4c provides more fine-grained and nuanced analysis regarding usage of the different inorganic fertilizers. As the notes accompanying Table 4c explain in detail, our main insights remain unchanged.

suggests that the samples are quite balanced. As a more formal statistical test we also carried out pairwise t-tests for each of the variables for Intervention A and B relative to the base program. The equality of means could not be rejected in any of the cases at conventional levels (p=0.05), indicating once more that our sample was well balanced and that our randomization had worked as expected.

## 5. ANALYSIS OF THE PRIMARY OUTCOMES

### 5.1 Univariate analysis

As the simplest way of testing our pre-registered hypotheses, we start with a comparison of the post-experiment means for our four primary outcomes - *Continuation*, *Land allocated*, *Tillage* and *Inorganic fertilizer* - across our experimental groups. We then carry out a difference-in-differences calculation for the last three of these outcomes, as pre-experiment values are also defined for these.

As panel (i) in Figure 4a shows, the post-experiment mean for *Continuation* is not meaningfully different from zero for Intervention A (p=0.68), while that for Intervention B is 6.87 percent points greater than for the base program (8.17% increase; p=0.00). As panel (ii) similarly shows, the post-experiment mean for *Land allocated* for Treatment A is again not meaningfully different from that for the base program (p=0.98), while that for Intervention B is 0.57 hectares greater than that for the base program (38.78% increase; p=0.00). For both *Continuation* and *Land Allocated*, direct comparisons confirm that Intervention B has stronger impact than Intervention A (p=0.00).

[Insert Figure 4a here]

Turning to the environmental outcomes, as panel (i) in Figure 4b shows, the post-experiment mean for *Tillage* for Treatment A is statistically indistinguishable from that for the base program (p=0.28), while that for Intervention B is 0.36 less than for the base program (8.16% decrease; p=0.00). Panel (ii) shows that the post-experiment mean for *Inorganic fertilizer* for Treatment A is 4.16 kgs/hectare less than that for the base program (3.20% decrease; p=0.00), while that of Intervention B is 8.77 kgs/hectare less than that for the base program (6.75% decrease; p=0.00). For both *Tillage* and *Inorganic fertilizer,* direct comparisons further confirm that Intervention B has a stronger impact than Intervention A (p=0.00).

[Insert Figure 4b here]

As an alternative way of testing our hypotheses, Table 4a provides difference-in-differences (DID) calculations where feasible. The DID statistic for *Land allocated* for Intervention A is indistinguishable from zero (p=0.77), while that for Intervention B is 0.46 hectares (30.67% increase over the base program pre-experiment; p=0.00). The DID statistic for *Tillage* is -0.09 (2.02% decrease; p=0.00) for Intervention A, and -0.39 (8.76% decrease; p=0.00) for Intervention B. Finally, the DID statistic for *Inorganic fertilizer* is -3.67 kgs/hectare (2.73% decrease; p=0.00) for Intervention A, and -7.97 kgs/hectare (5.94% decrease; p=0.00) for Intervention B.

[Insert Table 4a here]

To summarize, for Intervention B there is an unambiguous treatment effect for all four primary outcomes. In contrast, for Intervention A we find some (but weaker) treatment effect for the environmental outcomes but no treatment effect for the business outcomes. Direct comparisons confirm that Intervention B has a greater impact than Intervention A for all four outcomes. For the business outcomes we therefore have strong support for Hypothesis 2a and 3a, but not for Hypothesis 1a. For the environmental outcomes, we have strong support for Hypothesis 2b and 3b, but mixed support for Hypothesis 1b. We now turn to multivariate regressions to further validate these findings.

### 5.2. Multivariate regression analysis

Although our randomization was carried out at the level of the village, we carry out our regression analysis at the level of the farmer to fully use all available data (Angrist and Pischke 2009). In doing so, we employ village-level clustering to calculate standard errors in line with the established econometric practice of clustering the standard errors at the level at which the randomized treatment takes place (Abadie et al. 2023, Bertrand et al. 2004, Cameron and Miller 2015, Roth et al. 2023).

We use two linear models to evaluate the business as well as environmental impacts of our interventions. The first is a cross-sectional specification comparing only the post-experiment levels of a given outcome across conditions, an econometrically valid approach given our randomized design (Glennerster and Takavarasha 2013, Mian and Sufi 2014).[10] The estimation equation is thus:

$$Y_{v,i} = \alpha + \beta_A A_v + \beta_B B_v + \gamma X_{v,i} + \delta W_v + \tau_{center(v)} + \varepsilon_{v,i} \qquad \text{(I)}$$

where $v$ indexes the village, $i$ indexes the farmer within the village, $Y$ represents any of our four outcome variables, $A$ and $B$ are indicators for Intervention A and Intervention B (zero for the base program, the control group), $X$ represents farmer-level controls (as in Table 3b), $W$ represents village-level controls (as in Table 3a), $\tau$ captures center fixed effects (corresponding to the center the village $v$ belongs to) and $\varepsilon$ is the error term. The two treatment effects of interest are $\beta_A$ and $\beta_B$.

Our second model also includes pre-experiment information to employ a DID approach. Given that we have only two time periods (pre and post), this can be implemented as a cross-sectional model where the dependent variable is the *change in outcome* between the pre-experiment and post-experiment periods (Angrist and Pischke 2009, Card 1992).[11] Our second estimation equation is thus:

$$\Delta Y_{v,i} = \alpha + \beta_A A_v + \beta_B B_v + \gamma X_{v,i} + \delta W_v + \tau_{center(v)} + \varepsilon_{v,i} \qquad \text{(II)}$$

where $\Delta Y$ represents the difference between post-experiment and pre-experiment values for a given outcome variable. The coefficients $\beta_A$ and $\beta_B$ are now to be interpreted as DID estimates.

Recall that one of our four outcome variables, *Continuation*, is not defined pre-experiment. Table 4b therefore reports regression estimates for all of our primary outcomes using equation (I) but only the remaining three using equation (II). For brevity in the text, we discuss in detail here the findings and interpretation for only the preferred model for each of the outcomes, which is equation (I) for *Continuation* and equation (II) for *Land Allocated*, *Tillage*, and *Inorganic Fertilizer*. As Table 4b shows, the main insights are unchanged even if we use equation (I) for the last three outcomes.

In column (1), which uses estimation equation (I) for *Continuation* (our first business outcome), the estimated treatment effect for Intervention A is statistically indistinguishable from zero (p=0.68). The corresponding coefficient for Intervention B is 0.068 (p=0.01), implying that 6.84%

---

[10] A recent application of this estimation approach in the management literature is Dimitriades and Koning (2022).

[11] See Boulogne et al. (2023) and Flammer and Ioannou (2021) for recent applications of this approach.

more farmers were interested to continue next season after Intervention B relative to those after the base program. A statistical comparison between the coefficient estimates for Interventions A and Intervention B rejects their equality (p=0.00).

In column (4), which uses estimation equation (II) for *Land allocated* (our second business outcome), the estimated treatment effect for Intervention A is statistically indistinguishable from zero (p=0.45). The corresponding estimate for Intervention B is 0.484 hectares (p=0.00), implying that the farmers in Intervention B planned to allocate 0.484 hectares more land to grow Crop X for the firm next season relative to those in the base program. A statistical comparison between the coefficient estimates for Intervention A and Intervention B once more rejects their equality (p=0.00).

In column (6), which uses estimation equation (II) for *Tillage* (our first environmental outcome), the estimated treatment effect for Intervention A is -0.108 (p=0.01), while that for Intervention B is -0.403 (p=0.00). This implies that the farmers in Intervention A reduced their tillage count by 0.108 and those in Intervention B reduced their tillage count by 0.403, both relative to those in the base program. A statistical comparison between the coefficient estimates of Intervention A and Intervention B again rejects their equality (p=0.00).

Finally, in column (8), which uses estimation equation (II) for *Inorganic fertilizer* (our second environmental outcome), the estimated treatment effect for Intervention A is -2.794 kgs/hectare (p=0.01), while that for Intervention B is -8.158 kgs/hectare (p=0.00). This implies that farmers in Intervention A reduced inorganic fertilizer usage by 2.794 kgs/hectare, and those in Intervention B by 8.158 kgs/hectare relative to farmers in the base program.[12] A statistical comparison between the coefficient estimates for Intervention A and Intervention B once more rejects their equality (p=0.00).

[Insert Table 4b here]

Overall, the findings from our multivariate regression are very similar to those from our univariate analysis, except that Hypothesis 1b now also has unambiguous support. In line with our

---

[12] Table 4c reports further analysis related to how the overall reduction in inorganic fertilizer use arises through a combination of a more efficient use of both kinds of inorganic fertilizers (DAP and urea) based on the specific soil needs for each farmer and a partial substitution of some inorganic fertilizer use by organic fertilizers that are also better for long-term soil health (as explained in Table 2).

expectations, the null hypothesis is rejected (in the respective preferred models) for Hypotheses 2a, 3a, 1b, 2b and 3b, but cannot be rejected (in any of the models) for Hypothesis 1a. In other words, for Intervention A we find a treatment effect in line with our hypotheses only for (both of) our environmental outcomes, but not for (either of) our business outcomes. In contrast, for Intervention B we observe a strong treatment effect for (both) business outcomes as well as (both) environmental outcomes, and all of these estimated effects are greater for Intervention B than for Intervention A.

### 5.3. Indicative cost-benefit analysis

We now extend our analysis of relative impacts across interventions to also compare their cost effectiveness through an indicative cost-benefit analysis. Although we build upon the best practices in doing such analyses and on the scientific recommendations from the relevant literature, we are still cautious in calling our analysis "indicative" because we cannot rule out a possibility that a more in-depth and comprehensive cost-benefit analysis could lead to a revision of some of our estimates.

On the cost side, as reported in Table 5a, the firm's main incremental cost for Intervention A relative to the base program is the 700 INR (USD 8.43) it pays for the soil testing service per farmer.[13] Since the personalized support based on the soil test results is provided through the field officer visits that would occur anyway, there is no incremental cost associated with this additional support. However, in Intervention B, the firm does incur the additional cost of expert agronomist visits (conducted only in Intervention B), amounting to a further cost per farmer of 600 INR (USD 7.23) and hence a total incremental cost per farmer of 1,300 INR (USD 15.67).[14]

In terms of environmental benefits, emissions reductions in both Intervention A and Intervention B arise from reduced use of inorganic fertilizers (DAP and urea) and reduced diesel use due to reduced tillage. As per the calculations presented in Table 5a, the treatment effects reported in Tables 4b and 4c imply that for Intervention A the incremental emission reduction is 17.78 $CO_2$-

---

[13] "INR" is a short form for "Indian Rupees". Whenever useful for interpretation, we also provide the corresponding US Dollar ("USD") figures based on the December 2023 exchange rate of approximately 83 INR/USD.

[14] Agronomists have multiple duties and often also travel to the field for reasons unrelated to our interventions. The cost calculation for their cost is therefore sensitive to how the costs are allocated, which in turn varies with the opportunity cost of time and travel plans for a given agronomist. Our calculations should therefore be taken as approximate.

equivalent kgs for the average farmer, which represents a reduction of 2.11 kgs per incremental dollar spent on Intervention A (over and above the activities also in the base program). For Intervention B, the corresponding estimate is 60.17 $CO_2$-equivalent kgs for the average farmer, i.e., a reduction of 3.84 $CO_2$-equivalent kgs per incremental dollar spent on Intervention B. Putting together these calculations for the emissions reduction realized per farmer and the previous numbers for the cost per farmer, Intervention A costs about USD 474 per ton of $CO_2$-equivalent emissions (henceforth referred to as $tCO_2$) reduced, while Intervention B costs about USD 260 per $tCO_2$ reduced. [15]

[Insert Table 5a here]

It is worth noting that the estimated cost of USD 260 per $tCO_2$ emissions reduction using Intervention B is within the range of social cost of carbon suggested in many scientific studies (though the cost figures currently in use by policy makers generally lag behind scientific recommendations). For example, Rennert et al. (2022) suggest a preferred estimate of USD 185 per $tCO_2$, with a 5% to 95% range of USD 44 to USD 413 per $tCO_2$ (depending in part on the discount rate used). Importantly, emissions reductions achieved within a firm's value chain are considered more credible and count towards SBTi-backed science-based "net zero" targets, unlike the case of the firm simply choosing to buy cheaper voluntary carbon offsets externally (Science Based Targets Initiative 2023).

Recall that, as per our intervention design, the cooperation of supplier farmers for achieving emissions reduction under Intervention A and Intervention B was expected to come from benefits farmers receive from the program. While we do not measure the full benefits farmers perceive directly (though we discuss indirect ways of verifying such benefits in the next section), our regression estimates do allow us to compute a part of these benefits accruing to the farmers specifically as incremental cost savings generated by Intervention A or Intervention B. These cost savings are the result of reduced usage of inorganic fertilizers (DAP and urea) and reduced diesel usage due to less land tillage. As detailed calculations in Table 5b show, these incremental savings add up to 403 INR

---

[15] We have not included emissions from the increased use of organic fertilizer because the organic waste from livestock in our context would have been produced as a by-product of farmer's existing activities and lead to emissions anyway. In fact, partial substitution of inorganic fertilizer by organic fertilizer where sufficient organic waste is already available for recycling is a recommended way of mitigating net emissions (Menegat et al. 2022, Iqbal et al. 2020).

(USD 4.85) per farmer for Intervention A, and to 1,354 INR (USD 16.31) per farmer for Intervention B (relative to the base program). These figures do not include the further cost saving of 700 INR (USD 8.43) for any farmer who would have otherwise procured the soil testing service privately if it were not being provided for free by the firm under Intervention A or Intervention B.

[Insert Table 5b here]

To summarize, both Intervention A and Intervention B lead to reduced emissions relative to the base program, with Intervention B being more cost-effective than Intervention A in terms of the emissions reduction per incremental dollar invested. Both interventions also lead to significant social impact in terms of the cost savings realized by the farmer, with Intervention B also being superior in terms of the cost savings per farmer. [16] Finally, the overall "business case" for choosing Intervention B over Intervention A appears to be further strengthened by bringing into consideration our previous finding that Intervention B is also better than Intervention A for farmer retention.

## 6. FURTHER ANALYSIS OF UNDERLYING MECHANISMS

To generate further insight into the above findings, we carry out two additional investigations. The first involves post-experiment field interviews to understand the farmers' direct experience. The second analyzes additional outcomes to shed further light on the impacts and underlying mechanisms.

### 6.1. Insights from post-experiment field interviews

In order to better understand how our interventions were perceived by the farmers, we conducted 40 semi-structured interviews with the participating farmers after the experiment. Each interview lasted about 30-45 minutes, and Table 6 provides illustrative quotes from some of these interviews.

[Insert Table 6 here]

Several farmers confirmed that the interventions had led them to reduce the use of inorganic fertilizer, and in the process helped them reduce costs (e.g., interviews [1] and [2] in Table 6). Some

---

[16] There can be several other aspects of the social impact achieved per farmer besides the cost savings quantified here. These include the value of the time savings from reduced tillage (Intervention A and B), the productivity benefits from the soil test and the personalized advisory accompanying it (Intervention A and B), and the productivity benefits from the additional personalized agronomist advice (Intervention B). In addition, optimizing fertilizer use also helps improve the soil organic carbon content and enhances soil fertility (O'Brien and Hatfield 2019, Han et al. 2016, Liu et al. 2020).

also noted that the nature of support provided in the interventions had improved their knowledge of soil nutrients (e.g., interview [2], [6] and [7] in Table 6), and helped them practice appropriate tillage and optimum fertilizer usage. Some farmers, especially those in Intervention B, also noted a resulting improvement in their knowledge of climate-friendly as well as general practices, including detailed understanding of soil nutrient management, the implication of these practices for the long-term health of the soil, and appropriate methods for application of different kinds of fertilizers that influenced their adoption of climate-friendly practices (e.g., interviews [6] and [7] in Table 6).

Many interviewees specifically mentioned their relationship with the firm as being valuable and sometimes even the reason to be more open to adopting the recommended climate-friendly practices (e.g., interviews [3], [4] and [6] in Table 6). Such perceptions of relational engagement came through particularly strongly in several interviews with farmers in Intervention B: farmers expressed the increased trust in the firm due to the firm’s efforts and investments to build a long-term relationship as well as the firm’s willingness to even look beyond its immediate value chain and help farmers on broader matters relevant to their well-being (e.g., interviews [5], [7] and [8] in Table 6).

To summarize, our interviews suggest that the farmers’ increased intention to continue in the program as well as to adopt climate-friendly practices were indeed likely driven by a combination of the greater value derived from the firm’s support and the sense of reciprocity triggered by the firm investing in them. Overall, the firm’s investments in relational strategies by providing personalized support seemed to have led to stronger engagement from the farmers, an effect that came through more strongly for Intervention B than for Intervention A even during our field interviews.

### 6.2. Analysis of additional outcome variables

We now statistically examine a range of additional outcomes (not pre-registered) to dig further into the possible mechanisms underlying the findings for our primary outcomes. Table 7 presents a comparison across our experimental groups for these outcomes, which capture different aspects of the farmers’ relational engagement and perceptions of value derived from the program.

[Insert Table 7 here]

The analyses reported in columns (1) through (4) of Table 7 employ additional outcome variables, all derived from more endline survey questions based on a seven-point Likert scale. As per column (1), the treatment effect for *Willingness to adopt recommended practices* (relative to the base program) is 0.396 for Intervention A (p=0.00) and 1.897 for Intervention B (p=0.00). As per column (2), the treatment effect for *Perception of firm investment in relationship* is 0.740 for Intervention A (p=0.00) and 1.985 for Intervention B (p=0.00). As per column (3), the treatment effect for a farmer's *Satisfaction with the program* is 0.717 for Intervention A (p=0.00) and 2.168 for Intervention B (p=0.00). Finally, as per column (4), the treatment effect for the variable *Would recommend program to others* is 0.628 for Intervention A (p=0.00) and 1.726 for Intervention B (p=0.00).

Column (5) of Table 7 reports findings for *Reasonable hypothetical annual fees,* measured using an endline survey question that asked farmers to select from one of five possible monetary amounts that they would consider reasonable in a *hypothetical* scenario where the firm were charging the farmers a small annual fees for membership in the firm's program (the five choices being 50 INR, 100 INR, 150 INR, 200 INR and 250 INR per annum). The survey question made clear that the firm had no intention to introduce any such fees in reality, and that the intention behind the question was simply to shed further light on how useful the farmers found the program. The estimated treatment effect is 34 INR/annum (p=0.00) for Intervention A and 87 INR/annum (p=0.00) for Intervention B. This finding is consistent with our results so far that the farmers found the interventions useful, and that they saw Intervention B as delivering significantly more value for them than Intervention A did.

Extending beyond our endline survey data, column (6) of Table 7 presents analysis for the outcome *Sold Crop X to other buyers* derived from data that the firm directly collects at the procurement centers. This is an indicator for whether a given farmer sold Crop X also to other buyers or exclusively to the firm, providing us with an independent measure of their relational engagement with the firm. Our regression estimates indicate that, relative to the base program, the fraction of farmers who sold to other buyers is practically indistinguishable in Intervention A (p=0.61). In contrast, the fraction of farmers selling to other buyers did drop by four percent points for Intervention

B (p=0.08). In terms of economic magnitude, this four percent points drop represents a 35% decrease relative to the same fraction for the base program, where 11.6% of the farmers sold to other sellers.

To summarize, the analyses for all our additional outcome variables as reported in Table 7 are consistent with a view that the supplier farmers demonstrated greater relational engagement with the firm and saw greater value in the relationship in Intervention A and Intervention B relative to the base program, with these effects being consistently larger for Intervention B than for Intervention A.

## 7. SUMMARY, LIMITATIONS AND DISCUSSION

Pursuing value chain decarbonization requires the cooperation of diverse stakeholders, and achieving this through purely contractual means is often impractical. One solution is to make relational investments to boost the partners' willingness to participate. To test the effectiveness of this approach, we designed a field experiment involving a firm procuring a crop from supplier farmers in India. Our base program provided basic training in climate-friendly agricultural practices, while two other interventions also added personalized agricultural support - one only within the firm's value chain (Intervention A) and the other also beyond it (Intervention B) - as a way to strengthen the firm's relationship with the farmers. Both interventions lead to reduced emissions relative to the base program, with Intervention B being more impactful in terms of reducing not only absolute emissions but also emissions per dollar invested. Both interventions also lead to significant cost savings being realized by the farmer, with Intervention B providing more cost savings for the farmer than Intervention A did. Intervention B also improved farmer's likely retention in the firm's program.

Relying on a field experiment in the context of a real decarbonization initiative makes our study both rigorous and relevant. However, caution needs to be exercised in interpreting the findings, especially regarding generalizability beyond the specific setting. For example, although we find that our Intervention B that involved greater investment to meet the supplier farmers' needs even beyond the firm's value chain had greater environmental impact per dollar than our Intervention A that involved a lower investment and just within the value chain, this should not be interpreted as general "more is always better" result. There is likely a threshold beyond which further investment is not as cost effective per dollar. We can also not rule out the possibility that an entirely different kind of investment we did not investigate might have yielded even better environmental impact per dollar.

We should also note three additional limitations of our study, which can provide ideas for follow-up research. First, in line with prior field experiments involving similar contexts (e.g., in development economics), we had to rely in part on survey-based data collection. While biases due to the resulting measurement errors are likely reduced by our randomized design, such self-reported survey data have limitations. Second, while we would have liked to measure the various impacts also in the longer term (e.g., actual farmer retention rather than their stated intention to stay), further data collection for our farmer sample was made infeasible by certain changes in how the program was to be implemented in the following year. Third, given the scope of our research question and study design, we have only considered impact on supplier farmers already in the firm's sourcing program; an interesting extension could be to examine spillovers to other farmers not in the original program.

Despite the above limitations, we hope our work inspires further research related to decarbonization in the context of emerging economies, where issues pertaining to social and environmental impact are often intertwined. While a majority of past GHG emissions have come from the more developed economies, growth in emissions is coming largely from emerging economies – with China and India already comprising 21% of the global GHG emissions as of 2022 (Ritchie et al. 2023). Our research provides an in-depth illustration of why mitigating emerging economy emissions often requires an understanding of and sensitivity to their contextual uniqueness.

More broadly, our study can be seen as an empirical contribution to the literature on the "new stakeholder theory" that "relies primarily on economic and legal arguments that stakeholders will sustain their connection to an organization only if they expect and ultimately receive appropriate returns on their contributions" (McGahan 2021, p. 1735). In line with the calls in this literature, we have focused on stakeholder prominence in the firm's value creation and distribution processes (Barney 2018, Garcia-Castro and Aguilera 2015, Jones et al. 2018), and on socially important dependent variables beyond financial performance (McGahan 2023). Firm-driven efforts can play a pivotal role in addressing collective action problems, sometimes driving effective action even when government policy or public institutions do not (Gatignon and Capron 2023, Luo and Kaul 2019). We hope our study motivates further work on decentralized experimentation and efforts by firms with a genuine aspiration – as well as relevant expertise – to contribute to solving major societal issues.

## REFERENCES

Abadie, A., Athey, S., Imbens, G. W., & Wooldridge, J. M. (2023). When should you adjust standard errors for clustering? *The Quarterly Journal of Economics*, 138(1), 1-35.

Abdul Latif Jameel Poverty Action Lab (J-PAL). 2023. Improving agricultural information and extension services to increase small-scale farmer productivity. *J-PAL Policy Insights*.

Adewoyin, A. O., & Ajav, E. A. (2013). Fuel consumption of some tractor models for ploughing operations. *Agricultural Engineering International: CIGR Journal*, 15(3), 67-74.

Aghion, P., Bénabou, R., Martin, R., & Roulet, A. (2023). Environmental preferences and technological choices: Is market competition clean or dirty? *American Economic Review*: *Insights*, 5(1), 1-19.

Akbarnia, A., & Farhani, F. (2014). Study of fuel consumption in three tillage methods. *Research in Agricultural Engineering*, 60(4), 142-147.

Alberini, A., & Austin, D. (2002). Accidents waiting to happen: Liability policy and toxic pollution releases. *Review of Economics and Statistics*, 84(4), 729–741.

Angrist, J. D., & Pischke, J. S. (2009). Mostly Harmless Econometrics: An Empiricist's Companion. *Princeton University Press*.

Asher, S., Lunt, T., Matsuura, R., & Novosad, P. (2021). Development research at high geographic resolution. *The World Bank Economic Review*, 35(4), 845-871.

Barney, J. B., Edwards, F. L., & Ringleb, A. H. (1992). Organizational responses to legal liability: Employee exposure to hazardous materials, vertical integration, and small firm production. *Academy of Management Journal*, 35(2), 328–349.

Barney, J. B. (2018). Why resource-based theory’s model of profit appropriation must incorporate a stakeholder perspective. *Strategic Management Journal*, 39(13), 3305-3325.

Barrett, C. B., Islam, A., Mohammad Malek, A., Pakrashi, D., & Ruthbah, U. (2022). Experimental evidence on adoption and impact of the system of rice intensification. *American Journal of Agricultural Economics*, 104(1), 4-32.

Becker, R., & Henderson, V. (2000). Effects of air quality regulations on polluting industries. *Journal of Political Economy*, 108(2), 379–421.

Berry, H., Kaul, A., & Lee, N. (2021). Follow the smoke: The pollution haven effect on global sourcing. *Strategic Management Journal*, 42(13), 2420–2450.

Bertini, M., Buehler, S., Halbheer, D., & Lehmann, D. R. (2022). Carbon Footprinting and Pricing Under Climate Concerns. *Journal of Marketing*, 86(2), 186-201.

Bertrand, M., Duflo, E., & Mullainathan, S. (2004). How much should we trust differences-in-differences estimates? *The Quarterly Journal of Economics*, 119(1), 249-275.

Bhan, S., & Behera, U. K. (2014). Conservation agriculture in India–Problems, prospects and policy issues. *International Soil and Water Conservation Research*, 2(4), 1-12.

Birner, R., & Anderson, J. R. (2007). How to make agricultural extension demand driven? The case of India's agricultural extension policy (Vol. 729). *International Food Policy Research Institute.*

Bjørn, A., Tilsted, J. P., Addas, A., & Lloyd, S. M. (2022). Can science-based targets make the private sector Paris-aligned? A review of the emerging evidence. *Current Climate Change Reports*, 8(2), 53-69.

Blader, S., Gartenberg, C. M., Henderson, R., & Prat, A. (2015). The real effects of relational contracts. *American Economic Review*, 105 (5), 452-456.

Blanco, C., Caro, F., & Corbett, C. J. (2016). The state of supply chain carbon footprinting: analysis of CDP disclosures by US firms. *Journal of Cleaner Production*, 135, 1189-1197.

Bode, C., & Singh, J. (2018). Taking a hit to save the world? Employee participation in a corporate social initiative. *Strategic Management Journal*, 39(4), 1003-1030.

Boulongne, R., Durand, R., & Flammer, C. (2023). Impact Investing in Disadvantaged Urban Areas. *Strategic Management Journal*, 45(2), 238-271.

Bridoux, F., & Stoelhorst, J. W. (2016). Stakeholder relationships and social welfare: A behavioral theory of contributions to joint value creation. *Academy of Management Review*, 41(2), 229-251.

Burbano, V. C. (2016). Social responsibility messages and worker wage requirements: Field experimental evidence from online labor marketplaces. *Organization Science*, 27(4), 1010-1028.

Burbano, V. C., Delmas, M. A., & Cobo, M. J. (2023). The Past and Future of Corporate Sustainability Research. *Organization & Environment*.

Cameron, A. C., & Miller, D. L. (2015). A practitioner's guide to cluster-robust inference. *Journal of Human Resources*, 50(2), 317-372.

Card, D. (1992). Using regional variation in wages to measure the effects of the federal minimum wage. *ILR Review*, 46(1), 22-37.

Cenci, S., Burato, M., Rei, M., & Zollo, M. (2023). The alignment of companies' sustainability behavior and emissions with global climate targets. *Nature Communications*, 14(1), 7831.

Chatterji, A. K., Findley, M., Jensen, N. M., Meier, S., & Nielson, D. (2016). Field experiments in strategy research. *Strategic Management Journal*, 37(1), 116-132.

Cheng, B., Ioannou, I., & Serafeim, G. (2014). Corporate social responsibility and access to finance. *Strategic Management Journal*, 35(1), 1-23.

Cole, S. A., & Fernando, A. N. (2021). 'Mobile'izing agricultural advice technology adoption, diffusion and sustainability. *The Economic Journal*, 131(633), 192-219.

Cole, S., & Sharma, G. (2017). The promise and challenges of implementing ICT in Indian agriculture. *India Policy Forum* (pp. 11-12).

Cui, Z., Zhang, H., Chen, X., Zhang, C., Ma, W., Huang, C., ... & Dou, Z. (2018). Pursuing sustainable productivity with millions of smallholder farmers. *Nature*, 555(7696), 363-366.

Dar, M., De Janvry, A., Emerick, K., Sadoulet, E., & Wiseman, E. (Forthcoming). Private input suppliers as information agents for technology adoption in agriculture. *American Economic Journal: Applied Economics*

Dietz, S., Fruitiere, C., Garcia-Manas, C., Irwin, W., Rauis, B., & Sullivan, R. (2018). An assessment of climate action by high-carbon global corporations. *Nature Climate Change*, 8(12), 1072-1075.

Dimitriadis, S., & Koning, R. (2022). Social skills improve business performance: Evidence from a randomized control trial with entrepreneurs in Togo. *Management Science*, 68(12), 8635-8657.

Dorobantu, S., Kaul, A., & Zelner, B. (2017). Nonmarket strategy research through the lens of new institutional economics. *Strategic Management Journal*, 38(1), 114-140.

Dorobantu, S., & Odziemkowska, K. (2017). Valuing stakeholder governance: Property rights, community mobilization, and firm value. *Strategic Management Journal*, 38(13), 2682-2703.

Duflo, E., Kremer, M., & Robinson, J. (2011). Nudging farmers to use fertilizer: Theory and experimental evidence from Kenya. *American Economic Review*, 101(6), 2350-2390.

Durand, R., & Huysentruyt, M. (2022). Communication Frames and Beneficiary Engagement in Corporate Social Initiatives: Evidence from a Randomized Controlled Trial in France. *Strategic Management Journal* 43(9): 1823-1853.

Elfenbein, D. W., & Zenger, T. R. (2014). What is a relationship worth? Repeated exchange and the development and deployment of relational capital. *Organization Science*, 25(1), 222-244.

Erenstein, O., Sayre, K., Wall, P., Dixon, J., & Hellin, J. (2008). Adapting no-tillage agriculture to the conditions of smallholder farmers in the tropics and sub-tropics. *No-till Farming Systems*, 253-278

Fankhauser, S., Smith, S. M., Allen, M., Axelsson, K., Hale, T., Hepburn, C., ... & Wetzer, T. (2022). The meaning of net zero and how to get it right. *Nature Climate Change*, 12(1), 15-21.

Fehr, E., & Gächter, S. (2000). Fairness and retaliation: The economics of reciprocity. *Journal of Economic Perspectives*, 14(3), 159–181.

Flammer, C., & Ioannou, I. (2021). Strategic management during the financial crisis: How firms adjust their strategic investments in response to credit market disruptions. *Strategic Management Journal*, 42(7), 1275-1298.

Flammer, C., Toffel, M. W., & Viswanathan, K. (2021). Shareholder activism and firms' voluntary disclosure of climate change risks. *Strategic Management Journal*, 42(10), 1850-1879.

Garcia-Castro, R., & Aguilera, R. V. (2015). Incremental value creation and appropriation in a world with multiple stakeholders. *Strategic Management Journal*, 36(1), 137-147.

Gatignon, A., & Capron, L. (2023). The firm as an architect of polycentric governance: Building open institutional infrastructure in emerging markets. *Strategic Management Journal*, 44(1), 48-85.

George, G., Howard-Grenville, J., Joshi, A., & Tihanyi, L. (2016). Understanding and tackling societal grand challenges through management research. *Academy of Management Journal*, 59(6), 1880-1895.

Gibbons, R., & Henderson, R. (2012). Relational contracts and organizational capabilities. *Organization Science*, 23(5), 1350-1364.

Glendenning, C. J., Babu, S., & Asenso-Okyere, K. (2010). Review of agricultural extension in India: Are farmers' information needs being met? (No. 1048). *International Food Policy Research Institute (IFPRI).*

Glennerster, R., & Jayachandran, S. (2023). Think globally, act globally: opportunities to mitigate greenhouse gas emissions in low-and middle-income countries. *Journal of Economic Perspectives*, 37(3), 111-135.

Glennerster, R., & Takavarasha, K. (2013). Running Randomized Evaluations: A Practical Guide. *Princeton University Press.*

Haddaway, N.R., Hedlund, K., Jackson, L.E. et al. How does tillage intensity affect soil organic carbon? A systematic review. Environmental Evidence 6, 30 (2017).

Han, P., Zhang, W., Wang, G., Sun, W., & Huang, Y. (2016). Changes in soil organic carbon in croplands subjected to fertilizer management: a global meta-analysis. *Scientific Reports*, 6(1), 27199.

Hardy, J., & Sandys, L. (2022). Anticipating customer-centred zero-carbon energy business models. *Nature Energy*, 7(5), 383-385.

Henisz, W. J. (2023). The value of organizational purpose. *Strategy Science*, 8(2), 159-169.

Henisz, W. J., Dorobantu, S., & Nartey, L. J. (2014). Spinning gold: The financial returns to stakeholder engagement. *Strategic Management Journal*, 35(12), 1727-1748.

Hoskisson, R. E., Eden, L., Lau, C. M., & Wright, M. (2000). Strategy in emerging economies. *Academy of Management Journal*, 43(3), 249-267.

Howard-Grenville, J., Buckle, S. J., Hoskins, B. J., & George, G. (2014). Climate change and management. *Academy of Management Journal*, 57(3), 615-623.

Hsu, A., & Rauber, R. (2021). Diverse climate actors show limited coordination in a large-scale text analysis of strategy documents. *Communications Earth & Environment*, 2(1), 1-12.

Intergovernmental Panel on Climate Change (2022). Summary for Policymakers. *Cambridge University Press*, Cambridge, UK and New York, NY, USA, 3-33.

IPCC (2019). Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, vol.4, Chapter 11. *(IPCC, 2019).*

Islam, M., & Beg, S. (2021). Rule-of-thumb instructions to improve fertilizer management: Experimental evidence from Bangladesh. *Economic Development and Cultural Change*, 70(1), 237-281.

Iqbal, A., He, L., Ali, I., Ullah, S., Khan, A., Khan, A., ... & Jiang, L. (2020). Manure combined with chemical fertilizer increases rice productivity by improving soil health, post-anthesis biomass yield, and nitrogen metabolism. *Plos one*, 15(10), e0238934.

Jack, B. (2013). Market inefficiencies and the adoption of agricultural technologies in developing countries. *UC Berkeley: Center for Effective Global Action*.

Jack, B. K., & Jayachandran, S. (2019). Self-selection into payments for ecosystem services programs. *Proceedings of the National Academy of Sciences*, 116(12), 5326-5333.

Jack, B. K., Jayachandran, S., Kala, N., & Pande, R. (2022). Money (Not) to Burn: Payments for Ecosystem Services to Reduce Crop Residue Burning. *NBER Working Paper* 30690.

Jayachandran, S. (2023). The inherent trade-off between the environmental and anti-poverty goals of payments for ecosystem services. *Environmental Research Letters*, 18(2), 025003.

Jira, C., & Toffel, M. W. (2013). Engaging supply chains in climate change. *Manufacturing & Service Operations Management*, 15(4), 559-577.

Jones, T. M., Harrison, J. S., & Felps, W. (2018). How applying instrumental stakeholder theory can provide sustainable competitive advantage. *Academy of Management Review*, 43: 371–391.

Koh, S. L., Jia, F., Gong, Y., Zheng, X., & Dolgui, A. (2023). Achieving carbon neutrality via supply chain management. *International Journal of Production Research*, 61(18), 6081-6092.

Lal, R., Monger, C., Nave, L., & Smith, P. (2021). The role of soil in regulation of climate. *Philosophical Transactions of the Royal Society* B, 376(1834), 20210084.

Lazzarini, S. G., Boehe, D., Pongeluppe, L. S., & Cook, M. L. (2020). From instrumental to normative relational strategies: A study of open buyer-supplier relations. In *Academy of Management Proceedings* (Vol. 2020, No. 1, p. 17403). Briarcliff Manor, NY 10510: Academy of Management.

Lee, J., & Bansal, P. (2024). Sweeping it under the rug: Positioning and managing pollution-intensive activities in organizational hierarchies. *Strategic Management Journal*, 1–29.

Lenox, M. & Duff, R. (2021). The Decarbonization Imperative: Transforming the Global Economy by 2050. Redwood City: *Stanford University Press*.

Levine, S. S., Schilke, O., Kacperczyk, O., & Zucker, L. G. (2023). Primer for Experimental Methods in Organization Theory. *Organization Science*, 34(6), 1997-2025.

Li, X., & Zhou, Y. M. (2017). Offshoring pollution while offshoring production? *Strategic Management Journal*, 38(11), 2310–2329.

Liu, S., Wang, J., Pu, S., Blagodatskaya, E., Kuzyakov, Y., & Razavi, B. S. (2020). Impact of manure on soil biochemical properties: A global synthesis. *Science of the Total Environment*, 745, 141003.

Lumpkin, G. T., & Bacq, S. (2019). Civic wealth creation: A new view of stakeholder engagement and societal impact. *Academy of Management Perspectives*, 33(4), 383-404.

Luo, J., & Kaul, A. (2019). Private action in public interest: The comparative governance of social issues. *Strategic Management Journal*, 40(4), 476-502.

Marquis, C., & Raynard, M. (2015). Institutional strategies in emerging markets. *The Academy of Management Annals*, 9(1), 291-335.

Marquis, C., & Qian, C. (2014). Corporate social responsibility reporting in China: Symbol or substance? *Organization Science*, 25(1), 127–148.

McGahan, A. M. (2021). Integrating insights from the resource-based view of the firm into the new stakeholder theory. *Journal of Management*, 47(7), 1734-1756.

McGahan, A. M. (2023). The new stakeholder theory on organizational purpose. *Strategy Science*, 8(2), 245-255.

McGahan, A. M., & Pongeluppe, L. S. (2023). There is no planet B: Aligning stakeholder interests to preserve the Amazon rainforest. *Management Science*, 69(12), 7860-7881.

Menegat, S., Ledo, A., & Tirado, R. (2022). Greenhouse gas emissions from global production and use of nitrogen synthetic fertilisers in agriculture. *Nature Scientific Reports*, 12(1), 14490.

Mian, A., & Sufi, A. (2014). What explains the 2007-2009 drop in employment? *Econometrica*, 82(6), 2197–2223.

O'Brien, P. L., & Hatfield, J. L. (2019). Dairy Manure and Synthetic Fertilizer: A Meta-Analysis of Crop Production and Environmental Quality. *Agrosystems, geosciences & environment*, 2(1), 1-12.

Poppo, L., & Zenger, T. (2002). Do formal contracts and relational governance function as substitutes or complements? *Strategic Management Journal*, 23(8), 707-725.

Portocarrero F.F., & Burbano, V.C. (2023). The Effects of a Short-Term Corporate Social Impact Activity on Employee Turnover: Field Experimental Evidence. *Management Science*, forthcoming.

Pratibha, G., Srinivas, I., Rao, K. V., Raju, B. M. K., Shanker, A. K., Jha, A., ... & Reddy, K. S. (2019). Identification of environment friendly tillage implement as a strategy for energy efficiency and mitigation of climate change in semiarid rainfed agro ecosystems. *Journal of Cleaner Production*, 214, 524-535.

Prechel, H., & Zheng, L. (2012). Corporate characteristics, political embeddedness and environmental pollution by large U.S. corporations. *Social Forces*, 90(3), 947–970.

Rahman, M. M., Aravindakshan, S., Hoque, M. A., Rahman, M. A., Gulandaz, M. A., Rahman, J., & Islam, M. T. (2021). Conservation tillage (CT) for climate-smart sustainable intensification. *Environmental and Sustainability Indicators*, 10, 100106.

Reid, E. M., & Toffel, M. W. (2009). Responding to public and private politics: Corporate disclosure of climate change strategies. *Strategic Management Journal*, 30(11), 1157-1178.

Rennert, K., Errickson, F., Prest, B. C., Rennels, L., Newell, R. G., Pizer, W., ... & Anthoff, D. (2022). Comprehensive evidence implies a higher social cost of $CO_2$. *Nature*, 610(7933), 687-692.

Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Cornell, S. E., Donges, J. F., ... & Rockström, J. (2023). Earth beyond six of nine planetary boundaries. *Science Advances*, 9(37), eadh2458.

Ritchie, H., Rosado, P., and Roser, M. (2023). $CO_2$ and Greenhouse Gas Emissions. Published online at *OurWorldInData.org*.

Ritchie, H. (2024). Not the end of the world: How we can be the first generation to build a sustainable planet. *Hachette UK*.

Rockström, J., Gaffney, O., Rogelj, J., Meinshausen, M., Nakicenovic, N., & Schellnhuber, H. J. (2017). A roadmap for rapid decarbonization. *Science*, 355(6331), 1269-1271.

Roth, J., Sant'Anna, P. H., Bilinski, A., & Poe, J. (2023). What's trending in difference-in-differences? A synthesis of the recent econometrics literature. *Journal of Econometrics*.

Samberg, L. H., Gerber, J. S., Ramankutty, N., Herrero, M., & West, P. C. (2016). Subnational distribution of average farm size and smallholder contributions to global food production. *Environmental Research Letters*, 11(12), 124010.

Samii, C., Lisiecki, M., Kulkarni, P., Paler, L., Chavis, L., Snilstveit, B., ... & Gallagher, E. (2014). Effects of payment for environmental services (PES) on deforestation and poverty in low and middle income countries: a systematic review. *Campbell Systematic Reviews*, 10(1), 1-95.

Sautner, Z., van Lent, L., Vilkov, G., & Zhang, R. (2023). Pricing climate change exposure. *Management Science*, 69(12), 7540–7561.

Science Based Targets Initiative (SBTi) (2023). Net-Zero Standard.

Singh, J., Teng, N., & Netessine, S. (2019). Philanthropic Campaigns and Customer Behavior: Field Experiments on an Online Taxi Booking Platform. Management Science 65(2): 913-932.

Spicer, A., Wagner, M., & Zollo, M. (2021). Tinkering with the plumbing of sustainable enterprises: The case for field experimental research in corporate sustainability. *Organization & Environment*, 34(3), 351-360.

Steenbergen, V., & Saurav, A. (2023). The Effect of Multinational Enterprises on Climate Change: Supply Chain Emissions, Green Technology Transfers, and Corporate Commitments. *World Bank Publications*.

Stenzel, A., & Waichman, I. (2023). Supply-chain data sharing for scope 3 emissions. *npj Climate Action*, 2(1), 7.

Suri, T. (2011). Selection and comparative advantage in technology adoption. *Econometrica*, 79(1), 159-209.

Teodorovicz, T., Lazzarini, S., Cabral, S., & McGahan, A. M. (2023). Investing in general human capital as a relational strategy: Evidence on flexible arrangements with contract workers. *Strategic Management Journal*, 1–37.

Tidy, M., Wang, X., & Hall, M. (2016). The role of Supplier Relationship Management in reducing Greenhouse Gas emissions from food supply chains: supplier engagement in the UK supermarket sector. *Journal of Cleaner Production*, 112, 3294-3305.

Verbeke, A. (2021). The long-term energy transition and multinational enterprise complexity: A BJM–JIBS Joint Initiative. *Journal of International Business Studies*, 52(5), 803-806.

Wright, C., & Nyberg, D. (2017). An inconvenient truth: How organizations translate climate change into business as usual. *Academy of Management Journal*, 60(5), 1633–1661.

York, J. G., Vedula, S., & Lenox, M. J. (2018). It's not easy building green: The impact of public policy, private actors, and regional logics on voluntary standards adoption. *Academy of Management Journal*, 61(4), 1492-1523.

## Table 1: Illustrative quotes from pre-experiment field interviews

| | |
|---|---|
| ***The farmers' experience with the firm's original program*** | |
| [1] | "When <Field Officer> first visited and checked my field and told me I should water my <Crop X> only certain fixed times during the season, I did not believe him...But I listened to his advice over the years because he has studied these matters, plus he was traveling this distance to visit and inspect my field 4-5 times during the season and only then give advice. That has saved me so much water, not to mention better yield and quality over the years now." (Farmer #10) |
| [2] | "I had grown <Crop X> a few times before but did not get good yield, also when I sold at the mandi (center) buyers never worried much about quality. Prices were not great as it was volume selling. But since I became a [program] member I got guidance on when to sow, how to prepare land, how much seed to use, when to water, even right time to harvest and especially advice on pest problems on time at critical <Crop X> growing stage, when <Field Officer> comes and visits…Now the yield and quality of <Crop X> has improved a lot…Last year another company offered to buy my <Crop X> because of good quality but I did not sell to them, I sold to the <Firm> because it was their advice that helped me and they gave good price too." (Farmer #05) |
| [3] | "The company cannot benefit unless we farmers benefit - it's a relationship where we walk together. The company is good at understanding this so helps its member farmers to grow better <Crop X> and also keep costs low by using less seeds, water…The advice they give is useful…sometimes I ask <Field Officer> to check my other crops in the neighboring fields when he comes for visit but his focus is the <Crop X>…Some companies these days offer advice on phones but how will they know what my agricultural problems are unless I have shown them on my field." (Farmer #17) |
| ***The farmer's needs unmet by the firm's original program*** | |
| [4] | "Agriculture takes many years of experience to get it right. I have been doing this for more than 45 years and still learn new things sometimes…Every field is different, my farm is different from my neighbor's and from my brother's – nature of soil is different, water level is different…Agricultural advice is only useful if you tell things specific to my field and soil conditions. Otherwise, the government also gives lots of common advice, sometimes on radio and sometimes in village meetings…What is true in textbooks does not work in the field; unless you visit my field, see and touch my crops, check my soil, then that advice is useful for me. Otherwise, it's just a friendly chat over a cup of tea but no good for agricultural activities." (Farmer #06) |
| [5] | "The government extension officer took my soil sample last year, but I never got a report back telling me what they found. It [the service] was no good…it would only help if someone can bring the report and explain to me what I should do, what does my soil need, to produce good crops…I studied only till class 5. When I was born it was usual for farmer to start helping on farms and not waste time in school. I have seen a relative's soil test report, but we don't understand how to use it." (Farmer #03) |
| [6] | "Last few years it's not been easy to be a farmer – the weather changes suddenly often bringing rains when it's bad for crops. Last year my neighbor lost one entire crop because of badly timed rain. And pests are a big issue. These days we see new types of pests on crops, and we don't always know what to do...I learnt farming from my father and he from his. But they had not seen these problems then." (Farmer #02) |
| [7] | "New things are always coming up – new tools, new farming techniques, and the seasons are unpredictable but worst of all new pests and insects keep coming…So agricultural advice is useful especially as I don't meet the government's district extension officer many times in a year…In the past the <Firm> once brought knowledgeable doctors [agronomy experts] from <Agricultural Institution> who visited my village, came to my field and told me many useful things about how to do better agriculture…he was not trying to sell me anything so I trust his advice…I showed him all my growing crops and he checked the growth and recommended good fertilizer practice that would work for my farm and the crops I was growing…getting good knowledge on all my crops from somewhere trustworthy is important for the advice to be useful." (Farmer #14) |
| [8] | "When my field officers conduct field visits, farmers often request them to look at their other crops growing at the same time as <Crop X> on their other plots. But our field officers are not trained with knowledge of wide range of crops beyond <Crop X> matters as knowing about multiple other crops requires significant training, knowledge and experience. We are careful to not give farmers wrong advice, so we ask field officers not to discuss matters beyond the <Crop X>…On many occasions they have asked the field officers either for advice or requested them to ask the firm to provide advisory on other crops. We know and understand that farmers lack systematic access to scientific practices, newer agricultural technologies and need more support to increase their productivity without damaging their soil in the long term." (Regional manager #1) |
| ***The farmers' attitude towards adoption of climate-friendly practices*** | |
| [9] | "One must always respect the environment, but I have to sustain myself too…It is always good for me to know good practices that don't harm the environment, but you must first explain how it relates to my land and soil… I must think about the effects and how it will affect my income today or tomorrow…Farming is my primary family income so I can't change everything overnight and suffer large productivity loss…first <Firm> must check and advise how it will affect my land and crops." (Farmer #04) |

## Table 2. Linkage between decarbonization practices and GHG emissions reduction

| **Firm-recommended practice** | **Link to GHG emissions reduction** |
|---|---|
| 1. Reducing land tillage | Tillage refers to turning over of the soil to prepare it for crop cultivation, and is measured as the number of times that a farmer ploughs a given plot of land. In the absence of awareness and prioritization of its impacts on the environment as well as on their own soil health, farmers tend to do too much tillage relative to what is appropriate (Bhan and Behera, 2014, Erenstein et al. 2008, Rahman et al. 2021)<br>• Tillage has a negative impact on $CO_2$ emissions as ploughing of soil is generally done using tractors and agricultural machinery that runs on diesel. Reducing tillage reduces burning of diesel, which leads to a reduction in overall agriculture-related GHG emissions (Akbarnia and Farhani 2014, Bhan and Behera 2014, Pratibha et al. 2019).<br>• Tillage also has a longer-term impact on the soil's structure and organic carbon content. Reducing tillage can thus also improve the soil's organic content and ultimately fertility, while also enhancing the soil's ability to sequester carbon over multiple sowing seasons by improving its biological activity (Haddaway et al. 2016). |
| 2. Reducing inorganic fertilizer use | In the absence of awareness and prioritization of environmental impacts of fertilizer use, farmers tend to use too much of inorganic fertilizers (as they are easily and cheaply available, especially due to government subsidies) relative to what is optimum from the point of view of minimizing negative climate impact without compromising on agricultural productivity (Cole and Sharma 2017, Dar et al. 2023, Duflo et al. 2011, Islam and Beg 2021).<br>• Inorganic fertilizers are responsible for a substantial fraction of agriculture-related GHG emissions in the form of $N_2O$ (Menegat et al. 2022).). It is generally possible to reduce these emissions without compromising on farm productivity (Lal et al. 2021), e.g., through better tailoring of inorganic fertilizer use to a specific farm's soil requirements so that only the necessary amount of each kind of inorganic fertilizer is used.<br>• Further reduction in inorganic fertilizer use can be achieved by using an organic fertilizer (e.g., farmyard manure often available as a by-product of agricultural activities) to substitute for some of the soil nutrients for which farmers over-rely on inorganic fertilizers (Menegat et al. 2022). This also has the additional long-term benefit of enhancing soil fertility and sequestering more organic carbon in soil over time, even though farmers are often not aware of this (O'Brien and Hatfield 2019, Han et al. 2016, Liu et al. 2020). |

## Table 3a. Village-level summary statistics and balance check for the randomization

| Variable | Description | Base Program | Intervention Group A | Intervention Group B | Full Sample |
|---|---|---|---|---|---|
| *Total population* | Village level population based on Govt. of India’s 2011 census data | 3,379.73<br>(3,806.62) | 3,056.79<br>(3,696.86) | 2,723.33<br>(3,230.86) | 3,064.19<br>(3,595.41) |
| *Village area* | Total area of village in hectares based on Govt. of India’s 2011 census data | 908.49<br>(704.69) | 844.46<br>(527.97) | 771.91<br>(521.11) | 843.53<br>(594.90) |
| *Literacy rate* | Share of total population that is literate (had some schooling and can read and write with some understanding) based on Govt. of India’s 2011 census data | 0.63<br>(0.06) | 0.62<br>(0.06) | 0.63<br>(0.06) | 0.63<br>(0.06) |
| *Rural poverty rate* | Share of total population below 31 INR poverty line based on Govt. of India’s 2012 SECC data | 0.17<br>(0.12) | 0.18<br>(0.13) | 0.17<br>(0.12) | 0.18<br>(0.12) |
| *Agriculture main income* | Share of the total population with agriculture as the main source of income, based on Govt. of India’s 2012 SECC data and 2011 census data | 0.44<br>(0.21) | 0.45<br>(0.19) | 0.44<br>(0.20) | 0.44<br>(0.20) |
| *Daily hours power* | Daily hours of power for all types of uses (average of daily summer and winter hours of power) based on Govt. of India’s 2011 census data | 17.33<br>(4.59) | 17.47<br>(4.76) | 18.25<br>(5.67) | 17.67<br>(5.02) |
| *Night light* | DMSP-OLS based on 2013 satellite data that gives annual measures of night light luminosity | 119.57<br>(104.23) | 119.68<br>(108.83) | 111.85<br>(94.23) | 117.17<br>(102.54) |
| ***Number of villages*** | | **127** | **120** | **115** | **362** |

*Notes*. Standard deviations in parentheses. This table has been generated using village-level socioeconomic census data from Asher et al (2021). Villages for which a particular variable’s value was missing (about 3% of the cases on average) were excluded in calculating its mean. As a formal statistical test for the balance check, we also carried out pairwise t-tests for each of the variables for Intervention A as well as Intervention B relative to the base program (our control group). Among the 14 t-tests following this procedure (7 variables x 2 pairs of groups), the equality of means could not be rejected in any of the cases at p=0.05, indicating that the sample was well balanced, and that the randomization worked as expected.

## Table 3b. Farmer-level summary statistics

| **Variable** | **Description** | **Base Program** | **Intervention Group A** | **Intervention Group B** | **Full Sample** |
|---|---|---|---|---|---|
| *Age* | Age of the farmer in years pre-experiment | 41.73<br>(8.13) | 41.76<br>(7.77) | 42.90<br>(8.79) | 42.08<br>(8.22) |
| *Household size* | Total members in the farmer's household pre-experiment | 7.10<br>(2.70) | 6.88<br>(2.61) | 7.22<br>(2.61) | 7.05<br>(2.64) |
| *No formal education* | Indicator variable for whether the farmer completed any formal schooling | 0.05<br>(0.21) | 0.10<br>(0.30) | 0.05<br>(0.23) | 0.07<br>(0.25) |
| *Only primary education* | Indicator variable indicating whether the farmer completed primary education (Class 1-5) | 0.10<br>(0.31) | 0.12<br>(0.33) | 0.12<br>(0.33) | 0.12<br>(0.32) |
| *Land area* | Total land in hectares used by the farmer for all agricultural purposes | 4.48<br>(3.26) | 4.88<br>(3.78) | 4.88<br>(4.70) | 4.74<br>(3.92) |
| *Land ownership* | Fraction of the farmer's agricultural land that is fully owned by them | 0.84<br>(0.24) | 0.84<br>(0.24) | 0.84<br>(0.25) | 0.84<br>(0.24) |
| *Agriculture primary source of income* | Indicator variable for whether agriculture is the primary source of income for the farmer's household | 0.86<br>(0.35) | 0.90<br>(0.30) | 0.88<br>(0.32) | 0.88<br>(0.33) |
| ***Number of farmers*** | | **914** | **926** | **765** | **2,605** |

*Notes*. Standard deviations in parentheses. This table has been generated using our baseline data collected just before the experiment. Instances in which a particular variable was missing for a farmer (only 4 cases) were excluded in calculating its mean.

## Table 4a. Summary statistics and difference-in-differences calculation for our four primary outcomes

| | **Primary Business Outcomes** | | | | | | | | **Primary Environmental Outcomes** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Continuation* (indicator variable) | | | | *Land allocated* (in hectares) | | | | *Tillage* (count variable) | | | | *Inorganic fertilizer* (in kgs/hectare) | | | |
| | *Pre* | *Post* | *First Difference* | *DID* | *Pre* | *Post* | *First Difference* | *DID* | *Pre* | *Post* | *First Difference* | *DID* | *Pre* | *Post* | *First Difference* | *DID* |
| *Base Program* | - | 0.841<br>(0.012) | - | - | 1.501<br>(0.046) | 1.472<br>(0.047) | -0.026<br>(0.050) | - | 4.452<br>(0.036) | 4.409<br>(0.036) | -0.043<br>(0.016) | - | 134.248<br>(0.716) | 129.913<br>(0.752) | -4.298***<br>(0.399) | - |
| *Intervention A* | - | 0.847<br>(0.012) | - | - | 1.529<br>(0.048) | 1.473<br>(0.052) | -0.046<br>(0.045) | -0.020<br>(0.067) | 4.606<br>(0.038) | 4.465<br>(0.038) | -0.134<br>(0.020) | -0.091***<br>(0.026) | 133.828<br>(0.731) | 125.752<br>(0.757) | -7.965***<br>(0.525) | -3.667***<br>(0.661) |
| *Intervention B* | - | 0.909***<br>(0.010) | - | - | 1.602<br>(0.066) | 2.037<br>(0.069) | 0.434***<br>(0.065) | 0.460***<br>(0.081) | 4.482<br>(0.039) | 4.049<br>(0.043) | -0.434***<br>(0.033) | -0.391***<br>(0.035) | 133.494<br>(0.782) | 121.144<br>(0.826) | -12.270***<br>(0.631) | -7.972***<br>(0.724) |

$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

*Notes*: Standard errors are shown in parentheses. For the first primary outcome, *Continuation*, the pre-experiment, first difference and difference-in-differences (DID) statistics cannot be calculated as it is only defined for the post-experiment period. For the remaining three primary outcomes, *Land allocated*, *Tillage* and *Inorganic fertilizer*, the DID statistics are reported for Intervention A as well as Intervention B (relative to the base program, which serves as the control group in our field experiment).

## Table 4b. Multivariate regression analysis for our four primary outcomes

| | (1)<br>*Continuation*<br>(Post) | (2)<br>*Δ Continuation*<br>(Post – Pre) | (3)<br>*Land allocated*<br>(Post) | (4)<br>*Δ Land allocated*<br>(Post – Pre) | (5)<br>*Tillage*<br>(Post) | (6)<br>*Δ Tillage*<br>(Post – Pre) | (7)<br>*Inorganic fertilizer*<br>(Post) | (8)<br>*Δ Inorganic fertilizer*<br>(Post – Pre) |
|---|---|---|---|---|---|---|---|---|
| *Intervention A* | 0.010 | - | -0.077 | -0.067 | -0.103 | $-0.108^{***}$ | $-4.143^{**}$ | $-2.794^{**}$ |
| | (0.024) | - | (0.086) | (0.090) | (0.082) | (0.040) | (1.793) | (1.106) |
| *Intervention B* | $0.068^{***}$ | - | $0.442^{***}$ | $0.484^{***}$ | $-0.496^{***}$ | $-0.403^{***}$ | $-10.062^{***}$ | $-8.158^{***}$ |
| | (0.024) | - | (0.102) | (0.110) | (0.088) | (0.063) | (1.911) | (1.134) |
| Observations | 2,416 | - | 2,416 | 2,416 | 2,416 | 2,416 | 2,416 | 2,416 |
| Farmer and village level controls | Yes | - | Yes | Yes | Yes | Yes | Yes | Yes |
| Center FE | Yes | - | Yes | Yes | Yes | Yes | Yes | Yes |

$^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$.

*Notes*: Robust standard errors clustered at the village level (the unit of randomization) are reported in parentheses. The coefficient estimates for the farmer and village level controls, the center level indicator variables and constant terms are not shown here to save space but are available from the authors on request. The sample size used here is 2,416 farmers instead of 2,605 farmers in our original sample due to two reasons for which a total of 189 observations (7% of the original sample) get dropped. First, 24 farmers could not be surveyed post-experiment due to their unavailability (although there is no statistical difference in attrition rates across the experimental groups). Second, there were missing values for one or more of the control variables in 165 cases (although the findings remain very similar if we simply exclude the control variables with missing values in order to be able to use a more complete sample).

## Table 4c: Delving deeper into use of different kinds of fertilizers

| | (1)<br>*Inorganic fertilizer: DAP*<br>(Post) | (2)<br>*Δ Inorganic fertilizer: DAP*<br>(Post-Pre) | (3)<br>*Inorganic fertilizer: Urea*<br>(Post) | (4)<br>*Δ Inorganic fertilizer: Urea*<br>(Post-Pre) | (5)<br>*Organic fertilizer: Farmyard manure (MT/hectare)*<br>(Post) | (6)<br>*Δ Organic fertilizer: Farmyard manure (MT/hectare)*<br>(Post-Pre) |
|---|---|---|---|---|---|---|
| *Intervention A* | $-4.008^{***}$ | $-3.454^{***}$ | $-4.279^{*}$ | -2.134 | $0.394^{*}$ | 0.190 |
| | (1.459) | (0.986) | (2.373) | (1.504) | (0.224) | (0.170) |
| *Intervention B* | $-10.423^{***}$ | $-9.054^{***}$ | $-9.701^{***}$ | $-7.262^{***}$ | $1.442^{***}$ | $1.561^{***}$ |
| | (1.757) | (1.413) | (2.442) | (1.306) | (0.323) | (0.292) |
| Observations | 2,416 | 2,416 | 2,416 | 2,416 | 2,416 | 2,416 |
| Farmer and village level controls | Yes | Yes | Yes | Yes | Yes | Yes |
| Centre FE | Yes | Yes | Yes | Yes | Yes | Yes |

$^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

*Notes*: Robust standard errors clustered at the village level (the unit of randomization) are reported in parentheses. The coefficient estimates for the farmer and village level controls, the center level indicator variables and constant terms are not shown here to save space but are available from the authors on request. Supplier farmers in our context use two kinds of inorganic fertilizers: DAP and urea. Digging further into the analysis of their average use as reported in Table 4b, this table provides detailed analysis of the two kinds of inorganic fertilizers separately as well as the associated change in use of organic fertilizer (as explained in Table 2). The findings demonstrate two ways in which reduction in inorganic fertilizers took place because of our interventions. The first was by reducing excessive inorganic fertilizer usage relative to appropriate quantity required by the soil-specific condition for crop growth. The second was by using greater quantity of organic fertilizers as the farmers learnt to substitute inorganic fertilizers with organic nutrient options such as farmyard manure.

## Table 5a: Average GHG emissions reduction per incremental dollar invested in Intervention A or B (relative to the base program)

| | **Intervention A** | **Intervention B** | **Data sources, assumptions and details of the calculations** |
|---|---|---|---|
| Average reduction in DAP fertilizer used by the farmers (in kgs per farmer) | 5.32 | 13.94 | This calculation involves taking the estimate for the average reduction in use of DAP per farmer in kgs per hectare from column (2) in Table 4c and multiplying it with the average farmer's plot size of 1.54 hectares allocated for growing Crop X for the firm as per the firm's records. |
| Average GHG emissions reduction from reduction in DAP fertilizer used by farmers (in $CO_2$-equivalent kgs per farmer) | 3.60 | 9.45 | The fraction of nitrogen in DAP (by weight) is 0.18, which we use to calculate three kinds of GHG emissions in line with IPCC (2019). The first is the direct $N_2O$ emissions from the soil due to microbial conversion of the nitrogen. The second is indirect $N_2O$ emissions from the nitrogen emitted via volatilization and redeposition after application. The third is indirect $N_2O$ emissions from the nitrogen lost to water via leaching/runoff after application. For each component, the fraction of susceptible nitrogen in DAP is multiplied by the respective "Tier 1, $N_2O$-N" emissions factor (for dry climate with annual precipitation <1,000 mm, which is the case in our setting) to estimate the resulting "$N_2O$-N" emissions. These estimated emissions are then further converted to equivalent $N_2O$ emissions using the IPCC-recommended factor of 44/28, which are then finally converted to $CO_2$-equivalent terms using the relative global warming potential of 298 for $N_2O$. |
| Average reduction in urea fertilizer used by the farmers (in kgs per farmer) | 3.29 | 11.18 | This calculation involves taking the estimate for the average reduction in use of urea per farmer in kgs per hectare from column (4) in Table 4c and multiplying it with the average farmer's plot size of 1.54 hectares allocated for growing Crop X for the firm as per the firm's records. |
| Average GHG emissions reduction from reduction in urea fertilizer used by the farmers (in $CO_2$-equivalent kgs per farmer) | 6.60 | 22.45 | This calculation is analogous to the DAP calculation above except for two things. First, the fraction of nitrogen in urea (by weight) is 0.46. Second, for urea there is an additional component of emissions in the form of direct $CO_2$ emissions from urea hydrolysis post application, calculated using an emission factor of 0.2 per unit (IPCC 2019, Islam and Beg 2021). |
| Average reduction in the extent of tillage carried out by the farmers (in tillage count per farmer) | 0.108 | 0.403 | This is the estimated average reduction in tillage per farmer taken from column (6) in Table 4b. |
| Average GHG emission reduction from reduction in tillage by the farmers (in $CO_2$-equivalent kgs per farmer) | 7.58 | 28.28 | We take the average reduction in tillage for each intervention from the previous row, and multiply it by the diesel use averted per hectare, which is assumed as 17 liters per hectare (Adewoyin and Ajav, 2013, Akbarnia and Farhani 2014). To get the average quantity of reduced use of diesel per farmer we multiply this further by the average farmer's plot size of 1.54 hectares allocated for growing Crop X for the firm. Finally, to get the reduction in $CO_2$ emissions (in kgs per farmer), we multiply the previous figure by the quantity of $CO_2$ emissions averted per liter of diesel use averted, assumed to be 2.68 kgs/liter. |
| ***Total incremental average GHG emissions reduction realized by the farmers (sum of the above three, in $CO_2$-equivalent kgs per farmer)*** | ***17.78*** | ***60.17*** | This is the sum of the three kinds of GHG emission savings calculated above for each of the two interventions relative to the base program: those from reduced usage of DAP, those from reduced usage of urea, and those from reduced land tillage. |
| Cost to the firm for providing free soil testing to the farmers (in INR per farmer) | 700.00 | 700.00 | Providing the soil test costs the firm 700 INR per farmer as per the firm's records, and the firm provided this service to the farmer for free in both Intervention A and Intervention B. |
| Cost to the firm for providing the agronomist support to the farmers (in INR per farmer) | | 600.00 | Assumes a cost allocation of 400 INR from salary and 200 INR from travel expenses per farmer visit by the agronomist. |
| Total incremental average cost of the intervention relative to the base program (calculated as sum of above two, in INR per farmer) | 700.00 | 1,300.00 | This is the sum of the two kinds of costs of investments made by the firm: cost of the soil test service in the case of Intervention A and cost of soil test service and firm provided agronomist support in the case of Intervention B. |
| Effective GHG emissions reduction per INR (in $CO_2$-equivalent kgs per INR) | 0.03 | 0.05 | |
| Effective GHG emissions reduction per dollar (in $CO_2$-equivalent kgs per dollar) | 2.11 | 3.84 | This calculation uses the average exchange rate of approximately 83 INR/USD for December 2023. |
| ***Effective cost per unit of emissions reduction achieved (in dollars per $CO_2$-equivalent tons)*** | ***474*** | ***260*** | |

*Notes*: This table documents three kinds of potential emissions reduction achieved in Intervention A as well as Intervention B. For Intervention A, the average GHG emissions reduction relative to the base program was 17.78 $CO_2$-equivalent kgs per farmer, and the intervention's incremental cost was 700 INR (USD 8.43) per farmer, implying an average effective cost of USD 474 per CO2-equivalent tons for emissions reduction. For Intervention B, the incremental average GHG emission reduction relative to the base program was 60.17 $CO_2$-equivalent kgs per farmer and the incremental cost was 1,300 INR (USD 15.67) per farmer, implying a lower cost of USD 260 per CO2-equivalent tons for emissions reduction.

## Table 5b: Average cost savings realized by a farmer in Intervention A or B (relative to the base program)

| | Intervention A | Intervention B | Data sources, assumptions and details of the calculations |
|---|---|---|---|
| Average reduction in DAP fertilizer used by the farmers (in kgs per farmer) | 5.32 | 13.94 | This calculation involves taking the estimate for the average reduction in use of DAP per farmer in kgs per hectare from column (2) in Table 4c and multiplying it with the average farmer's plot size of 1.54 hectares allocated for growing Crop X for the firm as per the firm's records. |
| Average cost saving from reduction in DAP fertilizer used by the farmers (in INR per farmer) | 127.66 | 334.64 | This is calculated based on the cost savings resulting from the reduced use of DAP, by assuming the price of one bag of DAP as 1200 INR and the size of one bag of DAP as 50 kgs as per the firm's records. |
| Average reduction in urea fertilizer used by the farmers (in kgs per farmer) | 3.29 | 11.18 | This calculation involves taking the estimate for the average reduction in use of urea per farmer in kgs per hectare from column (4) in Table 4c and multiplying it with the average farmer's plot size of 1.54 hectares allocated for growing Crop X for the firm as per the firm's records. |
| Average cost saving from reduction in urea fertilizer use by the farmers (in INR per farmer) | 20.45 | 69.59 | This is calculated based on the cost savings resulting from the reduced use of urea, by assuming the price of one bag of urea as 280 INR and the size of one bag of urea as 45 kgs as per the firm's records. |
| Average reduction in land tillage carried out by the farmers (in tillage count per farmer) | 0.108 | 0.403 | This is the estimated average reduction in tillage per farmer taken from column (6) in Table 4b. |
| Average cost saving from reduction in land tillage by the farmers (in INR per farmer) | 254.47 | 949.55 | This calculation is based on the cost saving resulting from reduced use of diesel from reduced tillage. We take the average reduction in land tillage by the farmer (from the previous row) and multiply it by the averted rate of diesel burnt per hectare assumed as 17 liters per hectare (Adewoyin and Ajav, 2013). To get the average quantity of reduced use of diesel per farmer we multiply by the average farmer's plot size of 1.54 hectares allocated for growing Crop X for the firm as per the firm's records. Finally, we calculate the average cost saving by multiplying with the price of diesel assumed as 90 INR/liter. |
| ***Total incremental average cost saving per farmer (sum of the above three, in INR per farmer)*** | ***403*** | ***1,354*** | This is the sum of the three kinds of cost savings listed above for the two interventions relative to the base program: those from reduced usage of the two kinds of inorganic fertilizers (DAP and urea), and those from reduced tillage. |
| Additional cost saving from the free soil testing service for farmers who would have otherwise purchased it (in INR per farmer) | 700.00 | 700.00 | This was a conservative estimate based on the firm's internal cost for providing a soil test to the farmer. If the farmer were to procure the soil testing service externally, it would likely cost at least 700 INR, but it was provided to the farmer for free in both intervention A and intervention B. |

*Notes*: This table documents the cost savings accruing to the average farmer in Intervention A or Intervention B relative to the base program from multiple sources: reduced use of the inorganic fertilizers, urea and DAP and reduced use of diesel due to reduction in tillage. The calculation reveals that Intervention A generated 403 INR (USD 4.85) in cost savings for the average farmer, while Intervention B generated 1,354 INR (USD 16.31) in cost savings for the average farmer. Further cost savings of 700 INR (USD 8.43) would also have been realized from getting access to free soil testing service through the firm for farmers who would have otherwise paid for procuring a similar service externally on their own instead.

## Table 6: Illustrative quotes from post-experiment field interviews

| | |
|---|---|
| ***The farmers’ experience with the firm’s program following Intervention A*** | |
| [1] | “Productivity and quality of my <Crop X> has improved a lot. The soil test report this year in particular helped me add to my soil the required balanced nutrients and add fertilizers in appropriate quantities...My knowledge of <Crop X> improved and I am more aware of climate-friendly practices...The soil testing facilities from the company are very helpful as I was able to reduce fertilizer costs...Through the <Field Officer> the company has built good relations but I will hesitate to adopt practices if it reduces my crop productivity by a large amount...May be I will adopt for a year on a trial basis because of the good relations with the company...” (Farmer #16) |
| [2] | “The <Field Officer’s> visits are planned for critical crop growing stages. This year he also got my soil sample as the company offered the soil testing service for free. As a result the <Field Officer> was able to show me what my soil was lacking and also his advice for <Crop X> was more relevant, tailored for my soil conditions...I also added more farm yard manure (organic fertilizer) to the soil based on the soil test report and <Field Officer’s> advice...<Crop X> productivity was the best this year compared to other crops and I am always assured that I will get the best price from the <Firm> compared to other buyers in the market.” (Farmer #20) |
| [3] | “I will try and consider adopting the climate-friendly practices that the company recommends. Their advice based on the soil report is useful but for me the trust I have on the <Firm> because of the relationship built by the field staff - that is more fundamental.” (Farmer #21) |
| [4] | “The <Field Officer’s> advice on the quantity of <Crop X> seed required to be applied for my fields has saved me both cost of seed purchased as well as quality because of how I was able to manage soil nutrients. I have seen the result myself as well as the regularity of the support I have received. I feel assured that the company cares about farmers, and I am more open to the climate friendly practices they recommended...” (Farmer #22) |
| ***The farmers’ experience with the firm’s program following Intervention B*** | |
| [5] | “This time <Agronomist> came and advised me on my agricultural matters - I have faith in what they say. If any person from a company, I am not familiar with turns up and offers advice for my agricultural matters I would suspect the information he provides whereas I now readily listen to <Field Officer> or <Agronomist> advice as I know the company has built a good relationship with us over time that has proven to be beneficial for us in the past. I value that the company invested in sending knowledgeable, trained and expert staff to visit us and trust their advice reliably much more than any advice I would receive from my peers or neighbors.” (Farmer #03) |
| [6] | “The <Agronomist’s> visit was especially helpful. I was able to ask questions to understand my soil's nutrients and its health in more details such as nitrogen, magnesium and zinc content. I no longer had to guess-work how much fertilizers I need to add, and I saved costs by adding the appropriate quantity of fertilizer for productivity. The company's initiative to not only provide soil testing service but also send the <Agronomist> to provide us information and advice showed it wants to invest in us farmers...I also reduced tillage because the <Agronomist> advised that excess tillage does not benefit productivity but increases cost and harms my soil in the long term...I trust his advice and adopted reduced tillage even though I have been practicing higher tillage since I started farming.” (Farmer #01) |
| [7] | “I reduced tillage and also started using farmyard manure (organic fertilizer) according to proper methods. I was not aware before that higher tillage harms the soil nor did anyone point out the appropriate method for adding organic inputs...The <Agronomist> visit gave me the opportunity to ask about these things in detail. But just knowledge and awareness is not enough. I have to be sure that the advisory comes from a trustworthy source...The company has been providing good seeds and <Crop X> sale price last few years and now I trust the <Firm’s> staff completely...Unlike other <Competitor firm> who only sends its officers to sell their seeds for its own profit without ongoing support for or investing in farmers and the relationship, <Field Officer> and <Agronomist> have provided so much support that there is a strong relationship - I can rely on any advice they give as the <Firm> provided support has benefitted before...” (Farmer #04) |
| [8] | “Every year for the past few years the <Firm> has been providing continuous support for <Crop X>. I have seen the ongoing commitment to building this relationship with farmers. This year I received additional support from <Field Officer> and <Agronomist>...The support is timely and reliable and I do not hesitate to take up their advice because in my experience the company wants to profit but by creating more benefit for farmers...The company recommends various practices because it wants farmers to be more productive...The <Agronomist> visit was not targeted at just <Crop X> but also for other crops, so the company is not focusing on just its own <Crop X> profits but also on things that will benefit the farmer in the long term for the ongoing relationship...I have adopted their recommendations for climate-friendly practices and will see what the results are at the end of the season...I have recommended other farmers to join this program.” (Farmer #11) |

## Table 7: Regression analysis for additional outcomes of interest

| | (1) *Willingness to adopt recommended practices* (7-point Likert scale) | (2) *Perception of firm investment in relationship* (7-point Likert scale) | (3) *Satisfaction with the program* (7-point Likert scale) | (4) *Would recommend program to others* (7-point Likert scale) | (5) *Reasonable hypothetical annual fees* (INR/annum) | (6) *Sold Crop X to other buyers* (indicator variable) |
|---|---|---|---|---|---|---|
| *Intervention A* | $0.396^{***}$ | $0.740^{***}$ | $0.717^{***}$ | $0.628^{***}$ | $33.697^{***}$ | 0.012 |
| | (0.108) | (0.109) | (0.115) | (0.082) | (3.841) | (0.023) |
| *Intervention B* | $1.897^{***}$ | $1.985^{***}$ | $2.168^{***}$ | $1.726^{***}$ | $86.857^{***}$ | $-0.041^{*}$ |
| | (0.108) | (0.105) | (0.128) | (0.109) | (4.581) | (0.023) |
| Observations | 2,416 | 2,416 | 2,416 | 2,416 | 2,416 | 2,439 |
| Farmer and village level controls | Yes | Yes | Yes | Yes | Yes | Yes |
| Center FE | Yes | Yes | Yes | Yes | Yes | Yes |

$^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$.

*Notes*: Robust standard errors clustered at the village level are reported in parentheses. The coefficient estimates for the farmer and village level controls, the center level indicator variables and the constant term are not shown to save space but are available upon request. The first four outcomes are based on seven-point Likert scale questions from our endline survey: *Willingness to adopt firm recommended practices* captures how willing a farmer would be to adopt climate-friendly practices recommended by the firm, *Perception of firm investment in relationship* captures the extent to which a farmer thought the firm had invested in building a relationship with them, *Satisfaction with the program rating* captures how satisfied a farmer was with the firm's program, and *Would recommend program to others* captures how likely a farmer would be to recommend the firm's program to other farmers. The outcome *Reasonable hypothetical annual fees* is measured using an endline survey question asking farmers to select (from a hypothetical set of choices provided) the annual monetary fee they would be willing to pay for the services they received through the firm's program (the lowest choice being "50 INR per annum" and the highest being "250 INR per annum"). The sample size for columns (1) to (5) is 2,416 farmers instead of 2,605 farmers due to two reasons that led to a total of 189 observations (7% of the original sample) getting dropped. First, 24 farmers could not be surveyed post-experiment due to their unavailability (though there is no statistical difference in attrition across the experimental groups). Second, as already mentioned, there were missing values for one or more of the control variables in 165 cases (though the findings again remain similar if we simply exclude the controls with missing observations). The outcome *Sold Crop X to other buyers* employed in column (6) is an indicator defined using the firm's proprietary data and capturing whether or not a given farmer sold their Crop X produce to buyers other than our partner firm. The sample size for column (6) is 2,439 instead of 2,605 farmers in our original sample due to two reasons that led to a total of 166 observations (6.4% of the original sample) getting dropped. First, post-experiment Crop X sale data was not available for one farmer. Second, there were missing values for one or more of the crols in 165 cases (though the findings remain similar if we simply exclude the controls with missing observations).

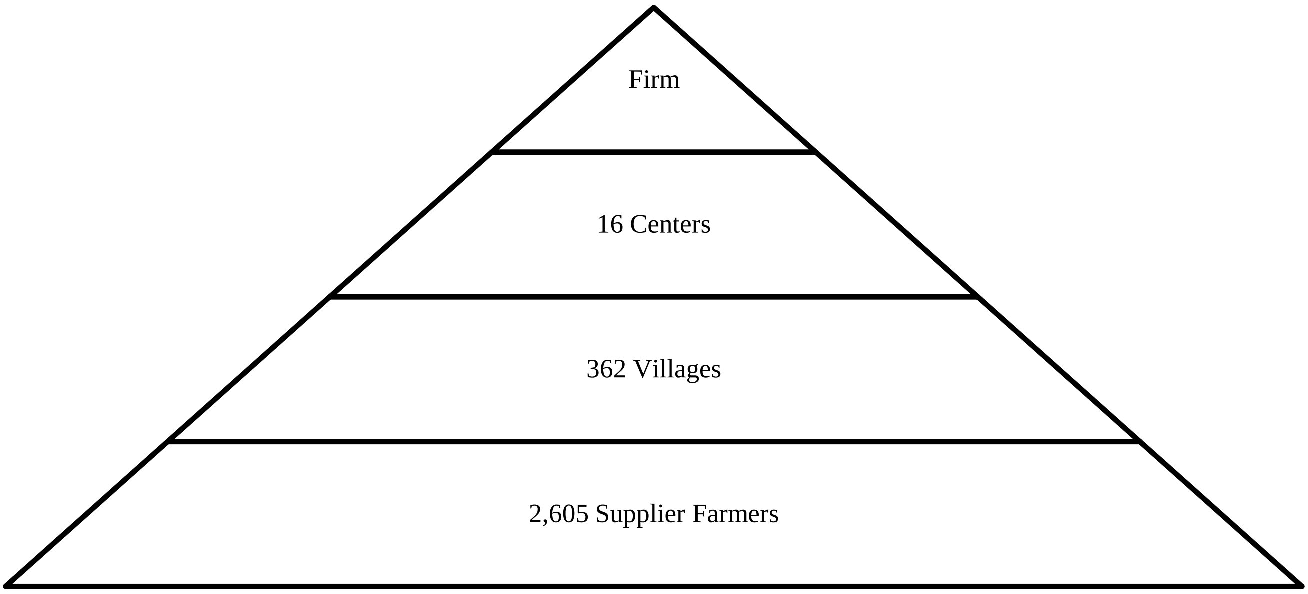

Figure 1. Organization structure of the firm's Crop X sourcing program

*Note*. Each center serves a group of villages. Farmers use the center closest to their respective villages as the place for selling their agricultural produce, and the potential buyers can include our partner firm as well as other buyers. The firm's operations within each center area were typically carried out by a unique field officer, the only exceptions being a large center that had two field officers and two small and proximal centers that were managed by a single field officer.

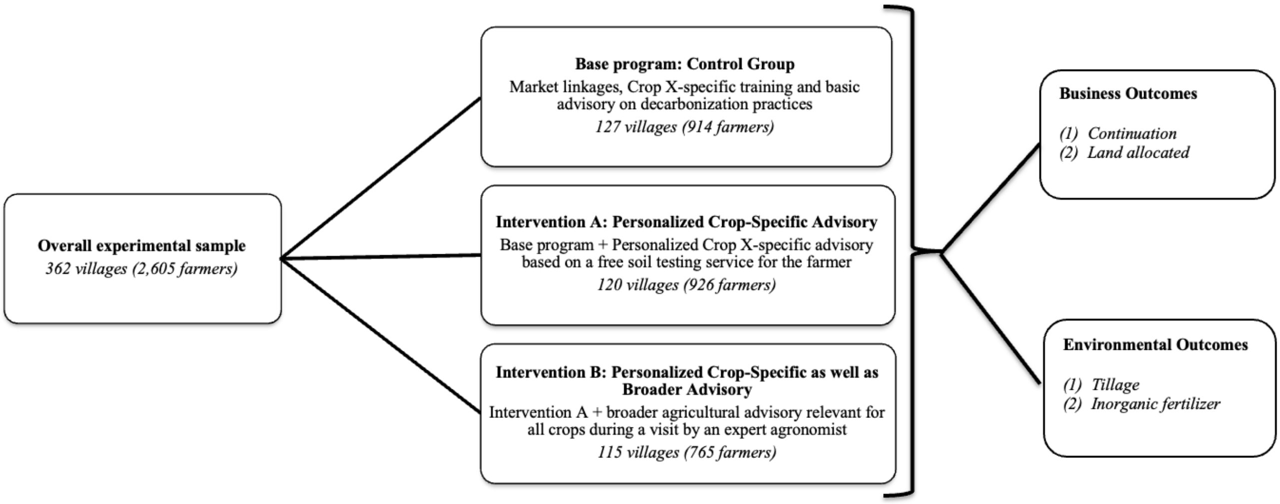

Figure 2. Design of our field experiment

*Note*. Our research design used a stratified randomization strategy wherein the program villages within each of the program centers were randomly assigned to one of three experimental groups: the base program (the control group), Intervention A (a lower-investment intervention that extended the base program by adding personalized Crop X-specific advisory based on a soil testing service provided to the farmer for free) and Intervention B (a higher-investment intervention that, in addition to including everything that Intervention A included, also included a visit by an expert agronomist to provide broad agricultural advisory relevant for all of the crops a given farmer grew). Although the unit of randomization was the village, all activities associated with a given intervention as well as with both the baseline and endline surveys were carried out one-on-one at the level of the individual farmers.

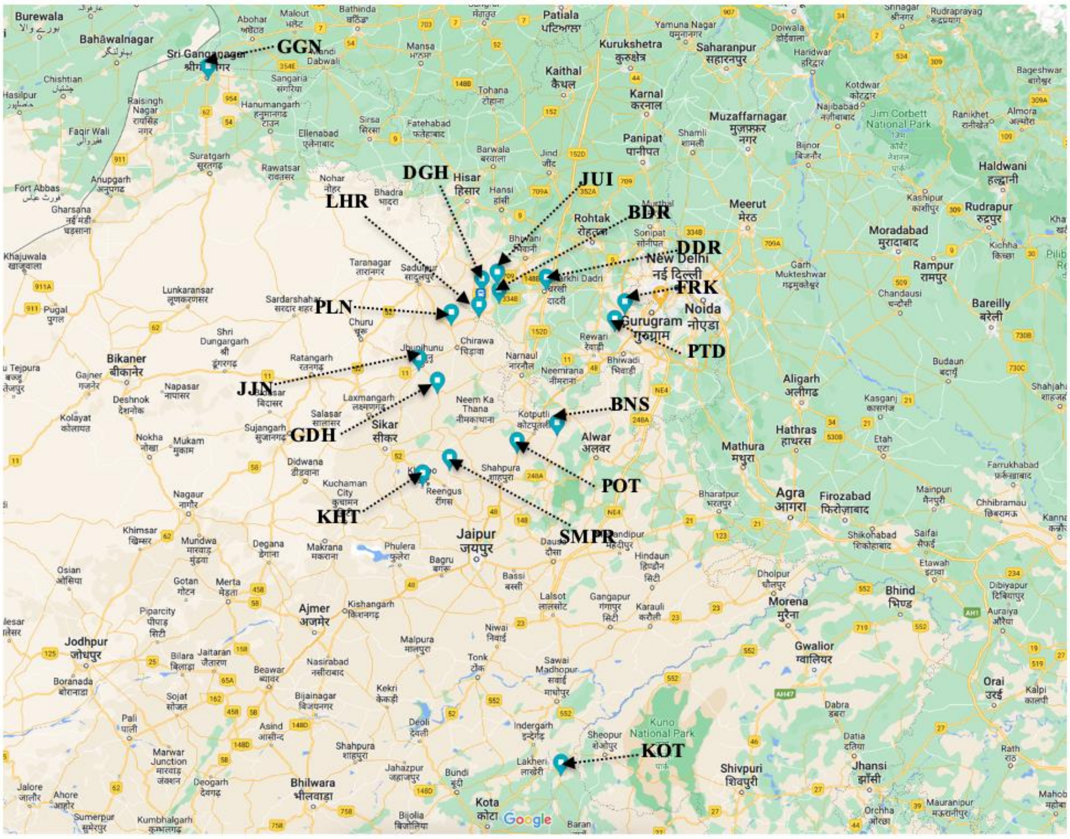

Figure 3a. Geographic location of the 16 centers used by the firm

| Center | Overall Sample | | Base Program | | Intervention A | | Intervention B | |
|---|---|---|---|---|---|---|---|---|
| | Number of villages | Number of farmers | Number of villages | Number of farmers | Number of villages | Number of farmers | Number of villages | Number of farmers |
| BDR | 10 | 156 | 4 | 88 | 3 | 23 | 3 | 45 |
| BNS | 36 | 188 | 12 | 59 | 12 | 55 | 12 | 74 |
| DDR | 27 | 224 | 9 | 73 | 8 | 92 | 10 | 59 |
| DGH | 19 | 127 | 7 | 45 | 6 | 58 | 6 | 24 |
| FRK | 25 | 170 | 9 | 64 | 8 | 57 | 8 | 49 |
| GGN | 39 | 81 | 13 | 20 | 13 | 26 | 13 | 35 |
| GDH | 31 | 206 | 11 | 69 | 10 | 78 | 10 | 59 |
| JJN | 19 | 173 | 7 | 71 | 6 | 42 | 6 | 60 |
| JUI | 20 | 212 | 6 | 34 | 9 | 69 | 5 | 109 |
| KHT | 26 | 330 | 9 | 128 | 8 | 101 | 9 | 101 |
| KOT | 21 | 88 | 7 | 44 | 7 | 34 | 7 | 10 |
| LHR | 19 | 256 | 6 | 102 | 6 | 119 | 7 | 35 |
| POT | 16 | 125 | 6 | 25 | 6 | 75 | 4 | 25 |
| PTD | 11 | 95 | 4 | 26 | 4 | 40 | 3 | 29 |
| PLN | 19 | 41 | 8 | 15 | 6 | 16 | 5 | 10 |
| SMPR | 24 | 133 | 9 | 51 | 8 | 41 | 7 | 41 |
| **Total 16 Centers** | **362** | **2605** | **127** | **914** | **120** | **926** | **115** | **765** |

Figure 3b. Distribution of our sample villages and farmers across the 16 centers

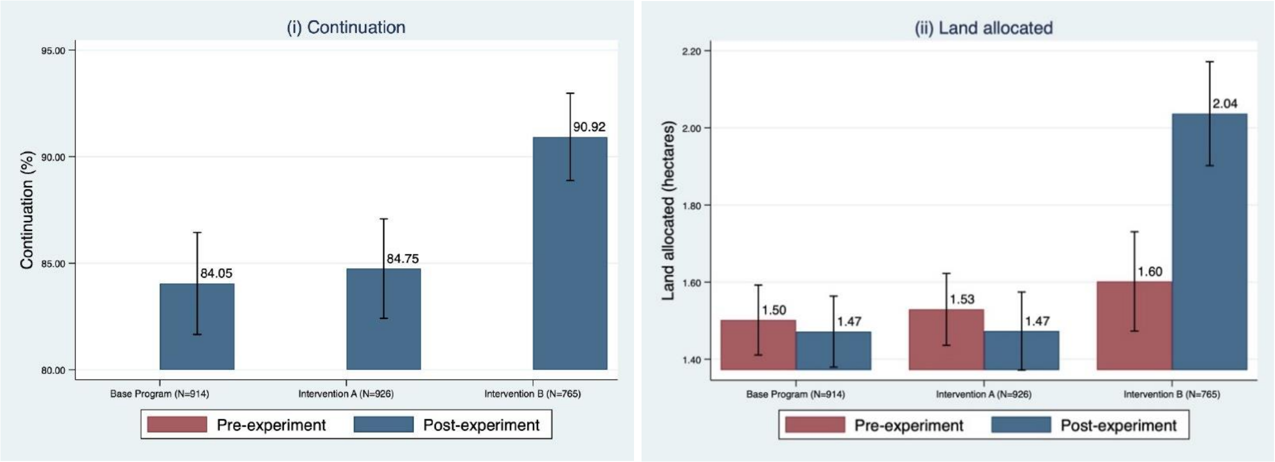

Figure 4a. Treatment effect for the primary business outcomes

*Notes*: Vertical bars indicate 95% confidence intervals. Note that *Continuation* is defined only post-experiment, but *Land allocated* was measured pre-experiment as well as post-experiment.

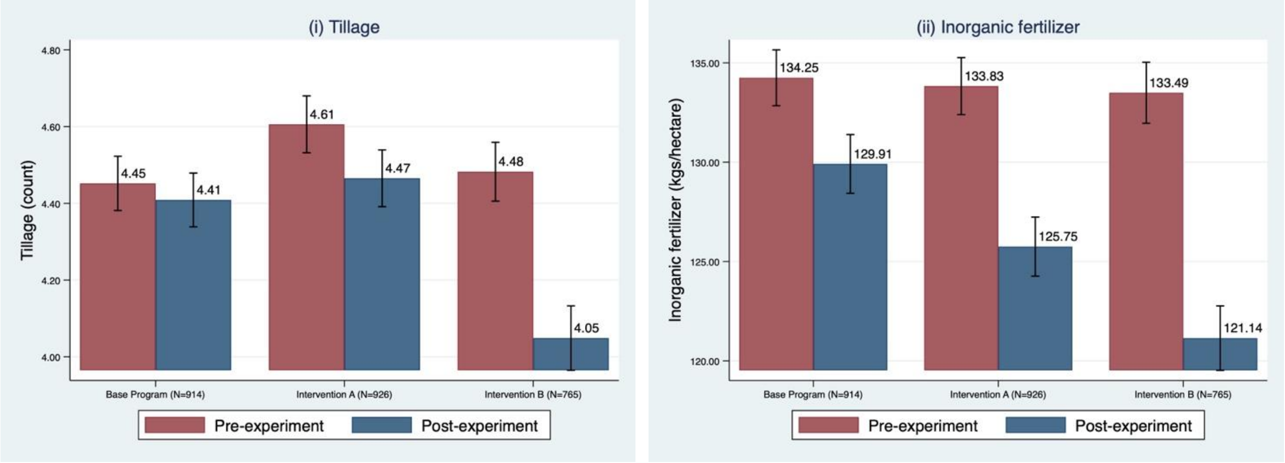

Figure 4b. Treatment effect for the primary environmental outcomes

*Notes*: Vertical bars indicate 95% confidence intervals. Note that *Tillage* and *Inorganic fertilizer* were both measured pre-experiment as well as post-experiment.