Impact Evaluation of the UNDP-Green Climate Fund (GCF) Project – 'Supporting Climate Resilience and Transformational Change in the Agriculture Sector in Bhutan'

First follow-up report

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[1] The consultant Marcos Agurto was in charge of revising and updating the follow-up survey first draft, which was provided by the local team, as well as analyzing the data which was collected by the local firm Kuenden Statistical Services. The consultant Marcos Agurto was not involved in the impact evaluation design, the intervention randomization process, collection of baseline survey, and baseline report. The consultant Marcos Agurto services started in November 2022. The consultant thanks Diana Tadeo for the excellent research work.

Content

1. Executive summary

This document presents the preliminary findings from the first follow-up impact evaluation of the UNDP-Green Climate Fund (GCF) Project – 'Supporting Climate Resilience and Transformational Change in the Agriculture Sector in Bhutan', which is currently under implementation. This first follow-up aims to evaluate the short-term impacts of both the soft and hard components of the program. The soft component is mainly related to the provision of agricultural extension services that promote the adoption of climate-resilient and sustainable agricultural practices and technologies, as well as the development, adoption and effective use of weather information systems. On the other hand, the hard program component is related to infrastructure interventions mainly related to the provision of irrigation systems and road building and maintenance.

To rigorously evaluate the above-mentioned program components, an impact evaluation design (IE) was developed in 2020[2]. For the purposes of the IE study, a total of 150 chiwogs in six districts, which by early 2021 have still not received any of the program components, were identified. To evaluate the impact of the soft-intervention component, a randomized control trial (RCT) was implemented, and the 150 chiwogs selected for the study were randomly assigned to the treatment and control groups. Those in the treated group were expected to receive the extension services provided by the program starting in late 2021, while those in the control group were temporarily excluded. The latter group is expected to start receiving the program benefits after 2024. Given random treatment assignment, a simple comparison of treatment and control raw means for the main outcomes of interest will suffice to capture the short-term program causal effects. It is important to highlight that the baseline survey, implemented in early 2021 (GCF Baseline Report, 2021) suggests that the randomization was properly implemented, as the two groups, treatment and control, were relatively similar in terms of their main pretreatment observable characteristics[3].

While it was still possible at the time of the IE design to randomly assign the soft-components of the intervention among a group of chiwogs that by early 2021 were still not served the program, the assignment of the hard-components (irrigation and roads), could not be randomized, and therefore a simple means comparison would not recover the causal effects of the program in this case. Given this situation, a difference in differences (DiD) design was proposed. Out of the 150 chiwogs included in the study, 45 belong to the irrigation and road intervention area. The DiD design will then compare the pre- and post-treatment changes in mean outcomes in these 45 chiwogs, against the same observed changes in the other 105, to isolate the effects of interest. This comparison will be valid if the DiD parallel trends assumption holds. This assumption requires that, in the hypothetical world in which the project was never implemented, the two areas would have experienced similar changes in outcomes across the pre and post treatment periods. In the recommendations section of this report how supporting evidence for the parallel trend's assumption can be provided.

The first program follow up-survey was originally planned for the first quarter of 2022, but due to the COVID-19 restrictions it had to be postponed and was finally implemented between late December 2022 and January 2023. This survey allows us to obtain post-treatment information on climate-resilient practices knowledge and adoption for approximately 1,600 households within the 150 study chiwogs. It also contains information on the adoption of climate resilient technologies and weather information systems, road and irrigated land access, agricultural outcomes, agricultural income and wellbeing and perceived resilience to extreme weather. Using this survey information, in

[2] The original IE design was developed by Dr. Habiba Djebari.

[3] In the technical jargon, treatment and control groups are balanced.

the next subsections 1.1. and 1.2, we briefly present the main results associated with the intervention. A more detailed discussion is provided in section 9 of this document.

1.1. Impacts of the soft intervention component

Table 1.1 below presents a summary of the main results related to the impacts of the soft intervention component. For each of the outcomes analyzed, we present the mean in the control group, the mean in the treated group and the observed difference in raw means. If the difference in mean outcomes is statistically different from zero, we indicate this by adding an asterisk at the right-hand side of the estimated coefficient. A single asterisk (*), a pair (**) and a triplet of asterisks (***) will indicate that the observed difference is statistically significant at the 10%, 5% and 1% significance levels, respectively. A statistically significant difference is taken as evidence that treated individuals mean outcomes are different than control ones. If no asterisk is added, this means that the spotted difference is not statistically significant, and therefore that we do not have enough statistical evidence to claim that those treated by the intervention performed differently than those in the control group.

As it can be observed in Panel A of Table 1.1, the estimated results related to the RCT do not allow us to conclude, at this stage of the program implementation, that treated households have a higher level of knowledge or adoption of climate-resilient and sustainable agricultural practices and technologies than control ones. Moreover, the results suggest that the current knowledge of the practices disseminated by the program is still relatively low. In this regard, for example, only 15% of treated individuals indicate having the necessary knowledge to fully implement climate-resilient and sustainable agricultural practices in their fields, a percentage which is not statistically different from the 14% of households in the control group that respond in a similar manner.

As part of the follow-up survey, we also designed a knowledge test to assess farmers' objective knowledge of the climate-resilient practices promoted by the program, such as mulching, biochar and bokashi. This test did not only ask households about whether or not they have heard about these practices, but also asked about their specific features and related benefits (The test is show in Appendix A). An aggregate index was then obtained as a function of the farmers responses to the test, which maximum score is 9. As we can see, treated and control groups obtained similarly low-test scores, 1.25 vs 1.32 respectively. As we can also observe, treated and control farmers seem to be equally aware of practices such as mulching or biochar production. For example, panel A in Table 1.1 shows that while 14% of treated individuals have heard about mulching, this percentage is relatively close in the control group, 16%, and the observed 2 percentage points difference across groups' mean outcomes lacks statistically significance (we cannot rule out that the observed difference is different from zero).

There are also not statistically significant differences among treated and control households in terms of sustainable land management (SLM) practices adoption, such as dry land bench terracing, wet land terrace consolidation and water source protection. Among treated and control groups, the self-reported adoption levels for such practices lie within the 30% to 40% interval, and the spotted differences across groups lack statistical significance. Regarding technologies such as improved seeds, poly-houses, greenhouses or sprinklers, the adoption levels observed among treated and control units is also relatively similar, and the observed differences across groups are not statistically significant. Moreover, for some of these technologies, the adoption levels are relatively low. For example, in the case of poly-houses and greenhouses, the observed adoption levels at follow-up are around 15%, and less than 10% of farmers report having adopted a water saving technology, such as a sprinkler. No difference across groups are also observed for the adoption and use of weather forecast information systems.

Table 1.1 - Impacts of the program soft component			
	Control mean(C)	Treated mean(T)	T-C
Panel A - Impacts on knowledge and adoption			
Perceived knowledge: Individual consider HH has necessary knowledge to fully implement climate-resilient and sustainable practices.	0.14	0.15	0.01 (0.03)
Average score obtained in knowledge test about practices and technologies such as mulching, biochar, bokashi and greenhouses – maximum score is 9	1.33	1.25	-0.08 (0.0)
Proportion of HHs that have heard about mulching	0.16	0.14	-0.02 (0.03)
Proportion of HHs that have heard about bokashi	0.02	0.04	0.02** (0.02)
Proportion of HHs that have adopted dry land bench terracing	0.40	0.34	-0.06 (0.06)
Proportion of HHs that have adopted wet land terrace consolidation	0.37	0.32	-0.05 (0.05)
Proportion of HHs that implements water source protection	0.33	0.38	0.05 (0.06
Proportion of HHs that use locally produced improved rice seeds	0.38	0.43	0.05 (0.06)
Proportion of HHs that have adopted poly house or green house	0.17	0.14	-0.03 (0.03)
Proportion of HHs that have water saving technologies (e.g. drip irrigation, sprinkler)	0.07	0.09	0.02 (0.03)
Proportion of HHs that have received forecast-warning information in 2022	0.55	0.58	0.03 (0.04)
Proportion of HHs predicted weather forecast during last cropping season	0.43	0.51	0.07 (0.05)
Panel B - Impacts on agricultural activity and income			
Proportion of HHs that cultivated rice – last cropping season	0.68	0.75	0.07 (0.05)
Total rice cultivated area – acres, last cropping season	0.40	0.42	0.02 (0.04)
Total rice production – kilos, last cropping season	281	257	-23.3 (29.5)
Total expenses in rice inputs, Nu	5682	5856	174 (758)
Total cultivated area – maize, acres	0.46	0.37	-0.09 (0.07)
Total cultivated area – chili, acres	0.05	0.06	0.01 (0.01)
Total area cultivated under poly-house or green house, acres	0.05	0.04	-0.01 (0.01)
Total agricultural income, Nu	38,926	36,398	-2,527 (4,223)
Proportion of HHs that report investments in farm equipment and tools	0.04	0.04	0.00 (0.02)
Total amount invested in farm equipment and tools, Nu	1361.9	1184.87	177.05 (520.4)
Panel C - Impacts on perceived wellbeing and vulnerability			
Perceived wellbeing – position in wellbeing ladder (ladder has ten steps)	6.05	6.1	0.05 (0.07)
Household at one point of time in last 12 months worried about food self-sufficiency	0.14	0.16	0.02 (0.02)
Perceived vulnerability: Proportion of individuals who considers that if extreme weather event occurs next year, HH will lose less than half its total rice production.	0.60	0.64	0.04 (0.04)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors are clustered at the chiwog level and are show in parenthesis.			

Given the lack of evidence on program effects on knowledge and adoption of climate resilient and SLM practices and technologies, and considering the program theory of change, it is unlikely that there will be any major evidence of program effects on agricultural production and income. We explore this in detail in Panel B of Table 1.1. As we can observe, the results clearly indicate there are not statistically significant differences among treated and control units for any of the variables included in this panel. Take for example the total rice cultivated area during the last cropping season. While treated households reports 0.42 acres on average, control one's report 0.40 acres, and the observed 0.02 acres difference lacks statistical significance. A similar conclusion is obtained for total rice production and total agricultural income. The spotted difference across groups for these outcomes, which in the first case is higher for the control group and in the second one higher for the treated group, is not statistically significant, and therefore the null hypothesis of no program effect cannot be rejected.

As discussed before, the program has also promoted the adoption of poly houses and greenhouses in treated villages, so considering this, we have estimated the total area cultivated under such agricultural technologies. As we can observe, treated and control groups also report very similar areas in this case, 0.05 vs 0.04. and the small 0.01-acre difference is not statistically different from zero.

To measure households perceived wellbeing, in the first place we asked individuals to visualize a 10 steps ladder, in which the top one represents the best possible life for the individual, and the bottom one the worst. We then asked households to identify where in the ladder they were standing at the time of the follow-up survey. As we can observe in Panel C of Table 1, both treated and control individuals placed themselves around the sixth step, 6.1 vs 6.05. The spotted difference across groups is therefore very small and not statistically significant. We also asked households about their food security. As we can observe in Panel C, there are no statistically significant differences across groups in this case either. Close to 16% households in the treated group worried about food security in the last 12 months, while 14% of households in the control group experienced the same situation. The 2-percentage point spotted difference across groups is not statistically different from zero.

To measure perceived vulnerability, we asked households about the expected rice losses that they would experience next year in the hypothetical case of an extreme weather event. As we can see in Panel C, approximately 64% of respondents in the treated group indicated that they will lose less than half their total rice production, while 60% of those in the control group responded in a similar fashion (note that in this case, a higher proportion indicates a lower level of perceived vulnerability). While a slightly lower perceived vulnerability in observed for those in the treated group, the estimated 4-percentage points difference across groups is not statistically different from zero.

1.2. Impacts of the hard intervention component

As mentioned before, the program also includes irrigation and road infrastructure interventions. However, assignment to these hard program components was not random, so the comparison of means across units that received and did not receive them will not capture the causal effect of such intervention. In total, 45 chiwogs of the total 150 included in the study belong to the area that is expected to benefit from the infrastructure components of the project. Given the no random assignment in this case, the original IE framework proposed a DiD design in order to estimate the effects of these components. The DiD design logic is relatively simple, and it implies comparing the pre and post intervention change in the variable/outcome of interest in the group that received the hard components package against the same change in the group that did not.

Panel A in Table 1.2 shows a summary of the hard program components' impacts on road connectivity and irrigation. As we can observe, the results indicate that farmers within the area served by the hard components are 5 percentage points more likely to have their farm connected to a pave road, spend 154 Nu less to transport their produce to their markets relative to control ones and have increased their irrigated area during the last cropping season by 9-percentage points; however, all these point-estimates are not statistically significant at this point of the program implementation.

In panel B of Table 1.2 we can also observe that while the point estimates for total rice cultivated area and total production suggest a 0.13 acre and 41.3 kg. increase individuals within the hard component intervention area, these estimates lack statistical significance. In other words, they are not statistically different from zero. Also note that agricultural income in the irrigation and road areas seem to be lower by 1,430 Nu relative to those not affected by these interventions; however, the estimate is, as the ones before, not statistically significant.

Table 1.2 Impacts of the program hard component – irrigation and road infrastructure

	DiD effect
Panel A - Impacts on road and irrigation quality and perceived reliability	
Proportion of HHs which farm is connected to paved road (road paved, feeder road paved or district-national highway)	0.05 (0.06)
Amount spent last year for transportation of harvest to markets	-154 (363.8)
Proportion of HHs which indicate their road network is reliable	-0.06 (0.05)
Proportion of rice area under irrigation – last cropping season 2022	0.09 (0.07)
Proportion of HHs which indicate their irrigation water is reliable	-0.01 (0.01)
Panel B - Impacts on agricultural activity and income	
Total rice cultivated area – acres, last cropping season 2022	0.13 (0.08)
Total rice production – kilos, last cropping season 2022	41.3 (51.6)
Total agricultural income	-1,430 (5,075)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors are clustered at the chiwog level and are show in parenthesis.	

Overall, at this stage of the program implementation, the statistical evidence from the first follow-up does not allow us to conclude that the hard components of the program had an impact over road and irrigation access and the rice agricultural activity in the area. During the field visits that the consultant made to the intervention area in early January 2023, the Project Management Unit (PMU) indicated that many of the irrigation and infrastructure projects were still under implementation and that a relevant proportion were expected to be completed during the current year (2023). This delay in the implementation of the hard components may be related to the absence of statistically significant effects for this component of the GCF program by the time of the first follow-up.

1.3. Heterogenous effects as a function of gender

While at the aggregate level there is no conclusive evidence of statistically significant impacts of the intervention; the program may have had an impact over female-headed households only or over male-headed households only for certain dimensions of the intervention. To test for this, we estimated separate regressions for the two gender groups. The results for the female regressions are shown in Tables B1 to B22 in the

Appendix, while the results for the corresponding male regressions are shown in Tables C1 and C22 in the Appendix.

While in general the results for the gender regressions are similar to those in the aggregate ones, there are few differences that deserve some discussion, in particular in the case of female-headed households. In first place, while in general there is little evidence that treated female- or male-headed households have considerable improved their knowledge and adoption of resilient and sustainable land management practices related to control ones, among treated female-headed households there is a statistically significant higher knowledge of hydroponic systems than female-headed control ones, 7%vs. 2%, but also a statistically significant lower implementation of orchard terracing and contour hedgerows, 6% vs 14% and 14% vs 26% respectively. Female-headed households also report a statistically significant lower proportion of rice irrigated area, 78% vs 88%, but at the same time a statistically significant higher proportion of mixed type area 19% vs 7%. Interestingly, treated female households report a statistically significant higher total production of rice than control female headed ones when the full 2022 year is considered, 617 vs 480 kilograms, as well as a statistically significant higher rice productivity, 890 vs 709 kilograms per acre.

Regarding male-headed households, there are not major difference with respect to control male-headed ones. It is relevant, however, to mention that during the last cropping season they experienced a lower rice productivity that control ones, 628 vs 716 kilograms per acre. Nevertheless, this difference is statistically significant only at the 10% significance level.

1.4. Preliminary discussion

At this point of the program implementation, we lack the necessary statistical evidence to conclude that the program had already an impact on treated farmers on several dimensions which were originally expected to be affected by it, such as knowledge and adoption of climate resilient and sustainable technologies and agricultural outcomes and income. Also, in general, the point estimates for the mean outcomes in the treated group are relatively close to those in the control one.

We must, however, be careful in terms of interpreting these results. The fact that no statistically significant evidence of program impacts is present at this stage of the intervention does not necessarily imply that the program has not or will not generate an impact. In the first place, as we mentioned before, the first follow-up survey was programmed for the first quarter of 2022, and had to be delayed for almost a year due to the COVID-19 restrictions. It is possible that, at the early stages of the program implementation, the treated performed differently than the control ones, and that the latter were able to catch-up with the treated after interacting with them along several settings. Also, the literature suggests that learning and adoption are processes that may take time, and while some individuals (maybe the more motivated, entrepreneurial or educated ones) could have started to experiment with the practices and technologies disseminated by the program, widespread learning and adoption are process that may be still on the make. This latter interpretation is in line with the low levels of knowledge and adoption of practices (such as mulching) and technologies (such as greenhouses) observed at this point of the program implementation. If individuals are still experimenting and learning with the newly promoted practices and technology, it is possible that stronger effects related to the intervention are observed in the next years.

Another challenge for the interpretation of our estimates is related to the potential presence of information and learning externalities, as control farmers may have learnt from their treated neighbors about the agricultural practices promoted by the program. If such externalities are present, our estimates underestimate the true program impacts.

The original IE design was not conceived to assess the presence of such learning externalities; however, it may still be possible to approximate their possible presence by exploiting the georeferenced location data of households obtained during the baseline survey. We explore this possibility in detail in Section 9, in which we exclude from the analysis those control households that are extremely close to treatment area, and which are therefore more exposed to interactions with treated ones. Our preliminary results from these regressions suggest that externalities may be present, and that treated farmers appear to have higher levels of knowledge and adoption of certain practices and technologies when they are compared with control units which are geographically distant from treated chiwogs. These results however must be taken with extreme caution, as there are some issues related to the precision of the GPS data collected at baseline, which we discuss in detail in Section 9 of this report.

Regarding our estimations results as a function of the gender of the household head, it is important to highlight that the sampling framework related to the IE was conceived taking as reference the total aggregate effects, and not the effects by gender. Therefore, we should take these results with caution, and evaluate whether or not they remain in the next follow-ups. Also, importantly, we strongly suggest the PMU to carefully analyze the female-headed household results, to better understand whether they make sense under the lens of the program intervention theory of change and implementation timeline.

It is critical to highlight that it will be problematic to recover the program causal effects of the soft-components if program implementation has not rigorously followed the original treatment assignment - that is, if a relevant number of treated villages did not finally receive the program or if a significant number of control ones were able to benefit from the program components. Based on information received from the PMU, while no control chiwog has received any of the elements of the program, some chiwogs assigned to treatment have not been reached by the program activities by the time of the first follow-up. In this sense, the intervention results should be interpreted as capturing the Intention to Treat (ITT) effect of the program, that is, the effect related to having been assigned to the treated group, independently of whether the program finally reached you or not. Using the local field team reports, it may be possible to recover the effect of having effectively received the program, by estimating a LATE (local average treatment effect) regression, in which initial assignment to treatment can be used as an instrumental variable (IV). Depending on the validity of the assumptions, the LATE regressions can be included in the next follow-up study.

Estimating the program causal effects will also be problematic if other programs funded by the government or other organizations have systematically targeted individuals in control villages. If the latter has been the case, our estimations for the soft components of the program will not capture the causal effect of the GCF program but will just compare two completely different interventions. In the latter case we, we will not be able to know what the additional contribution of the program will be compared to a situation in which there were other close substitutes but the program was not available. With the support of the PMU, we have mapped all other programs or projects that have been implemented in the area since 2021 in order to assess whether or not these have systematically targeted control chiwogs exclusively. As discussed in section 12 of this document, the PMU's reports suggest that local and treated chiwogs have been similarly targeted by other interventions present in the country, and therefore the original impact evaluation design counterfactual assumptions are still likely to hold.

The rest of this document is organized as follows: Section 2 describes the intervention context; Section 3 describes the project and the theory of change while Section 4 describes the process to identify the target population and the project timeline. Section 5 identifies the impacts to be evaluated as a function of the theory of change and project timeline. Section 6 discussed the experimental and difference in differences designs, while section 7 describes the data sources. Section 8 presents the estimating equation and describes how the results should be interpreted. Section 9 presents the estimation results. Section 10 discusses effects by gender and Section 11 assesses the possibility of externalities being present. Section 12 presents the main conclusions from the first impact evaluation and finally Section 13 provides a set of recommendations for future work.

2. Intervention context

Bhutan is a small landlocked kingdom in the Himalayas with steep mountains and deep valleys. The country has a total population of 727,145, of which about two-thirds reside in rural areas (National Statistics Bureau, 2018). Although just about seven percent of the land is arable, more than half (51%) of its population depend on agriculture. Agriculture is an important contributor to the country's Gross Domestic Product and in 2019, its share to GDP was around 15.5% (National Statistics Bureau, 2020).

Bhutan's dependence for revenue and employment on climate sensitive sectors like agriculture makes it highly vulnerable to climate change and its impacts. Agriculture is highly climate-sensitive and distribution of rainfall and changes in temperature regimes affect crop production (Rahman, Kang, Nagabhatla, & Macnee, 2017). Further, extreme-weather events induced by climate change such as windstorms, pests and diseases outbreaks, and floods amongst others wreak havoc on farming communities. Bhutan's mountainous topography and small landholdings and farm size will be greatly impacted by climate change and extreme-weather related events will have concomitant effect on rural livelihoods.

Extreme-weather related disasters induced by climate change such as the windstorm in 2008 in the six eastern dzongkhag of Bhutan and Sarpang in the south that destroyed more than 100 acres of maize and affected 500 households (National Environment Commission, 2009), northern corn leaf blight in 2007 that damaged more than 50 percent of maize harvest in the east (Chhogye & Kumar, 2018), and in recent times, flash flood in Trashiyantse that killed three students and washed away livestock[4] are occurring in higher frequency. Climate change studies predict greater variability of precipitation and increasing trend of temperature in Bhutan (NCHM, 2019), which will all have significant bearing on smallholder farms in Bhutan.

Building resiliency of the agriculture sector to climate change has, therefore, become extremely important in these unprecedented times of rapid climate change. This Project, titled, 'Supporting Climate Resilience and Transformational Change in the Agriculture Sector in Bhutan', seeks to build resilience of smallholder farms to climate change in Bhutan. The Project focuses primarily on four domains: (1) climate information and services; (2) climate-resilient irrigation and agriculture; (3) sustainable land management (SLM); and (4) climate-resilient roads.

There are eight dzongkhag or districts which are targeted by the project - Dagana, Punakha, Trongsa, Tsirang, Sarpang, Samtse, Wangdue Phodrang, and Zhemgang, which were selected mainly because of their high poverty incidence and vulnerability to climate change. In addition, all these dzongkhags have high potential for upscaling agricultural production due to prevailing suitable climatical conditions and land feasibility. Altogether, more than 118,000 people, equivalent to 16 percent of the Bhutanese population, are targeted to benefit from this Project.

[4] www.bhutantimes.bt - 2021

3. The intervention strategy and theory of change

3.1. Intervention strategy

Temperature and rainfall changes, climate-related flash floods, landslides, and soil erosions are identified as key development challenges facing the agricultural sector of Bhutan (GCF-UNDP 2019). As a result, the flow of water to farmers is expected to be majorly disrupted (water shortage during the main cropping season on rainfed land, drought, damages to roads and irrigation schemes due to excess rainfall, flash floods, and landslides). Further, soil erosion is expected to lower nutrients and organic matter content, reduce water retention capacity, soil stability, and workability, leading to lower agricultural yields and threatening livelihoods. Cropping patterns are also expected to change. More intense monsoons and extreme rainfall episodes are expected to increase damage to unpaved rural roads.

This Project intends to support the transition from 'responsive measures to climate change' to 'climate-informed planning for sustainable agriculture'. The Project strategy promotes the resilience of smallholder farmers in the face of climate change and strengthens the capacity of the institutions that support them through a combination of efforts. The strategy is threefold and based on the following:

a) The promotion of resilient agriculture practices;
b) the integration of climate change risks into water and land management practices; and
c) The reduction of risk and impact of climate change induced landslides.

The Project has three outputs, described below.

Output 1: Promote resilient agricultural practices in the face of changing climate patterns.

Firstly, building on the UNDP/LDCF's Addressing the Risks of Climate-induced Disasters through Enhanced National and Local Capacity for Effective Actions, the Project will initiate institutional capacity building on modeling, forecasting, and effectively disseminating climate information at the subnational levels to guide planning. It will tailor climate information for agricultural advisories that meets smallholder needs for climate-informed decision- making related to agriculture practices. Additionally, investments in climate-resilient practices involving alternative cultivation techniques, organic farming, and integrated pest management will also be made to support smallholder farmers. The Project will ensure training is delivered to farmers to build awareness on value chains and build capacity on agricultural marketing to promote market linkages.

Output 2: Integrate climate change risks into water and land management practices that affect smallholders

Secondly, to address the barriers related to institutional and community capacities in water and soil management, the Project will seek to scale up climate resilient practices to support sustainable water management and soil stability, and to improve smallholder agricultural productivity. A key intervention will involve water management, capacity building on integrating climate resilient practices in water management and monitoring. For improving soil management, the Project will scale up existing SLM practices and technologies that have been proven to enhance resilience of agricultural land against soil erosion and landslides caused by rainfall variation. This will involve identifying particular SLM interventions to protect against erosion and landslides, technical assistance and training to extension officers and communities to support implementation of SLM practices, investment in SLM using bio-engineering technology in specific areas, and regular soil monitoring to inform planning and policies on soil management. The Project will establish climate resilient water management infrastructure and technology through irrigation systems, dams and storage tanks interventions, as well as building up technical capacity through training on climate resilient water infrastructure construction and maintenance.

Output 3: Reduce the risk and impact of climate change induced landslides during extreme events that disrupt market access.

Finally, to reduce the impact of climate-induced landslides on smallholder market access, the Project will design and implement slope stabilization interventions across key sections of roads that are crucial for market access, complementing the RGoB's investment in climate-resilient roads. To support climate-resilient planning, the Project will also review and enhance road damage information collection and reporting methodology and deliver training on post-monsoon road assessment to improve repair cost estimate capacity.

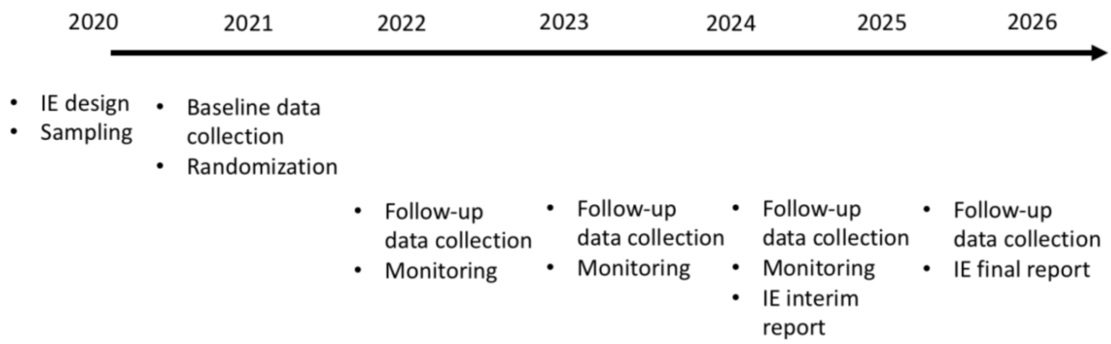
4. Program targeted population, timeframe, and other interventions in the area.

4.1. Targeted population and project time frame

Intended direct beneficiaries of the Project represent 46.5 percent of the rural population of Bhutan, with 27,598 farming households (118,839 people) overall beneficiaries, including 3,344 households (14,400 people) benefitting from enhanced irrigation, 24,000 households (103,346 people) from SLM interventions, and 15,000 households (64,591 people) benefitting from support to resilient agricultural practices. In response to a documented trend of men leaving agriculture and an increasing feminization of the agriculture sector, trainings were tailored to pay particular attention to the needs of women.

The Project activities span over the period 2020-2025. The impact evaluation features a baseline data collection (completed in Q2 of 2021) and originally included several follow-up data collections (scheduled in Q1 of 2022, Q1 of 2023, Q1 of 2024, Q1 of 2025) meant to assess the causal impact of the project, as it is shown in Figure 1. Due to the Covid19 restrictions and other context-specific issues, the first follow-up data collection intended for the first quarter of 2022 did not take place, occurring only in January 2023 (Q1 of 2023), approximately one year later than originally planned.

Figure 1 – original follow-up data collection schedule



4.2. Other interventions with similar objectives, implications for causal impact identification

It is important to highlight that there are other projects and programme targeting similar populations with overlapping objectives. Their presence may have implications for the impact evaluation, depending on the evaluation strategy. Two of these deserve special attention. The UNDP/GEF/LDCF Enhancing Sustainability and Climate Resilience of Forest and Agricultural Landscapes and Community Livelihoods project overlaps in its timeframe with the current project (2017-2021 for the former, 2020-2025 for the latter). It covers 12 dzongkhag and 38 gewog, including current project districts and gewog. Importantly, one of its objectives is to increase the resilience of farmers to climate change through support for diversification, SLM, and climate-smart agriculture, as well as enhanced infrastructure (as is the current project's objective). The Bhutan for Life has a project focused on the management of protected areas, some of which are located within the project districts. Protected areas are expected to experience better infiltration of water into the soil which should minimize both flash-flooding and rainfall-induced slope failure. In that sense, the Bhutan for Life project complements SLM interventions under the current project.

In addition, based on a rapid assessment elaborated and shared by the PMU in March 2023, 74 treatment and 63 control chiwogs have benefited from activities developed by the Government of Bhutan – such as fruit plant' and vegetable seeds' distribution as part of the Million Fruit Tree Project (MFTP) Royal Project. The same project supported farm road construction and maintenance in 12 treatment and 6 control chiwogs. Activities from projects implemented by other institutions – such as support of poly house, mulching plastic sheet, low-cost poly plastic, seeds and seedlings and provision/maintenance of irrigation technologies - have also taken place in 25 treatment and 42 control chiwogs. More details on these interventions across treatment and control chiwogs are described in detail in Section 12.

If all the other projects and interventions present in the area have targeted treated and control chiwogs with similar levels of intensity, our IE results will capture the additional or marginal causal effect of the GCF project, as control chiwogs will serve as a counterfactual for the situation in which these other projects were present in the treated villages, but the GFC program was not implemented. If the activities of all these other interventions with overlapping objectives have been systematically targeted towards control chiwogs, as a systematic response to the absence of the GFC project, we will not be able to capture the additional contribution of the project described in the above counterfactual. In this latter case we will be just comparing two different types of interventions. We will assess this issue in detail in Section 9, after our estimation results are presented.

5. Theory of Change and impacts to be evaluated in first follow-up

It is important to take stock of the various project inputs and activities and make explicit the processes through which improvement in climate resilience can be obtained because of the Project. One part of the Project focuses on making the physical environment more climate-resilient through hard investments in road works and by transforming the irrigation system. In addition, the Project provides farmers with skills to become individually and collectively resilient to climate change. This second part, in the form of soft investments, is locally implemented with the support of gewog agricultural extension services and dzongkhag agriculture sectors. The Project is best seen as developing an integrated approach, exploiting the possible complementarities between hard and soft investments in building climate resilience.

Climate resilience is an elusive concept, which makes it challenging to measure (Béné, 2013). Resilience is about capacity; capacity of the physical environment to endure climate change, and capacities of individuals and of communities to anticipate, absorb, and adapt to climate change. Higher socio-ecological resilience comes from a higher capacity to tolerate disturbances (Carpenter et al., 2001). Social resilience requires learning and social organization to maintain the functioning of the social system in response to a disturbance (Maclean, Cuthill and Ross, 2014). It also requires individuals and communities to resist and absorb the disturbance by mobilizing strategies and resources. As a result, resilience cannot be approached in a static framework; it is the result of an adaptative process that may only be measured through time, as disturbances unfold. To quantitatively assess the impact of the Project on resilience, several rounds of survey data are being collected (prior and after project implementation) and complemented will be complemented with climate information data.

The IE adopts a ‘bottom-up’ approach, focusing on farm-level adaptation and mitigation strategies. The approach will be mainly quantitative, based on the collection of farm household survey data across a representative sample of chiwog in the project dzongkhag. The quantitative data collection will follow farm households through time as they build resilience to climate change. The follow-up data collections will describe the changes experienced in areas exposed to the Project and those not yet exposed. The final objective is to identify in these changes those that can be attributed to project exposure, i.e., the actual impacts of the Project on a range of indicators selected based on the IE Theory of Change.

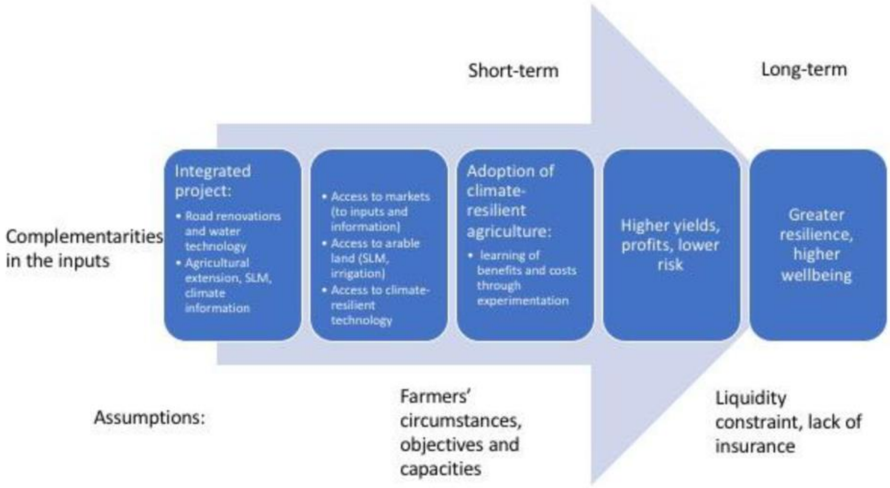
Two main types of adaptation responses are expected from the farmers: (i) a reactive adaptation; and (ii) a precautionary adaptation. Reactive adaptation refers to ex-post temporary coping strategies taken at the household and community level in the event of weather shocks. In contrast, precautionary adaptation is about long-term ex-ante response strategies. Some of these strategies may benefit from investments from government or non-government agencies (e.g., seed banks, climate information system, agricultural extension) because of their public good nature.

Informed by the literature review on transformational agriculture (see de Janvry and Sadoulet (2020) for a comprehensive review), the IE Theory of Change for the Project positions farmers’ adoption of climate-resilient agricultural practices at the center of the logic chain (see Figure 2). Hard and soft project components are expected to show complementarities. For instance, adoption of climate-resilient practices is more likely when farmers also benefit from improved access to water resources (e.g., for irrigation) and markets (e.g., for the purchase of inputs and sale of agricultural products). At the extreme, the expected agricultural transformation may require that all barriers be removed.

The final key outcome of interest is climate resilience. For the Project to be successful, adoption of climate-resilient agricultural practices should lead farmers to profoundly transform their short-term and longer-term risk-management strategies. Investments in roads, irrigation, and climate information services are expected to enhance resilience and adaptative capacity both directly and indirectly through their effect on adoption. Small holders typically pick from a wide array of strategies to cope with realized shocks: dis-saving; emergency borrowing at a high interest rate; sale of productive assets, among others. Before shocks are realized, a high-risk environment may induce farmers to use low-return-low-risk technology, hold precautionary savings (food stocks), and invest in liquid assets (animals). Both sets of strategies are also expected to decrease farmers' resilience. The project innovations, if adopted, have the potential to help farmers avoid taping into these harmful strategies, to improve their food security, increase farmers' investments in productive assets, health, nutrition, and skills, as well as build up life satisfaction.

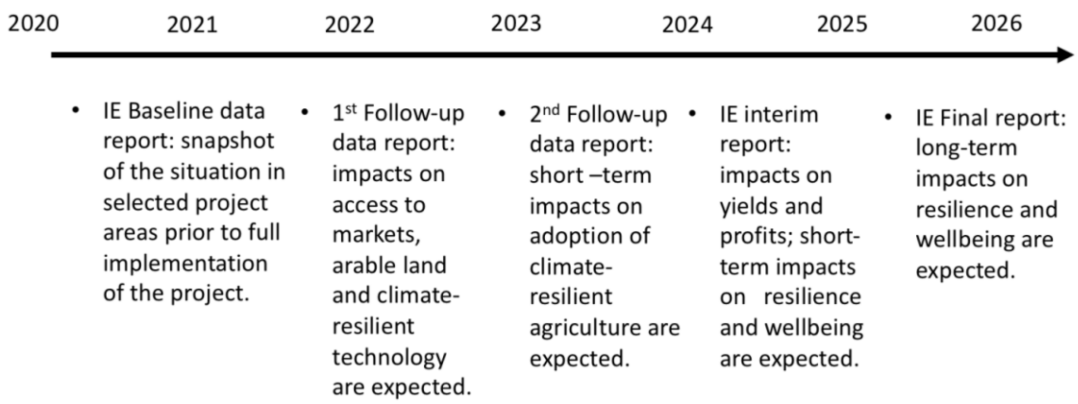
The Project is expected to be successful if hard and soft investments are delivered according to the project design and if they are well-tailored to the needs and capacity of farmers. Adoption of climate-resilient practices in agriculture depends on farmers' circumstances, their objectives, and capacities. Farm technical efficiency is also influenced by these factors. Farmers may need time to experiment and learn about the benefits and costs of climate-resilient practices. Yields may not immediately increase (e.g., because soil quality needs time to improve). Climate-resilient practices may be labor-intensive and difficult to adopt in the context of labor shortages. Their adoption may be costly in the short-term and the returns may be perceived as uncertain. Training should increase knowledge, lowering the impact from uncertainty. But attitudes and practices may take time to change. In addition, farmers may face liquidity constraints that limit the adoption of innovations. Finally, it is possible that farmers adopt the innovations but yields and profit fail to improve because of unforeseen change in their circumstances.

Figure 2 – Theory of Change



As described in Figure 3 below, the first follow-up originally scheduled for first quarter of 2022 was intended to capture the very short impacts related to the project on access to markets, arable land and climate resilient technology, while the second follow-up, planned for the first quarter of 2023, was intended to capture impacts on the adoption of climate resilient agricultural practices. As Q1-2022 did not take place, the Q1-2023 follow-up was designed to also capture the changes expected for the first one.

Figure 3 – Theory of change and original follow-up schedule



6. Experimental design, treatment assignment and sample size

6.1. Impact evaluation design

The quantitative approach to the IE aims to determine the causal impacts from the project. To do so, the study needs to compare the experience in the intervention areas to the experience in areas that are as similar as possible to the intervention areas but where the project is not implemented. In technical terms, it needs to identify a counterfactual, i.e., what farmers would have experienced had they not been part of the project. The impact is then derived by comparing outcomes for those farmers that were serviced by the Project and the outcomes in the counterfactual group of farmers i.e. those who did not. How the counterfactual group is defined determines data collection, in particular the appropriate sampling strategy, and the IE method of choice.

Importantly, the counterfactual group may be receiving benefits from other programme (such as NAPA-3, Bhutan for Life) which offer close substitutes to some of the current project interventions. In other words, the impact assessment provides a measure of project success vis-à-vis the benchmark situation where the project benefits are not being delivered but other close substitutes to the Project may be available. This benchmark situation offers the most appropriate counterfactual, unless the availability of these other program benefits is a systematic response to the absence of the Project currently evaluated. If this is the case, we will be just comparing two different interventions, but we will not be able to capture the additional effect of the program with respect to the counterfactual situation described above. In other words, the control areas in this latter case will not approximate the situation of the treated ones in the hypothetical world in which the treated areas did not receive the program.

This impact evaluation design makes use of two benchmark methods, each applied to a different component of the Project. The first is a randomized control trial (RCT) and will be used to assess the impact of the soft-investment component of the Project. All localities (chiwog) in project districts are eligible for the soft-investment component which heavily relies on the work of local agricultural extension agents for delivery.

The second method is the difference-in-difference (DiD) method and will be used to evaluate the effects of the hard-investment component of the Project. This component includes irrigation and road work to make the infrastructure more resilient to climate change. It only concerns the localities (chiwog) in the catchment areas of these works.

Both methods rely on a valid counterfactual to assess the project's effectiveness. In the RCT, the counterfactual situation is constructed by randomly selecting a sub-set of the project target population to be serviced after the end of the evaluation period.

For the DiD approach, the counterfactual is obtained by following up through time the situation of farmers living in localities both in the catchment area of irrigation and road works (intervention group) and those who are not (comparison group). Importantly, the baseline period should describe the reference situation before the intervention starts delivering benefits to farmers. For DiD to provide a valid estimate of project impacts, trends farmers experience throughout the evaluation period should be the same for those in the intervention group and those in the comparison group. This assumption holds true if all time-varying factors affecting the outcomes of interest have the same impact in the intervention and comparison group.

Prior to the implementation of the IE design, an impact evaluation design report laid these approaches down (December 2020). A series of consultations were carried out on the design of the survey instrument (clarifying the data needed to quantify the main project indicators, or outcomes of interest). In May 2021, a validation meeting on the question of randomization was held in the presence of national, district, and local chiwog stakeholders. To ensure buy-in on the protocols for the study, the risks and constraints related to the IE methods as well as the purpose of IE were discussed, and questions addressed in July 2021.

6.2. Randomized controlled trial for extension services

An RCT draws two groups from the population of beneficiaries. The first step was to identify the target population for this component of the Project. According to the Project, training in climate resilient agriculture, SLM, water use management, and use of climate information should be delivered through gewog extension agents from the eight project districts to farmers in their jurisdiction (chiwog) according to identified needs. The Project thus aims at using gewog extension as a channel to reach out to farmers with newly designed advisory services, activities, and inputs focused on socio-ecological climate-resilience. For the purpose of the evaluation, a representative sample was drawn from the population of farm households in target districts not yet serviced by the project at the time of baseline data collection.

Prior to baseline data collection, the Project timelines were reviewed to identify the areas that could be included in the evaluation as well as the appropriate timing for random assignment. With the help of the project management unit, all chiwog where benefits were not delivered by the time of the baseline were listed. The listed chiwog belonged to two categories: (1) those in the catchment of a future road and irrigation work (R&I chiwog); (2) those that are not targeted with these interventions. Both are expected to benefit from the soft-investment component delivered through gewog agricultural extension agents.

This list provided the population from which the study sample of 150 chiwog in 6 of the 8 project districts was obtained. With the approval of the project management unit and after consultation with local district and gewog stakeholders, the decision was made to start delivering benefits to the treatment group farmers in year 2022 and wait until year 2024 to start delivering benefits to the control group farmers. With such a design, the delivery of benefits is postponed for a randomly selected group of farmers who are similar to the treatment group farmers in all aspects except for the later date for project benefit delivery. As a result, any observed difference in outcomes between treatment and control group during the evaluation period can be exclusively attributed to the project impact. Random assignment was conducted in May 2021, after the study sample was selected and baseline data collection was completed, and before project benefits were distributed in the treatment group chiwog. Half of the chiwogs were assigned to the treated group, the group that will receive the soft program interventions, and the other half to the control group.

6.3. Difference-in-difference research design for infrastructure investments

The Project also aims to assess the impacts of the infrastructure investments made under the Project. To do so, chiwogs in the catchment areas of planned but not yet executed infrastructure work (R&I chiwog) were identified from those where no infrastructure work was planned. The latter are chiwog not ranked high in terms of priority for infrastructure work.

The main benefit of this approach is that it provides us with a baseline reference situation on the experiences and challenges of farmers before the chiwog started benefitting from the Project, i.e., a ‘clean’ baseline from which a comparison of changes before and after project implementation for the two groups (with R&I and without R&I works) can provide an unbiased estimate of the impacts of the hard-investment component of the Project. The main drawback is that the Project had already started or planned to start delivering benefits in years 2020-21, while the baseline data collection had to be postponed to 2021. This had no consequence for the group without R&I work. But in the group with R&I work, only 45 chiwogs were left to include in the study sample. These chiwogs are in six of the eight project districts. The study, therefore, had to limit the impact assessment to these six districts (Tsirang and Trongsa are the two districts not included in the IE sample).

The objective was to sample from each group (with and without R&I work) an equal number of chiwogs to obtain a stratified sample based on whether the chiwog benefitted from the infrastructure work. It was originally aimed at a balanced sample, with the same number of chiwog with and without executed/planned infrastructure work in order to increase the precision of impact estimates. However, the sampling frame for the stratum of chiwog was exhausted with planned infrastructure work (all 45 of them are included in the study sample). Chiwog without R&I were also sampled.

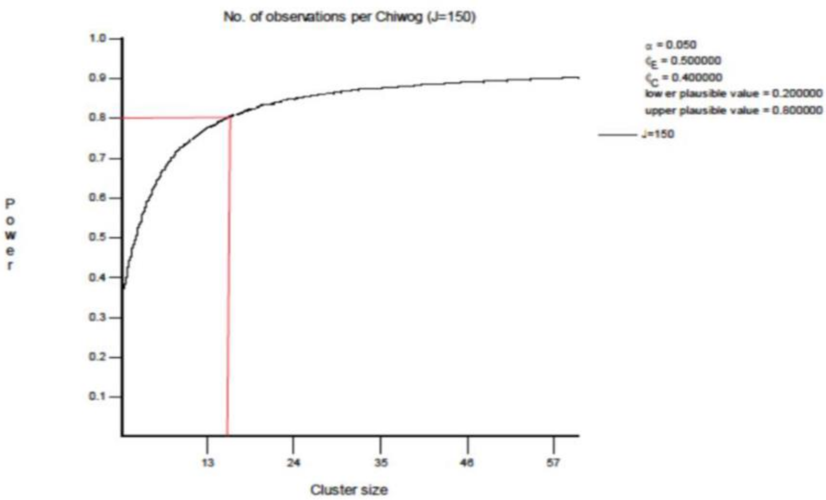
In January 2023 the consultant in charge of the IE evaluation visited the intervention area. Regarding the hard program infrastructure intervention elements, irrigation and roads, the PMU informed the consultant that they are still being implemented, and that several activities within this component in the treated area will be completed during the current 2023 year. As mentioned before, the IE considers a difference in differences design to evaluate the impacts of the hard program components; nevertheless, the real impact of these components will depend on its implementation progress. If progress has been relatively low, it is unlikely that any effect will show up in the short-term IE. Given this context, we consider that a medium-term evaluation taking place during the first quarter of 2024 will be more appropriate to assess the hard intervention package impacts (which, and again depending on program execution, are likely to affect the 2023 agricultural year production)

6.4. Power calculations and sample size

The study sample was calibrated based on power calculations. The objective of the power calculations was to determine the number of clusters (chiwog) and number of observations within clusters (farm households) necessary to statistically detect a minimum project effect size. Chiwogs are the Primary Sampling Unit; farm households are the Secondary Sampling Unit. The main outcome of interest (resilience) is a binary indicator. The results of power calculations are shown graphically; power is plotted against the number of cluster and against the number of observations per cluster.

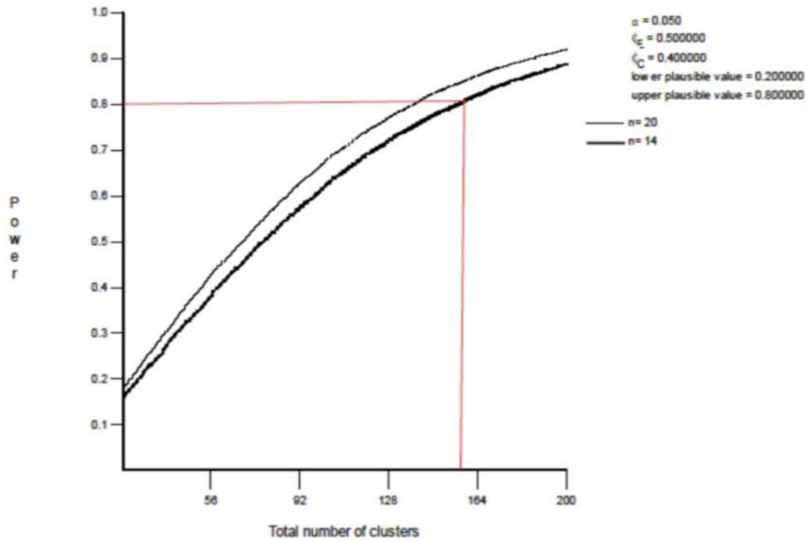
For the binary case, the probability of success was first fixed (probability that the indicator of resilience is equal to one) under the Project (ϕE) and in the control state (ϕC). The smaller the gap between the two values, the more conservative is the power calculation, meaning that the study should then be powered to detect even such a small change when it exists. The power calculations performed at baseline set ϕE=0.5 and ϕC=0.4. By convention, α was set are 0.05. Based on this it was determined how statistical power (y-axis) varies with the number of observations per cluster (n). Power was set at 80% (red lines). The resulting number of observations per cluster is n=14 as it can be seen in figure 4.

Figure 4 – Power Calculation with 150 chiwogs



In the second exercise, the same values for ϕE,ϕc and α were maintained and two sizes per cluster n=14 and n=20 were considered. It was determined how power (y-axis) depends on the number of clusters J (x-axis). As before power was set at 80% (red lines). When n=14, the resulting number of is clusters is J=150.

Figure 5 – Number of Households Based on 80% Power and 150 chiwogs



Based on the above power calculation, the study sample was set at 150 PSUs and 14 households from each PSU. This involved a total sample of approximately 2100 households.

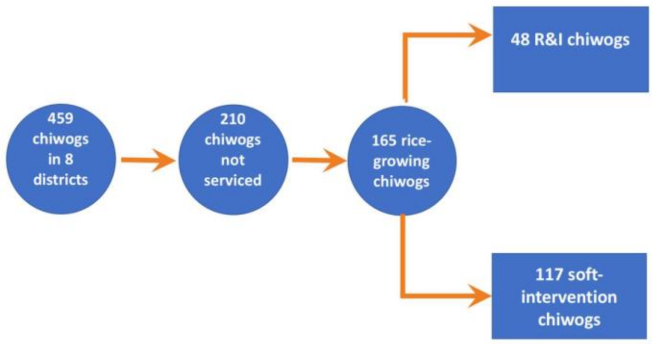
6.5. Sampling frame

To determine the sampling frame, the study started with all 459 chiwogs in the 8 districts, i.e., the total number of chiwogs in the project districts. Based on information provided by the project management unit, these chiwogs were classified in two categories: (1) those already serviced by the Project in year 2020 or that were planned to be serviced in year 2021 and (2) those not already serviced. To obtain a proper description of the situation before farmers started to receive project benefits, all chiwog in category (1) were excluded. That left the study with 210 chiwogs. Ten additional chiwogs were excluded because, based on existing RNR census data for 2019, these chiwogs had no farm households cultivating rice. A further 35 chiwogs were excluded again because, according to the same RNR microdata, they had less than 20 farm households cultivating rice on some of their land and less than 10 respondents from each gender. A final count of 165 chiwog was left in 6 districts, of which 48 were hard-investment R&I chiwog and 117 were not.

For this study, the chiwogs were stratified by whether they were in the vicinity of project road or irrigation (R&I) schemes. Initially, equal numbers of chiwog with and without R&I (75 chiwog of each type) were planned. After field inspection, only 45 (out of 48) R&I chiwog were left that met the inclusion criteria and all of those were included in the sample. In order to have 150 chiwogs, the study had to sample 105 out of 117 chiwogs without R&I. Figure 6 provides a schematic explanation to visualize the sampling frame.

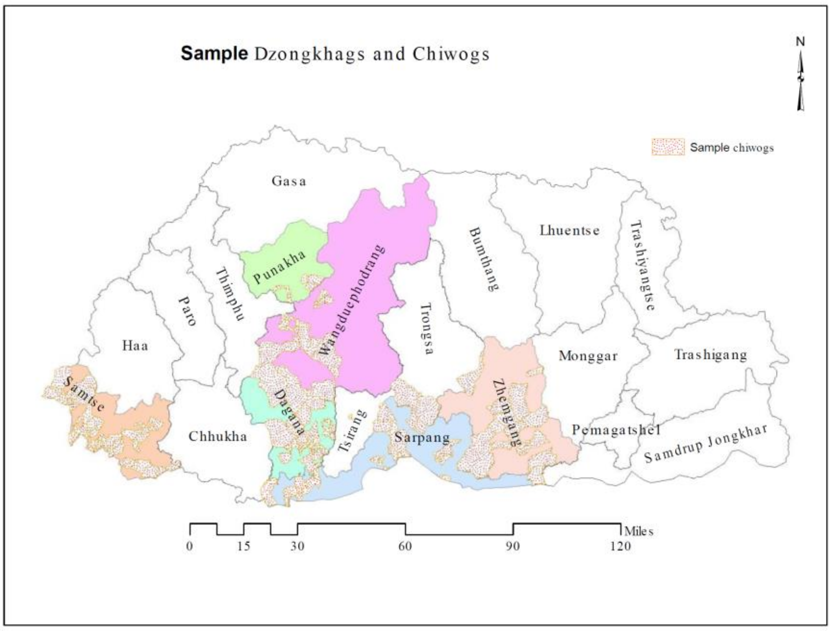
Once the sampling frame was determined, a two-stage sampling procedure was applied: (1) to select 150 Primary Sampling Units (chiwog); and (2) to select farm households within the chiwog. To obtain a stratified sample according to R&I status, all 48 R&I chiwogs of the sampling frame were retained, exhausting the frame for this stratum. The remaining 102 chiwog were obtained by simple random sampling. Figure 7 shows the successfully sampled chiwog (and dzongkhag) for the baseline survey.

Figure 6



Project beneficiaries were distributed in all the 459 chiwogs of the 8 project districts. Chiwog that were already serviced (or planned to be serviced in 2021) were removed, resulting in 210 chiwogs. Only 165 rice-growing chiwog (information obtained from RNR 2019 census) were kept. This final sampling frame includes chiwog located in only 6 of the 8 districts (Figure 8). It comprised of 48 chiwogs located in the vicinity of a Road or Irrigation project intervention. The remaining 117 chiwog in the sampling frame were meant to receive soft-intervention benefits only.

Figure 7 – Map of study district and chiwogs



To sample households within each sample chiwog, a complete enumeration of rice-growing farm households was conducted in each sample chiwog. Once the complete enumeration was completed, a simple random sampling procedure was implemented to select the sample farm households. To ensure gender representativeness of the survey, an equal proportion of respondents of each gender were targeted to be interviewed from each PSU. The respondent type (i.e., gender) was pre-determined through simple random sampling so that enumerators could not choose based on their convenience.

7. Data Sources

7.1. Baseline data – treatment and control balance

The baseline survey covered six of the eight project dzongkhag of Bhutan and finally interviewed a total of 1,816 households that are farming rice on at least some of their land. The survey covered a total of 53 gewog from the six selected dzongkhag. The baseline report checked whether the randomization process actually led to two groups (treatment and control) that were similar at baseline. The baseline report estimated and compared the averages across the two experimental groups (columns 1 and 2 of Table 54) over a number of selected covariates. Column 3 shows the difference in averages across the groups and Column 4 tests whether, as expected by randomization, these differences are equal to zero. As shown in Column 4, none of the differences are statistically different from zero, consistent with randomization. Consequently, estimating a simple difference in outcomes across experimental groups on follow-up data should provide us with causal effects from the project soft-investment component.

Table 7.1. Covariate Balance between Treatment and Control Groups

	Treatment:	Control:	(1) vs. (2)	p-value f~y:
Gender(1=male):mean	0.484	0.454	0.03	0.312
Age(years):mean	47.69	48.135	-0.445	0.617
Formal education (1=Yes):mean	0.287	0.276	0.01	0.708
Gender of the head (1=Male):mean	0.337	0.307	0.03	0.338
Life satisfaction (0=lowest~10=:mean	6.628	6.596	0.031	0.851
Piped water in the dwelling (~Y:mean	0.689	0.697	-0.009	0.845
Wall material (1=Cement-bonde~b:mean	0.291	0.346	-0.055	0.209
Floor material (1=Clays/earthen):mean	0.168	0.119	0.05	0.096
Own TV (1=Yes):mean	0.637	0.659	-0.023	0.545
Lack food (1=Yes):mean	0.225	0.23	-0.004	0.885
Staple self-sufficient (1=Yes):mean	0.749	0.767	-0.018	0.65
# of distinct income sources:mean	1.725	1.663	0.062	0.275
Notice shift (1=Yes):mean	0.885	0.902	-0.017	0.357
# of distinct natural hazards:mean	3.186	3.022	0.164	0.167

For more details on the baseline survey, we refer the reader to the following document: Djabari, H (2021). Baseline Report for the Impact Evaluation (IE) of UNDP-Green Climate Fund (GCF) Project – Supporting Climate Resilience and Transformational Change in the Agriculture Sector in Bhutan.

7.2. Follow-up data

Field data collection for the follow-up survey was conducted from 26 December 2022 to 23 January 2023 by 12 teams consisting of 12 supervisors and 36 enumerators. Data was collected through face-to-face personal interviews using Computer-assisted Personal Interviewing (CAPI). For households where respondents could not be contacted during the first visit, a minimum of two visits were undertaken to reduce non-response rate. The same households enumerated in the baseline survey were intercepted by pre-populating the identifiers, including the name of the household head, in CAPI.

The primary sampling unit (PSU) was chiwog, and households were the secondary sampling unit (SSU). Power calculation was used to determine the number of clusters and observations required to statistically detect an effect. The baseline survey sampled 150 PSUs and 14 households from each, resulting in 1,816 households being sampled. The follow-up survey targeted the same households, with a 93 percent response rate - which can be considered high for household surveys Table 7.2 below compares the total samples collected during the baseline and follow-up surveys.

Table 7.2. Total number of observations collected at Baseline vs Follow-up

Dzongkhag	Baseline		Follow-up	
	Number	Percent	Number	Percent
Dagana	511	28.1	471	28.0
Punakha	93	5.1	84	5.0
Samtse	609	33.5	585	34.8
Sarpang	150	8.3	131	7.8
Wangdue Phodrang	216	11.9	180	10.7
Zhemgang	237	13.1	230	13.7
Total	**1,816**	**100.0**	**1,681**	**100.0**

The study team developed a questionnaire for the follow-up survey with guidance from an international consultant. The questionnaire was based heavily on the baseline survey questionnaire, and supervisor and enumerator manuals were also developed. The questionnaire was digitized in Kobo Toolbox for CAPI and pilot-tested in 30 households in Punakha, with half from the treatment chiwog and half from the control chiwog. A one-day orientation was conducted prior to the pilot-test, and changes were incorporated based on observations from the pilot exercise.

The sampling methodology was developed jointly by national consultants and an international impact evaluation expert, using a scientific approach based on RCT and DID study designs. The sample frame was based on the reliable 2019 RNR census. The survey teams evaluated the sampling strategy in the field, and appropriate measures were taken. The survey questionnaire was translated into Dzongkha, with certain terms translated into other dialects. The survey teams received training to ensure quality data gathering using CAPI format. The survey implementation was continuously monitored, and certain quality assurance protocols were followed during data collection. Quality checks were also carried out during data analysis, including response rate and item non-response.

8. Estimating equations

8.1. Estimating equation for outcomes relates to the soft program component.

Given the random assignment of the soft program components, a simple mean comparison across treated and controls will suffice to capture their causal effect. The mean difference in outcomes across treated and control households can be captured by the following simple linear regression:

$$y_{icd} = \propto + \rho_1 T_{icd} + \mu_{icd} \quad (1)$$

Where y_{icd} is variable that captures the outcome of interest, for example total rice production, for household i in chiwog c in district d. The variable T_{icd} is a binary indicator that captures whether household i in chiwog c in district d belongs to the treated group (if treated, the dummy takes the value of 1, if not it takes the value of 0). Therefore, the parameter ρ_1 captures the causal effect of interest, e.g. the average difference in mean outcomes across treated and controls that is due to the GCF program. The term μ_{icd} is a random error component, which is assumed to be correlated among individuals that belong to the same chiwog. In other words, we assume that the outcome of individuals that belong to the same chiwog can be correlated.

In addition to the simple linear equation expressed in (1), we also estimate a district fixed effect regression. Intuitively, this means that we are controlling for the district in which the chiwog is located, as district characteristics that are fixed in time, such as soil quality or soil slope, are likely to influence household outcomes, e.g. agricultural productivity. The fixed effects regression is given by equation (2) below.

$$y_{icd} = \propto + \rho_2 T_{icd} + \theta_d + \mu_{icd} \ (2)$$

Where in addition to the variables included in equation 1, we add district dummies, given by θ_d. These dummies are intended to capture factors that are generally fixed at the district level and which, as mentioned before, may influence the main outcomes of interest, such as soil quality or slope. As in equation 1, the parameter ρ_2 in equation 2 captures the causal effect of interest, that is, the average difference in mean outcomes across treated and controls. Also, as in equation 1, the term μ_{icd} is a random error component, which is assumed to be correlated among individuals that belong to the same chiwog.

8.1.1. Interpretation of the results from equations 1 and 2.

The parameter of interest in both equations is given by ρ_1 and ρ_2 respectively, which capture average differences in mean outcomes across treated and control households. The results corresponding to equations 1 and 2, which capture the impacts of the soft program components, will be presented using the following table format:

Table 8.1 Format in which RCT results will be presented

	1	2	3	4	5	6
	Mean in control group	Number of observations in control group	Mean in treated group	Number of observations in control group	Raw difference treated - control	FE difference treated-control
Outcome of interest	$\bar{\mu}_{control}$	$N_{control}$	$\bar{\mu}_{treated}$	$N_{treated}$	ρ_1	ρ_2

As observed, column 5 presents ρ_1, which is just the raw difference in means across treated and control units, as estimated by equation 1. That is, column 5 simply presents the difference between the mean in the treatment group, shown in column 3, minus the mean in the control group, shown in column 1. Column 6 presents the difference across treated and control units in the fixed effects regressions, which conditions on district dummies. Intuitively, in the fixed effect regressions first treated and control means within any given district are compared, and then an average for all the district mean differences is obtained. In general, as we will see in section 9, ρ_1 and ρ_2 are relatively similar to each other.

We will also indicate whether or not the estimated differences given by ρ_1 and ρ_2 are statistically significant, that is statistically different from zero, at the standard significance levels. To do this, we add asterisks to the right of ρ_1 and ρ_2. A single asterisk (*), a pair of asterisks (**) and a triplet of asterisks (***) indicate that the observed difference is statistically significant at the 10%, 5% and 1% standard significance levels correspondingly. Statistically significant differences will be taken as evidence that treated individuals mean outcomes are different than control ones. If no asterisk is added, this means that the spotted difference is not statistically different from zero, and therefore, that we do not have enough statistical evidence at this stage of the program implementation to claim that those treated by the intervention performed differently than those in the control group.

8.2. Estimating equation for outcomes related to the hard program component and results interpretation.

To estimate the impact of the hard components of the intervention we will follow a DiD identification strategy, this implies estimating equation (3) below.

$$y_{icdt} = \propto + \gamma I_{cd} + \delta P_t + \rho_3 I_{cd} \times P_t + \mu_{icdt} \quad (3)$$

In this equation, I_{cd} is a dummy which equals to one if the household chiwog of residence belongs to the road and infrastructure group and P_t is a dummy variable which equals one in the post-treatment period (Follow-up period). The treatment effect of interest in this case is captured by the parameter ρ_3, which captures the effect of the program among the treated. This parameter is simply estimated by comparing the pre and posttreatment change in the outcome of interest in the treated group against the same change in the control group. Also, as in equations 1 and 2, μ_{icdt} is a random error component, which is assumed to be correlated among individuals that belong to the same chiwog.

The results corresponding to equation 3, will be presented using the following table format:

Table 8.2 Format in which DiD results will be presented

	Treatment effect
Outcome of interest	ρ_3

As in the previous case, we will also use asterisks to indicate whether the estimated treatment effect is statistically significant, statistically different from zero, at the standard significance levels of 10%, 5% and 1%.

9. Impacts of the soft intervention components

9.1. Impacts on climate-resilient and sustainable agricultural practices knowledge and adoption

One of the project's main objectives is to improve households' knowledge and adoption of climate-resilient and sustainable agricultural practices and technologies. To assess the intervention impacts on this dimension, we first directly asked households about their perceived knowledge of such practices. As it can be observed in Table 9.1, at this stage of the project implementation, just 15% of households in the treated group indicate that they have the necessary knowledge to fully implement these practices in their fields. In the control group, this percentage is similar, 14%, so the difference across treatment and control units is relatively small as well as not statistically significant. This implies that we cannot conclude, at this point of the program intervention, that there are differences in terms of perceived resilient and sustainable practices knowledge across treated and control units.

Table 9.1 – Perceived knowledge of climate resilient and sustainable agricultural practices						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of Individuals who indicates their HHs have the necessary knowledge to fully implement climate resilient and sustainable agricultural practices .	830	0.14	813	0.15	0.012	0.029
		(0.02)		(0.01)	(0.03)	(0.03)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors are clustered at the chiwog level.						

Table 9.1 presents the differences across treated and control units in terms of self-reported perceived and therefore subjective knowledge. However, there are several limitations regarding self-reported, subjective indicators. For example, treated households may report a high level of perceived knowledge just to not disappoint the technical staff in the field, or control households may report a low perceived knowledge in order influence the future decisions related to program assignment. Given such difficulties, it’s highly recommended to include objective indicators in any impact evaluation that assess individuals’ knowledge. To provide a more objective measure of households’ knowledge of climate-resilient and sustainable agricultural practices, we designed a knowledge-test which was based on the material used and provided by the local staff during farmer training sessions (see Annex 1). The test did not only asked households about whether they have heard or not about a given agricultural practice, but it also asked basic and case-specific questions related to the practices - such as mulching and its benefits, the preparation of biochar and bokashi and topics related to hydroponic systems. Using these responses, an aggregate test performance index, which maximum score is 9, was calculated. The results from Table 9.2 suggest that there are no differences at this stage of the program across treatment and control groups. Important to note that the average score for the test in the treated group was just 1.25 out of 9 points. Two factors can explain this low score: first, few individuals have heard about the practices included in the test, and second, even fewer individuals are aware of the benefits and procedures relate to these practices. Take the example of mulching: just 14% of individuals in the treated group have heard about this practice and, on average, less than one mulching’s benefit is correctly identified by the treated population. We can also observe in Table 9.2 that, only in the case of bokashi, there seem to be a statistically significant difference across treated and control units. But only 4%, (less than 1 in 20 households) of treated households report that they have heard about bokashi, and the observed difference with the control group is just about 2 percentage points. Regarding hydroponic systems, note that only 5% of treated farmers report having heard about such systems, compared to 3% in the control group. Moreover, as in the case of mulching, the observed difference across treated and controls is relatively small in absolute size, and not statistically significant.

Table 9.2 - Knowledge of mulching, biochar, bokachi, water harvesting ponds and greenhouses management as assessed by objective test						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Overall test score	830	1.325	813	1.247	-0.078	-0.062
		(0.06)		(0.03)	(0.08)	(0.07)
Test components						
Proportion of HHs who have heard about biochar	830	0.025	813	0.04	0.017	0.018
		(0.01)		(0.01)	(0.01)	(0.01)
Average number of biocahr benefits identified.	830	0.037	813	0.05	0.014	0.016
		(0.01)		(0.01)	(0.02)	(0.02)
Proportion of HHs who have heard about mulching	830	0.158	813	0.14	-0.015	-0.023
		(0.02)		(0.01)	(0.03)	(0.02)
Average number of muching benefits identified.	830	0.259	813	0.19	-0.067	-0.080*
		(0.04)		(0.02)	(0.05)	(0.04)
Proportion of HHs who identify at least one risk related to the uses of clear plastic sheets for mulching	830	0.128	813	0.1	-0.023	-0.023
		(0.02)		(0.01)	(0.03)	(0.03)
Proportion of HHs who have heard about bokachi	830	0.014	813	0.04	0.022**	0.018*
		(0.00)		(0.01)	(0.01)	(0.01)
Average number of possible uses of bokashi identified.	830	0.02	813	0.05	0.031*	0.027
		(0.01)		(0.01)	(0.02)	(0.02)
Proportion of HHs who know how to evaluate quality of bokashi made from rice bran	830	0.002	813	0.01	0.005	0.005
		(0.00)		(0.00)	(0.00)	(0.00)
Proportion of HHs who correctly identify the optimal location for a water harvesting pool	830	0.33	813	0.32	-0.009	-0.003
		(0.03)		(0.02)	(0.03)	(0.03)
Proportion of HHs who have heard about hydroponic systems	830	0.031	813	0.05	0.018	0.015
		(0.01)		(0.01)	(0.01)	(0.01)
Average number of common disease management practices in hydroponic systems identified	830	0.031	813	0.03	-0.003	-0.002
		(0.01)		(0.01)	(0.01)	(0.01)
Average number of preventive measures for proper sanitation to avoid pest and disease and greenhouse identifeid.	830	0.592	813	0.57	-0.020	0.000
		(0.05)		(0.03)	(0.08)	(0.07)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors are clustered at the chiwog level.						

We now explore in Table 9.3 the self-reported implementation of sustainable land management (SLM) practices. We create a binary indicator that takes the value of 1 in the person indicates that his/her households either has implemented some SLM practices or has fully implemented SLM practices. As we can see in Table 3, 46% of individuals in the treated group indicate that their households have partially or fully implemented some SLM practices. In the control group this percentage is 41%. While a 5-percentage point positive difference is observed for the treated relative to controls, it is not statistically significant, so we cannot rule out the null hypothesis of no effect at all.

If we now pay attention to the specific SLM practices described in Table 9.3, we can see that the three most popular ones in the treated and control groups are dry land bench terracing, wet land terrace consolidation and water source protection. In the first two cases, adoption levels in the treated versus de control group are 34% vs 40% and 32% vs 37%, respectively, while in the latter case it is 38% vs 33%, respectively. That is, in some cases the proportion of households adopting the practice is higher in the treated group, while in others it is higher for the control one. Note also that, for none of the practices reported, the observed differences in adoption across treated and control group is statistically significant; so, at this stage of the program intervention, we lack statistical evidence to conclude that the program has improved the adoption of SLM practices.

Table 9.3 – Implementation of SLM practices						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of HHs who consider that they have fully implemented or implemented some climate resilient and sustainable land practices.	830	0.412	813	0.46	0.043	0.055
		(0.03)		(0.02)	(0.04)	(0.04)
Proportion of HHs who consider than more than half theri neighbors adopt climate resilient agricultural practices.	830	0.431	813	0.48	0.046	0.065
		(0.03)		(0.02)	(0.05)	(0.05)
Proportion of HHs who have implemented dry land Bench terracing .		0.401	813	0.34	-0.063	-0.038
		(0.04)		(0.02)	(0.06)	(0.05)
Proportion of HHs who have implemented wet land Terrace consolidation.	830	0.372	813	0.32	-0.048	-0.047
		(0.04)		(0.02)	(0.05)	(0.05)
Proportion of HHs who have implemented Orchard terracing .	830	0.141	813	0.11	-0.030	-0.025
		(0.02)		(0.01)	(0.03)	(0.03)
Proportion of HHs who have implemented contour hedgerows.	830	0.252	813	0.2	-0.048	-0.027
		(0.03)		(0.01)	(0.04)	(0.03)
Proportion of HHs who have implemented contour stone bunds.	830	0.241	813	0.22	-0.018	-0.013
		(0.03)		(0.01)	(0.05)	(0.04)
Proportion of HHs who have implemented check dams/buffer zone .	830	0.063	813	0.05	-0.015	-0.013
		(0.02)		(0.01)	(0.02)	(0.02)
Proportion of HHs who have implemented creation/plantation.	830	0.214	813	0.22	0.002	-0.001
		(0.03)		(0.01)	(0.05)	(0.03)
Proportion of HHs who have implemented Land Stabilization.	830	0.211	813	0.16	-0.048	-0.044
		(0.03)		(0.01)	(0.04)	(0.04)
Proportion of HHs who have implemented Water source protection.	830	0.333	813	0.38	0.052	0.060
		(0.04)		(0.02)	(0.06)	(0.05)
Average Total number of agricultural practices implemented by HHs	830	2.228	813	2.01	-0.215	-0.149
		(0.21)		(0.07)	(0.27)	(0.25)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors are clustered at the chiwog level.						

9.2. Impacts on agricultural, water and climate information technology adoption

Another key objective of the GFC program is to encourage and support households´ adoption of climate resilient technologies, such as polyhouses and greenhouses, as well as water storage and water saving technologies. As it can be observed in Table 9.4, the level of adoption of such technologies is still relatively low in the treated group, and not higher, from the statistical point of view, than the adoption level observed in the control one. In the case of polyhouses or greenhouses for example, they have been adopted by 14% of households in the treated group and by 17%of households in the control one, and the observed 3-percentage point difference across groups is not statistically significant. In the case of all the other technologies included in Table 9.4, such water storage and saving technologies, the adoption levels in the treated group are always below 10%, and relative similar to those reported in the control group.

Table 9.4 – Adoption of poly houses/greenhouses – aerobic/hydroponic/vertical garden techniques - water storage and water saving technologies						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of HHs who have a poly house or greenhouse.	830	0.167	813	0.140	-0.027	-0.036
		(0.013)		(0.012)	(0.029)	(0.028)
Proportion of HHs who have implemented, aerobic, hydroponic or vertical garden techniques.	830	0.008	813	0.004	-0.005	-0.006
		(0.003)		(0.002)	(0.006)	(0.007)
Proportion of HHs who have a water storage technology (earthen ponds, concrete tanks, syntax tanks, others) .	830	0.040	813	0.038	-0.002	-0.001
		(0.007)		(0.007)	(0.015)	(0.014)
Proportion of HHs who have water saving technology (drip irrigation / sprinkler)	830	0.072	813	0.089	0.016	0.020
		(0.009)		(0.01)	(0.029)	(0.028)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors are clustered at the chiwog level. Yes=1						

Improved seeds are also among the technologies promoted in the context of the intervention. Regarding the adoption of such seeds, and only focusing on households that cultivated rice during the last cropping season, there is not statistically significant evidence to conclude that adoption levels in the treated group are higher than in the control one. As we can observe in Table 9.5, the point estimate for the level of adoption of locally produced improved seeds is about 43% for treated households and 38% for control ones. While there is a 5-percentage point observed difference in favor of the treated group, it lacks statistical significance, and therefore we cannot conclude that it is statistically different from zero.

Table 9.5 – Adoption of improved rice seeds						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of HHs that use improved / climate resilient locally produced rice seeds	565	0.382	607	0.43	0.046	0.022
		(0.04)		(0.02)	(0.06)	(0.06)
Proportion of HHs that use improved / climate resilient not locally produced rice seeds	565	0.117	607	0.11	-0.006	-0.006
		(0.02)		(0.01)	(0.03)	(0.03)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors are clustered at the chiwog level.						

Another important project goal is to promote the access and effective use of weather information systems. The results in Table 9.6 suggest that more than half of treated individuals report having received weather/climate information or accessed weather forecast reports during the year 2022. The observed proportions in the treated group are however similar to the ones observed among control households, and almost in all cases we lack statistical evidence to conclude that the program had an impact. Only in one case (Table 6) we observe a statistically significant difference across treated and control households. This corresponds to the proportion of households that reported that they had to predict weather during the last cropping season. In this case, the difference across treated and control individuals is statistically significant in the Fixed Effect regressions. We nevertheless must be cautious with this result given the relatively high number of outcomes we are analyzing. As the confidence level set for the impact evaluation is 5%, our Type-I error is also 5 percent, which implies that out of every 100 outcomes analyzed, 5 will show up as statistically significant just as a result of pure luck, even if the true impact of the intervention is 0.

Table 9.6 – Access to and adoption of weather information systems						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of HHs that eceived any weather/climate information in last 12 months.	830	0.596	813	0.63	0.035	0.033
		(0.03)		(0.02)	(0.04)	(0.04)
Proportion of HHs that this information to inform agricultural decisions in last 12 months.	495	0.776	513	0.75	-0.027	-0.016
		(0.03)		(0.02)	(0.04)	(0.03)
Proportion of HHs that received forecast/warning information in 2022.	830	0.548	813	0.58	0.032	0.039
		(0.03)		(0.02)	(0.04)	(0.03)
Proportion of HHs that accessed a weather forecast in 2022.	830	0.624	813	0.67	0.043	0.046
		(0.03)		(0.02)	(0.04)	(0.03)
Proportion of HHs that had to predict weather forecast during last cropping season.	830	0.434	813	0.51	0.074	0.093**
		(0.04)		(0.02)	(0.05)	(0.05)
Proportion of HHs that made farm decisions based on weather prediction during last cropping season.	830	0.347	813	0.4	0.056	0.070
		(0.03)		(0.02)	(0.05)	(0.04)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors are clustered at the chiwog level.						

9.3. Impacts on agricultural activity and agricultural sales

9.3.1. Impacts on rice production, sales and inputs

The results in the previous sections suggest that the level of knowledge and adoption of climate-resilient and sustainable agricultural practices and technologies is, on average, not higher in treated areas than in untreated ones. Given these results, and considering the program theory of change, it is unlikely that there will be statistically significant differences across treated and control areas in terms of agricultural productivity. We will explore this in more detail in the current section of the report.

As we can observe in Table 9.7, during the last rice cropping season in 2022, 75% and 68% of interviewed households reported cultivating rice in the treated and control group respectively. While the point estimate for this proportion is higher for the treated, the 7-percentage point difference across groups is not statistically significant. Note also that cultivated rice area is relatively similar across treated and controls, 0.42 vs 0.40 acres respectively. Also, there are no major differences in terms of irrigated or rainfed area. While on average 86.6% of the cultivated rice area is reported as irrigated in control chiwogs, this percentage is about 84% in treated ones. In terms of rice productivity, treated controls report on average 602 kg-per-acre during the last cropping season, while control ones report 650 kg-per-acre. While this last point estimate suggests a higher productivity for the control group of about 48 kg per acre, this observed difference lacks statistical significance, so it is not statistically different from zero.

Table 9.7 - Impacts on rice cultivated area, total production and productivity during last cropping season						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of HHs that cultivated rice during the last cropping season.	830	0.681	813	0.747	0.066	0.065
		(0.016)		(0.015)	(0.049)	(0.042)
Average total rice area cultivated in acres	830	0.400	813	0.419	0.020	0.023
		(0.019)		(0.018)	(0.041)	(0.037)
Percentage irrigated area	466	0.876	480	0.84	-0.041	0.019
		(0.02)		(0.02)	(0.04)	(0.03)
Percentage rainfed area	466	0.017	480	0.02	0.003	0.003
		(0.01)		(0.01)	(0.01)	(0.01)
Percentage mixed-type area	466	0.071	480	0.13	0.056*	0.022
		(0.02)		(0.02)	(0.03)	(0.03)
Percentage upland cultivation area	466	0.036	480	0.02	-0.019	-0.045**
		(0.02)		(0.01)	(0.02)	(0.02)
Average total production obtained in kg	830	280.589	813	257.268	-23.321	-19.370
		(13.34)		(12.18)	(29.51)	(26.58)
Aveage rice productivity kg -acre (production obtained / total area cultivated)	362	650.349	385	602.733	-47.616	-60.376
		(31.797)		(28.648)	(56.586)	(54.311)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Table 9.8 – Impacts on rice loses during last cropping season						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Total amount of rice lost in kg during last cropping season	565	112.257	607	105.07	-7.189	-2.998
		(8.60)		(4.99)	(11.02)	(9.026)
Percentage lost due to wildlife depredation	565	60.306	607	58.73	-1.578	-1.586
		(5.01)		(3.24)	(6.52)	(6.036)
Percentage lost due to extreme weather	565	26.276	607	25.6	-0.675	0.244
		(3.23)		(2.32)	(4.47)	(3.696)
Percentage lost due to pest and diseases	565	25.016	607	19.85	-5.169	-5.036
		(2.93)		(1.88)	(3.88)	(3.45)
Percentage lost due to post harvest losses	565	0.658	607	0.89	0.233	0.21
		(0.18)		(0.13)	(0.25)	(0.247)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Table 9.8 provides additional information related to rice production losses during the last cropping season due to difference causes, among them extreme weather events. In this case, we only focus on those individuals that cultivated rice during the last 2022 cropping season. On average, treated and control units lost relatively similar amounts of rice production in total, 105 kg. Vs 112 kg., due to each of the causes presented in Table 8. As we can observe in this Table, for none of the causes listed in Table 8, such as extreme weather or wildlife depredation, there are statistically significant differences across treated and control individuals.

If we consider total rice production in the last 12 months instead of the last rice cropping season, we also do not observe statistically significant differences across treated and control households, as it is shown in Table 9.9 below. As in Table 9.8, average rice productivity in Table 9 is higher for control units than for treated ones, but the relatively small 64 kilograms-per-acre observed difference is not statistically different from 0.

Table 9.9 – Impact on rice production last 12 months						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average total rice production in kg	830	474.274	813	546.982	72.708	58.104
		(18.057)		(19.653)	(49.66)	(42.003)
Average total rice area	830	0.836	813	0.889	0.053	0.058
		(0.030)		(0.030)	(0.079)	(0.064)
Average rice productivity kg per acre	557	850.688	598	786.62	-64.073	-100.426
		(127.92)		(26.97)	(133.26)	(137.36)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

We have already shown in the previous sections that there are not statistically significant differences among households in terms of adoption of rice improved seeds. We now explore whether or not there are differences in terms of the rice area that is cultivated with such type of seeds. As we can observe in Table 9.10 below, while the proportion of rice area cultivated with improved seeds among treated farmers is 26%, among control ones this is 29%, and the observed 3-percentage point difference is not statistically significant. Note also that there is almost no use of non-locally produced improved seeds across neither treated nor control households.

Table 9.10 – Use of improved seeds in rice land area						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average total rice area with improved / climate resilient locally produced rice seeds in acres	565	0.286	607	0.26	-0.022	-0.024
		(0.04)		(0.02)	(0.05)	(0.06)
Average total rice area with improved / climate resilient not locally produced rice seeds in acres	565	0.009	607	0.01	-0.000	-0.001
		(0.00)		(0.00)	(0.00)	(0.00)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Table 9.11 – Inputs expenses related rice production last cropping season						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average total amount spent on herbicides	565	159	607	196.49	37.493	36.988
		(40.83)		(19.86)	(60.40)	(32.65)
Average total amount spent on insecticides	565	12.777	607	12.58	-0.194	0.662
		(3.24)		(2.63)	(4.39)	(3.82)
Average total amount spent on fungicides	565	0.000	607	1.65	1.647	1.995
		(0.00)		(1.17)	(1.14)	(1.31)
Average totalquantity of chemical fertilizer used	565	67.428	607	162.22	94.794	73.631
		(43.64)		(91.31)	(106.15)	(104.80)
Average total amount spent on chemical fertilizer	565	252.494	607	215.65	-36.840	-24.864
		(92.10)		(28.8)	(108.32)	(93.80)
Average totall amount spent on compost manure	565	43.87	607	27.57	-16.301	-8.067
		(10.98)		(4.22)	(13.29)	(12.41)
Average total amount spent on power tiller hire	565	1216.216	607	1267.54	51.326	57.831
		(165.00)		(107.03)	(249.36)	(207.43)
Average total amount spent on tractor hire	565	483.329	607	554.7	71.366	95.036
		(210.74)		(95.7)	(265.75)	(269.57)
Average total amount spent on labor	565	3447.788	607	3418.5	-29.287	-41.923
		(444.57)		(269.24)	(563.09)	(652.36)
Average totall amount spent on rice inputs	565	5682.902	607	5856.91	174.006	191.289
		(561.42)		(329.98)	(758.17)	(778.37)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Finally, regarding expenses with rice production's inputs, and only focusing on those individuals who reported that they cultivated rice during the last cropping season, we also conclude that there is not statistically significant difference across treated and control units. As we can see at the very end of Table 9.11, expenses incurred with inputs for rice production are relatively close among treated and control farmers, and the observed difference is relatively small, just 174 Nu, and not statistically different from zero.

All in all, at this point of the intervention, we lack statistical significance evidence to conclude that the soft elements of the program have impacted the rice related agricultural activity in the treated group relative to the control one.

9.3.2. Impacts on other crops agricultural area

The type of climate resilient and sustainable land management agricultural practices and technologies promoted by the GCF program have also the potential to affect the productivity and returns of crops other than rice in the intervention area. In this section, we will explore whether we have supporting statistical evidence to conclude that this has been the case.

In Table 9.12 we explore differences among treated and control units in terms of the agricultural area of crops typically grown in the chiwogs that are part of the study during the last 2022 cropping season. In Table 9.3 we do the same, but we focus on the last winter cropping season. As we can observe, in general the differences in terms of agricultural cultivated area for crops such as potato, maize and wheat across treatment and control farmers is small and not statistically significant. We do, however, find evidence of statistically significant differences in two cases: during the last cropping season control units cultivated a higher area of cardamom, while during the last winter cropping season treated farmers seem to have cultivated a higher area of chilies, although in both cases the spotted difference is only statistically significant at the 10% significance level and, in the second case, only for the fixed effects regression. Again, as mentioned before, when testing a considerable number of outcomes, we may get statistical significances in a few cases by pure luck (if the significance level is 5%, in 5 out of 100 outcomes estimated), even if the true effect is equal to zero.

Table 9.12 – Cultivated area for other crops last cropping season

	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average maize area grown (Acres)	830	0.469	813	0.370	-0.099	-0.078
		(0.05)		(0.020)	(0.07)	(0.06)
Average wheat area grown (Acres)	830	0.04	813	0.041	0.001	-0.006
		(0.01)		(0.01)	(0.01)	(0.01)
Average potatoes area grown (Acres)	830	0.057	813	0.055	-0.002	-0.002
		(0.01)		(0.005)	(0.01)	(0.01)
Average chillies area grown (Acres)	830	0.05	813	0.058	0.008	0.008
		(0.01)		(0.004)	(0.01)	(0.01)
Average oranges area grown (Acres)	830	0.236	813	0.200	-0.036	-0.015
		(0.05)		(0.020)	(0.06)	(0.05)
Average cardamom area grown (Acres)	830	0.193	813	0.126	-0.067*	-0.052
		(0.03)		(0.012)	(0.04)	(0.04)
Average arecanut area grown (Acres)	830	0.058	813	0.068	0.011	0.016
		(0.01)		(0.006)	(0.02)	(0.02)
Average ginger area grown (Acres)	830	0.039	813	0.053	0.014	0.012
		(0.01)		(0.006)	(0.02)	(0.02)

*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.

Table 9.13 – Cultivated area for other crops last winter cropping season						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average maize area grown (Acres)	830	0.09	813	0.102	0.012	0.012
		(0.02)		(0.012)	(0.03)	(0.03)
Average wheat area grown (Acres)	830	0.016	813	0.028	0.012	0.005
		(0.01)		(0.005)	(0.01)	(0.01)
Average potatoes area grown (Acres)	830	0.044	813	0.041	-0.003	-0.005
		(0.01)		(0.005)	(0.02)	(0.02)
Average chillies area grown (Acres)	830	0.021	813	0.033	0.012	0.012*
		(0.00)		(0.003)	(0.01)	(0.01)
Average oranges area grown (Acres)	830	0.056	813	0.051	-0.005	0.001
		(0.02)		(0.011)	(0.03)	(0.02)
Average cardamom area grown (Acres)	830	0.041	813	0.017	-0.024	-0.022
		(0.01)		(0.007)	(0.01)	(0.01)
Average arecanut area grown (Acres)	830	0.034	813	0.044	0.010	0.013
		(0.01)		(0.008)	(0.02)	(0.01)
Average ginger area grown (Acres)	830	0.015	813	0.018	0.002	0.001
		(0.01)		(0.004)	(0.01)	(0.01)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

9.3.3. Impacts on greenhouse – polyhouse production

The program has also promoted the adoption of poly houses and greenhouses.. In this short section we explore the potential short-term impacts of the program on the total area cultivated and total sales obtained from production grown under a poly house or greenhouse. As we can observe, the point estimates for total area and value of sales are in this case higher for control units, 0.048 acres in area and 302 Nu in sales versus 0.036 acres and 166 Nu in the treated group, but the observed differences are not statistically significant. As in the case of rice production and other typical crops in the area, we lack the necessary statistical evidence to conclude that there are differences across treated and control units regarding the adoption of greenhouses and-or polyhouses.

Table 9.14 – Cultivated crops under poly house or green house						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average total crop area cultivated under green house or poly house - acres	830	0.048	813	0.036	-0.012	-0.014
		(0.01)		(0.005)	(0.01)	(0.01)
Average total value of sales from production obtained in green house or poly house - Un	830	302.214	813	166.255	-135.960	-129.647
		(84.35)		(40.98)	(97.73)	(106.62)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

9.4. Impacts on income and expenses, perceived wellbeing and resilience to climate change

We now explore in Table 9.15 potential differences across treated and control units in terms of income, perceived wellbeing and perceived resilience to climate change. With respect to total income, while the point estimate is higher for treated households by approximately 20,000 Nu., the observed difference is not statistically significant. Note however, that income from agricultural activities appears slightly higher for control units that treated ones, but as before, the difference across groups is not statistically significant. There are also not statistically significant differences across groups in terms of total spending, food expenditures, non-food expenditures and amounts invested in equipment and tools.

Table 9.15– Impacts on income, expenses and investments in farm equipment and tools						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average total HH income - Nu.	830	79,377.36	813	100,118.34	20,740.980	23,186.121
		(3,836.30)		(15,074.6)	(16,377.05)	(18,409.08)
Average income earned from agriculture products - Nu.	826	38,926.15	806	36,398.89	-2,527.26	-1,129.62
		(1,657.42)		(1,550.6)	(4,223.538)	(4049.49)
Average total expenditures - Nu.	830	52,550.254	813	56,440.66	3,890.409	1,975.380
		(2,468.58)		(1,669.9)	(3,909.72)	(2,746.41)
Average food expenditures - Nu.	830	5,317.201	813	5,356.19	38.991	77.872
		(133.13)		(97.9)	(190.70)	(182.94)
Average non-food expenditures - Nu.	830	47,233.055	813	51,084.47	3,851.418	1,897.507
		(2,406.94)		(1,645.9)	(3,836.44)	(2,682.56)
Proportion of HHs that invested in farm equipment and tools.	830	0.04	813	0.04	0.003	0.007
		(0.01)		(0.01)	(0.02)	(0.01)
Average amount invested in farm equipment and tools - Nu.	830	4,592.47	813	5,508.14	915.67	1,060.653
		(558.426)		(665.302)	(1,223.45)	(1,070.99)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

In Table 9.16 we explore some indicators directly connected to life satisfaction and the wellbeing of individuals. We asked individuals to visualize a ladder with 10 steps, in which the top one represented the best possible life for the individual and the bottom one the worst. We then ask households to indicate which step of the ladder they felt they were standing at the time of the survey. As we can observe, both treated and control individuals placed themselves around the sixth step, and the spotted difference across groups is minimal. We also asked households questions related to food security and access to drinking water. As we can observe in Table 9.16, there are not statistically significant differences across groups in these cases either, or the reported point estimates are relatively close. For example, while 16% of households in the treated group reported that they worried about food self-sufficiency in the last 12 months, 14% of households in the control group reported the same. The 2-percentage point observed difference in this case is not statistically different from zero.

Table 9.16 – Impacts on perceived wellbeing, food security and water access						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Household ladder position	830	6.049	813	6.1	0.055	-0.032
		(0.09)		(0.07)	(0.17)	(0.12)
Proportion of HHs ataht t one point of time in last 12 months worried about food self-sufficiency.	830	0.141	813	0.16	0.015	0.016
		(0.02)		(0.01)	(0.02)	(0.02)
Proportion of HHs that experienced a situation in which they did not have sufficient food to ensure that every HH member could have at least two meals in one day.	830	0.042	813	0.04	-0.002	-0.003
		(0.01)		(0.01)	(0.01)	(0.01)
Proportion of HHs that have access to water by pipe in dwelling/compound.	830	0.516	813	0.54	0.028	0.048
		(0.03)		(0.02)	(0.04)	(0.03)
Average number of days HH did not have access to drinking water in last moth	830	2.387	813	2.81	0.428	0.367
		(0.26)		(0.20)	(0.47)	(0.47)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Regarding vulnerability to weather events, we can observe in Table 9.17 that while 11% of households in the treated group reported losing land due to soil erosion since 2021, this percentage is about 8% in the control group. The difference 3-percentage point difference across groups is however not statistically significant. To measure perceived vulnerability, we asked households about the potential expected losses that they would experience next year in the case of an extreme weather events. As we can see in Table 9.17, approximately 64% of respondents in the treated group indicate that they will lose less than half their total production, while 60% of those in the control group responded in a similar manner. While this indicates a slightly lower estimated vulnerability for the treated group, the observed 4-percentage points difference is not statistically significant. Important to note that, in this case, a higher proportion is related to a lower level of vulnerability. We do, however, observe a statistically significant effect when we ask individuals about the vulnerability of their neighbors. In this case, 65% of treated individuals indicated that their neighbors will lose less than half of their rice production next year, while this percentage is around 59% in the control group. The observed difference of approximately 6-percentage points is statistically significant; however, we must be cautious about this result given the large number of outcomes being analyzed.

Table 9.17 – Impacts on vulnerability and vulnerability perceptions

	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of HHs that have lost land to soil erosions since April 2021	830	0.081	813	0.11	0.025	0.024
		(0.01)		(0.01)	(0.02)	(0.02)
Proportion of HH that consider that in an extreme weather event they will lose less than half of next year rice production.	830	0.6	813	0.64	0.037	0.041
		(0.03)		(0.02)	(0.04)	(0.03)
Proportion of HH that consider that in an extreme weather event their neighbors will lose less than half of next year rice production.	830	0.589	813	0.65	0.060*	0.064**
		(0.03)		(0.02)	(0.04)	(0.03)

*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.

10. Impacts of the hard intervention components

As mentioned in Section 3 of this report, the program also contemplates the provision and maintenance of irrigation and road infrastructure. However, as described in the baseline report related to this impact evaluation, the assignment of the hard components was not random, so the comparison of means across units that did and did not receive the related interventions will not provide us with their causal effect. In total, 45 chiwogs of the total 150 included in the study received the infrastructure components of the project.

Given the lack of random assignment of the hard intervention components, the original impact evaluation framework proposed a DiD design in order to estimate the effects of these components. The DiD logic is relatively simple, and it just implies comparing the pre- and post-treatment change in the variable/outcome of interest in the group that received the intervention against the same change in the group that did not receive it. Under the assumption of parallel trends, this comparison allows the researchers to recover the effect of interest. The parallel trends assumption implies that had the program been absent, the pre-posttreatment trend/change of the variable of interest in the intervention and no intervention areas would have been the same.

Table 9.18 shows the hard components' impacts on road connectivity and irrigation. The results indicate that farmers within the area served by the hard project components are 5 percentage points more likely to report that their farm is connected to a paved road, and that they spend 154 Nu less to transport their produce to their markets, relative to those outside the irrigation and road intervention area. However, these point estimates lack statistical significance, and therefore are not statistically different from zero. Table 18 also shows that treated farmers are 6 percentage points less likely to report that their road network is reliable and 1 percentage point less likely to report that their irrigation system is reliable, but again these point estimates lack statistical significance.

Table 9.18 - Impacts on Road Connectivity and Irrigation		
	Treatment effect	Obs
Proportion of HHs which farm isconnected to paved road	0.05	3561
	(0.06)	
Harvest transportation cost to markets - Nu.	-154.61	3561
	(363.79)	
Proportion of households that consider that their road network is reliable.	-0.06	3561
	(0.05)	
Proportion of households that consider that their irrigation water reliable.	-0.01	3561
	(0.06)	
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.		

Regarding the hard components impacts on rice production, Table 9.19 shows that farmers within the intervention area report 0.13 more acres of cultivated land and a 9-percentage increase in irrigated land relative to the control group. They also report a higher total production of about 41kg, however, as in the previous cases, all these estimates are not statistically significant.

Table 9.19 - Impacts on rice cultivated area, total production and productivity during last cropping season		
	Treatment effect	Obs
Total rice area cultivated - acres	0.13	3,561
	(0.08)	
Percentage of rice irrigated area	0.09	2,300
	(0.07)	
Production obtained - kg	41.28	3,561
	(51.66)	
Rice productivity kg/acre	-8.33	2,300
	(67.25)	
Total rice quantity sold - kg	5.38	3,561
	(7.80)	
Total transportation expenses for quantity sold - Nu.	-3.22	3,561
	(7.95)	
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.		

Finally, Table 9.20 presents the DiD estimates for the income and expenditure related variables. While farmers in the treated area report higher total income, they also report lower income from agricultural sources. However, these two point-estimates are not statistically significant.

Overall, at this stage of the program implementation, the statistical evidence from the first follow-up does not allow us to conclude that the hard components of the program have had an impact over the rice agricultural activity in the area and the total income and expenses of the individuals included within the irrigation and road project zone.

Table9. 20 – Impacts on income and expenses		
	Treatment effect	Obs
Total HH income - Nu.	22,940.12	3,561
	(17,044.48)	
Total HH income from agricultural products - Nu.	-1,430.92	3,259
	(5,075.94)	
Total HH xpenditures - Nu.	3,094.75	3,561
	(5,071.02)	
Total HH food expenditures - Nu.	-72.70	3,561
	(350.16)	
Total HH non-food expenditures - Nu.	3,167.45	3,561
	(4,908.66)	
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.		

10. Impacts among female-headed and male-headed households

We have also explored the possibility that the intervention could have generated impacts only among female-headed households or only among male-headed households for certain dimensions of the intervention. To test for this, we estimated separate regressions for the two gender groups. The results for the female regressions for the soft program components are shown in Tables B1 to B17 in the Appendix, while the results for the corresponding male regressions are shown in Tables C1 till C17 in the Appendix. Note that in the case of Tables B1 to B17 and C1 to C17, we only focus on the soft-program components.

Overall, the results for the gender soft-components related regressions are similar to those in the aggregate ones, but a few differences appear that deserve some discussion, particularly in the case of the female-headed households. While in general there is little evidence that treated female- or male-headed households have improved their knowledge and adoption of resilient and sustainable land management practices related to control ones, among treated female-headed households there is a statistically significant higher knowledge of hydroponic systems than control female-headed ones, 7% vs. 2%. However, we also observe a statistically significant lower implementation of orchard terracing and contour hedgerows, 6% vs 14% and 14%vs 26%, respectively. Female-headed households also report a statistically significant lower proportion of rice irrigated area, 78%vs 88%, but also a statistically significant higher proportion of mixed type area, 19% vs 7%. Interestingly, treated female households report a statistically significant higher production of rice than control ones when the full 2022 year is considered, 617 vs 480 kilograms, as well as a statistically significant higher productivity for rice, 890 vs 709 kilograms per acre (181 more kg-per-acre more that control units).

Regarding male-headed households, there are not major difference with respect to control male-headed ones. It is relevant however to mention that, during the last cropping season, they experienced a lower rice productivity that control ones, 628 vs 716 kilograms per acre. Nevertheless, this difference is statistically significant only at 10% significance level.

With respect to the hard program components, there is only a single statistically significant effect and only for female headed households. Those in the irrigation and road area produce 178 kg-per-acre per more rice than those not served by this hard-program components, and the effect is statistically significant only at the 10% significance level. Note that this effect is close in size to the one we obtained when we compared treated and control female-headed households in the soft-components program RCT regression (the gender specific table results for the hard component of the project are not presented in this report but can be provided at any time upon request).

It is important to highlight that the sampling framework related to the IE was conceived taking as reference the total aggregate effects, and not the effects by gender. Therefore, we should take these results with caution, and evaluate whether they remain in the next follow-ups. Also importantly, we strongly suggest the PMU to carefully analyze the female-headed household results in order to better understand whether they make sense under the lens of the program intervention theory of change and implementation timeline.

11. Externalities.

Our estimation of the program causal effects will be biased in the presence of learning externalities. Such externalities may occur if control households learnt from their treated neighbors about the program interventions, more specifically those related to information provision and training on agricultural practices and technologies. In this situation, our estimations will likely underestimate the real impact of the program, that is, the size of our estimates will be lower than the true effects. Given that in several cases the control units are located relatively close to treatment areas, as observed during the consultant fields visits in January 2023, the presence of externalities is a real concern in the area of study. While the original IE design was not conceived to assess the presence of such learning externalities, we may still be able to approximate their presence by exploiting the georeferenced location data of households obtained at baseline. Unfortunately, the GPS data collected at baseline is quite noisy and the average precision error is about 4 km. Moreover, during collection of this data at baseline, accuracy thresholds were not established, and around 18% of households lack any GPS information. Despite these limitations, we decided to use the GPS information to estimate the main regressions excluding households located less than 1 km from their closest treated neighbor. Given the data limitations described above, these results must, however, be taken with caution.

Given that the externalities are likely to occur due to control households learning from their neighbors about the practices and technologies promoted by the program, we only focus on the impacts of the soft components. That is, we estimate the same regressions shown in Tables 9.1 till 9.18 but excluding from the sample those controls who are located at less than 1 km from their closest treated neighbor. The results of these estimations are shown in Tables D.1 till D.18 in the appendix. In general, the results are similar to those in general regressions but a few differences arise, in particular regarding knowledge and adoption of resilient and sustainable land management practices and technologies. In the restricted GPS sample, the effects on bokashi knowledge, while still relatively small, are twice the size of the effects we estimated in Section 9. In the unrestricted estimations, the program appeared to increase knowledge of bokashi by 2-percentage points, in the restricted GPS sample the effect is about 4-percentage points. Moreover, in the restricted sample, the effect is statistically significant at the 1% level. In the restricted sample, treated farmers also have a statistically significant higher adoption of water storage and water saving technologies, as it can be observed in Table D.5. They are 3 percentage points more likely to adopt a water saving technology and 8 percentage points more likely to adopt a water saving technology, such as sprinkler. The spotted differences in this case are statistically significant at the 5% and 1% significance levels.

Another statistically significant difference that arises in these restricted regressions is related to the access and use of weather forecast for agricultural decisions. As observed in Table D.6, treated farmers are 8 to 9 percentage points more likely to have accessed a weather forecast, and the spotted difference is statistically significant at the 10% and 5% levels. Also, they are between 10 to 14-percentage points more likely to base their agricultural decisions on weather forecasts relative to the control group, and in this case the spotted difference is statistically significant at the 5% and 1% significance levels.

There are no major differences across treatment and control groups in the restricted geographical sample in terms of agricultural activity, income and wellbeing.

The fact that there are some differences that are only related to knowledge and adoption of resilient and sustainable land management practices in the restricted GPS data potentially suggests two things: first, externalities may indeed be present, and that control neighbors did learn from their closest treated neighbors; and second, it is still early, in terms of the intervention timeline, to detect impacts on other dimensions, such as agricultural output or income, as learning and adoption may still be processes on the making, and more time is required for the average farmers to fully translate this knowledge and learning into agricultural, income and wellbeing gains.

12. GFC program effective coverage and the extent of alternative interventions in treated and control areas

Based on information collected and shared by the PMU in March 2023, in Panel A in Table 12.1 we summarize the GCF program coverage in treated and control chiwogs by the time of the first follow-up survey (Annex 2 presents the PMU related reports in detail). As we can observe, no chiwog in the control group has received any GCF related intervention. In the case of chiwogs originally assigned to treatment, it seems to be the case that 10 of them have not received any type of program related intervention. If this context is confirmed, our results should be interpreted as an Intention to Treat (ITT) effect. That is, they will capture the effect of having been assigned to the treatment group. It is important that the PMU confirms this situation and that it closely monitors the ten treatment chiwogs supposedly not reached by the program, in order to evaluate the program current status, the reasons for the delay in the implementation activities, as well as the activities planned in these ten chiwogs for the rest of the current year.

Also based on the information shared by the PMU, in panels B and C in Table 12.1 we have mapped the alternative interventions implemented in the study area, around the same time as the GFC program execution, by the Bhutan government or other organizations. This mapping exercise is important in order to identify potential systematic differences in the coverage of these alternative interventions across treatment and control groups. If these interventions have systematically targeted control chiwogs exclusively, our impact evaluation estimates for the soft components of the program will not capture the causal effect of the GCF program as envisioned in the original IE design, but will just compare two completely different interventions. In other words, we will not be able to know the additional contribution of the program compared to a counterfactual situation in which there were other close substitutes but the program was not available.

As it is shown in Table 12.1, the alternative activities supported by the Government of Bhutan and other organizations are related to the distribution of fruit plants and seeds, the installation of greenhouses, polyhouses, mulching plastic, electric fencing, the renovation of irrigation schemes and farm road maintenance. The Government of Bhutan has also supported capacity building-related activities, while other organizations additionally conducted agricultural-related research. The supply of fruit plants/seeds is the most widespread activity implemented by other alternative interventions in both treatment and control areas, with 74 and 75 of the treatment and control chiwogs benefiting from it. As we can observe in Panels B and C, most of these other alternative interventions have reached treatment and control chiwogs with similar levels of intensity, suggesting that the original IE counterfactual assumptions are still likely to hold. It is critical nevertheless to track the progress and implementation of alternative interventions in the evaluation study area throughout the whole project implementation phase, in order to constantly evaluate the impact evaluation design assumptions.

Table 12.1 - Type of activities implemented by various projects in the study area

	Treatment	**Control**
Total number of chiwogs	**75**	**75**
Panel A - GCF CRA Project		
Climate resilient agriculture practices	51	0
SLM	31	0
Irrigation/Water saving technologies	34	0
Road Stabilization	1	0
No activity	10	75
Panel B - Projects of the Republic Government of Bhutan (RGoB)		
1 Distribution of fruit plants/seeds	74	73
2 Greenhouse, Polyhouse, Mulching plastic	7	16
3 Electric fencing	2	10
4 Irrigation scheme	13	4
5 Farm road maintenance	12	6
6 Capacity development (e.g. trainings)	0	1
7 Agricultural-related research	0	0
Panel C -Other projects (implemented by other organizations)		
1 Distribution of fruit plants/seeds	14	18
2 Greenhouse, Polyhouse, Mulching plastic	17	14
3 Electric fencing	1	0
4 Irrigation scheme	1	24
5 Farm road maintenance	1	4
6 Capacity development (e.g. trainings)	0	0
7 Agricultural-related research	0	1

Note: Chiwogs may record more than one project with several interventions

13. Conclusions

1. At this point of the program implementation, we lack the necessary statistical evidence to conclude that the program had already an impact on treated farmers on several dimensions which were expected to be affected by it by the time of the first follow-up - such as knowledge and adoption of climate resilient and

sustainable technologies. There is also no statistically significant evidence of program impacts on agricultural outcomes and income, and wellbeing and perceived vulnerability. Also, in general, the point estimates in the treated group are relatively close to those in the control one.

2. While a few of the outcomes in our estimations appear as statistically significant, these represent less than 5% of all outcomes analyzed and, therefore, these are likely the realization of what is known as Type-I error[5].

3. We must, however, be careful in terms of interpreting the aggregated results obtained in this follow-up survey. The fact that no statistically significant evidence of program impacts is observed at this stage of the intervention does not necessarily imply that the program has not or will not generate an impact. The first follow-up survey was programmed for the first quarter of 2022, and had to be delayed for almost a year due to the COVID-19 restrictions. It is possible that, at the early stages of the program implementation, the treated performed differently than the control ones, and that the latter were able to catch-up with the treated after interacting with them along several settings. However, we will not be able to recover these initial differences, if they existed.

4. Also, importantly, the literature on learning and adoption suggests that these are processes that usually take time, and while some individuals (maybe the more motivated, entrepreneurial or educated ones) may have started to experiment with the practices and technologies disseminated by the program, widespread learning and adoption are processes that may be still on the make. This latter interpretation is in line with the relatively lower levels of knowledge and adoption observed for several of the practices promoted by the program (such as mulching, and technologies such as greenhouses) which, in most cases, are below 10%. It is therefore possible that learning and adoption are still at their initial stages in treated areas, and that the impacts will be stronger by the time of the next follow-up.

5. The estimation of the program causal effects will also be affected in the presence of learning and information externalities, as control farmers may have learnt from their treated neighbors about the program contents. In this situation, our treatment estimates will likely be biased downwards, that is the size of our estimates will be lower than the true program effects. Given that in several cases the control units are located relatively close to treatment areas, as observed during the consultant field visits, the presence of externalities is a real concern in the area of study. While the original IE design was not conceived to assess the presence of such learning externalities, we may still be able to approximate their presence by exploiting the georeferenced locations of households in the study obtained at baseline. Unfortunately, the GPS data collected at baseline is quite noisy and the average precision error is about 4 km, as precision thresholds were not set at baseline. While we decided to use this data to estimate the main regressions excluding households located less than 1 km from their closest treated neighbor, we need to take these results with extreme caution given the GPS data limitations.

6. The restricted geographical sample suggests that there may be some differences among treated and control groups in terms of knowledge and adoption of new technologies. Treated farmers appear to have a higher knowledge of practices such as mulching and bokachi, as well as to have a higher adoption level of water

[5] Intuitively speaking if your significance level is 5% and the true effect is zero, if you evaluate 100 outcomes, in 5 cases you will find a statistically significant effect just by pure luck.

storage and saving technologies. No differences in the restricted sample are found in dimensions related to agricultural productivity, income and wellbeing.

7. The fact that there are differences only related to knowledge and adoption of resilient and sustainable land management practices in the restricted GPS data potentially suggests two things: first, externalities may indeed be present, and that control neighbors do learn from their closest treated neighbors; and second, it is still early in terms of the intervention timeline to detect impacts on other dimensions such as learning and adoption, which may still be processes on the making, and more time is required for the average farmer to fully translate this knowledge and learning into agricultural, income and wellbeing gains.

8. We have also explored the possibility that the intervention could have generated impacts only among female headed households or only among male headed households for certain dimensions of the intervention. Our results suggest that female-headed households may have improved their total rice production and rice productivity relative to treated ones. It is, however, important to highlight that the sampling framework related to the IE was conceived taking as reference the aggregated effects, and not the effects by gender. Therefore, we also should take these results with extreme caution, and evaluate whether or not they remain in the next follow-ups. Also importantly, we strongly suggest the PMU to carefully analyze the female-headed household results, in order to better understand whether or not they make sense under the lens of the program intervention theory of change and implementation timeline.

9. It will be problematic to recover the causal effects of the soft program component if program implementation has not rigorously followed the original treatment assignment. That is, if a relevant number of treated villages did not finally receive the program or if a significant number of control ones were able to receive the program components. Regarding this issue, information shared by the PMU indicate that, while no control chiwog has received any of the elements of the GCF program, some chiwogs assigned to treatment have not been reached by the program activities by the time of the first follow-up. In this sense, the intervention results should be interpreted as capturing the Intention to Treat (ITT) effect of the program, that is, the effect related to having been initially assigned to the treated group, independently of whether the program finally reached you or not. Using data and information from the PMU, and conditional on the PMU confirming this situation, it may however be possible to recover the effect of having effectively received the program by estimating a LATE (local average treatment effect) regression, in which initial assignment to treatment can be used as an instrumental variable (IV). Depending on the validity of the LATE assumptions, the LATE regressions can be included in the next follow-up report.

10. As stated in the original IE design, in the area of intervention there were other programs that in several aspects were close substitutes to some of GCF program interventions. As long as these other programs targeted treated and control areas with similar intensity levels, our estimations will capture the additional impact of the program vis a vis a counterfactual situation in which these other interventions were available but the program was not delivered. However, this will not be the case if other programs or interventions were systematically targeted towards control areas only. In this situation we will just comparing the impacts of two different types of interventions. With the support of the PMU, a mapping exercise with all other programs or projects implemented in the area since 2021 was done in order to assess whether or not these have systematically targeted control chiwogs exclusively. As discussed in section 12 of this document, the information shared by the PMU suggest that local and treated chiwogs have been similarly

targeted by other interventions present in the country, and therefore the original counterfactual assumptions are likely valid.

11. Regarding the hard components impacts which are assessed by the DiD design, during the consultant field visits that the consultant made to the intervention area in early January 2023, the PMU indicated that many of the irrigation and infrastructure projects were still under implementation and that a relevant proportion were expected to be completed during the current 2023 year. This situation, related to the implementation progress of the hard components, may be related to the absence of statistically significant effects for this component of the GCF program by the time of the first follow-up.

12. Some of the results deserve some additional discussion and assessment by the local implementation team. In particular, the impact evaluation sampling procedure put special emphasis on rice farmers, as they were expected to significantly benefit from the program. At baseline, more than 90% of the households interviewed reported rice cultivation. However, at follow-up just 68% of households in the control group and 75% of households in the treatment group report cultivating rice during the last 2022 cropping session. It is important to understand what dynamics are driving this important reduction in the crop portfolio of farmers in Bhutan.

13. Recommendations

1. As mentioned in the conclusion section, the low levels of adoption of climate resilient and land sustainable management practices and technologies, may reflect the fact that learning and adoption are processes that require time, and that, therefore, are still at their initial stages. Given this, we recommend at least an additional follow-up survey, which should take place after the last rice cropping season of year 2023, that is, during the first quarter of 2024.

2. The recommendation stated in the previous point is conditional on the continuous assessment of the other initiatives that have been implemented in the area. If these other initiatives mainly targeted control units, then the IE will not capture the additional impact of the program vis a vis a counterfactual where other interventions were available but the program was not delivered. Instead, the IE will simply compare two completely different types of interventions, and we will not be able to identify the program impacts. The two situations mentioned before lead to different sets of conclusions, and in the latter case the PMU must decide whether it is in their best interest or not to go ahead with the second evaluation round. Regarding this issue, while the evidence at follow-up suggest that treated and control villages have been similarly targeted by other initiatives present in the area, which alleviates concerns on this issue, PMU should still pay special attention at these other programs and intervention during the 2023 year, and inform the IE team of any variation in the current circumstances.

3. If the PMU decides to go ahead with the second follow-up, we strongly recommend to carefully review the survey to better capture the agricultural cycle in Bhutan as well as the type of agricultural activities that can be potentially affected by the program. For example, during the consultant field visits in January 2023, we could notice that vegetable production had the potential to be significantly affected by the types of practices and technologies that are promoted

by the program, such as mulching. However, the sample and survey design put a stronger emphasis on rice production. This has to be reevaluated by the PMU.

4. The first-follow report analyses more than 100 outcomes, which is not recommendable in the light of an IE. We strongly recommend that the IE consultants in charge of the next follow-ups and the program field team prepare a pre-analysis plan for the next follow-up that focuses only on a reduced number of outcomes which are closely connected to the program theory of change and the expected program progress by the end of year 2023. This pre-analysis plan should clearly state which outcomes will be evaluated during the second follow-up.

5. We strongly recommend that the next IE is accompanied by a qualitative field assessment of the program, not only to better understand how treated and control households perceive their lives and economic activities during the timeframe defined by the program, but also to understand some of the dynamics captured at baseline and follow-up. For example, the qualitative evaluation will allow us to better understand the presence of learning externalities in the study area as well as the reasons behind the lower proportion of households that indicate cultivating rice at follow-up relative to baseline. The qualitative analysis should also provide more lights into the performance of the extension services staff in the field.

6. While in this report we tried to assess the presence of externalities, the baseline GPS data is not reliable, as many households lack this information, and precision thresholds were not set. We recommend that, in the next follow-up, the household location GPS data is carefully collected, and questions about whether the household has change locations in the last two years are included.

7. As mentioned in the conclusions, the lack of statistically significant impacts for the hard-components, road and irrigation, of the program is likely related to the low progress of the related interventions, as observed by the consultant during the field visits in January 2023. It is then important that the PMU carefully monitors the progress of these interventions during the current year 2023, and carefully assess the progress in the road and irrigation activities by the end of the of the year.

8. As mentioned in the baseline and follow-up reports, the validity of the DiD design depends on the parallel-trends assumption. While this assumption cannot be proved, it is possible to provided strong supporting evidence towards it. In particular, data for the control and treated groups for several years before the intervention can be used to show that key outcomes in both groups evolved similarly. If administrative data is no available for this purpose, it may be possible to use a proxy variable created based on satellite agricultural data (on paddy crops, for example) in order to evaluate the evolution trough time of treated and control outcomes.

9. The program, is expected to start delivering benefits to the control group after the first quarter of 2024. If any announcement of this coverage was made to households in control units, this has to be honored. If that is not the case, this situation may affect the viability of future experimental evaluations in the study area. For example, in the future, control units that expected that the program may

not be delivered to them as promised, may try to obtain similar benefits through other channels, which will complicate the estimation of causal effects.

10. Finally, as it has been discussed with UNDP and the PMU during the consultant field visits, it is important to highlight that resilience to climate change is a long-term concept, and therefore must also be assessed in the long-term – similar to climate change, such as extreme weather events or gradual changes in temperature and precipitation. The program theory of change assumes that through SLMs practices and resilient agricultural technology adoption, as well resilient infrastructure, Bhutanese farmers will start developing and consolidating a resilient agricultural activity. The IE is designed to capture such improvements in knowledge and adoption of SLMs practices and resilient technologies in the short and medium-term, but it is not designed in any way to assess long-term adaptations and responses to climate change in the context area. In this context, it is important to have realistic expectations about what can be learned from a quantitative impact evaluation.

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Appendix A – Agricultural practices objective knowledge test

MODULE L: FARMER'S KNOWLDEGE AND RESILIENCE PRACTICES

I am now going to ask you some questions about agricultural knowledge and resilience practices, please answer to the best of your knowledge. If you do not know the specific practice you are being asked about, you can just answer "I don't know" likewise if you have heard about the practice but don't know the answer to the question, you can also just answer "I don't know".

L1a. Have you heard about Biochar? *

- ◯ Yes
- ◯ No

L 1b. What are the benefits of "Biochar"? Please list all the benefits you know *

- ☐ Improvement of soil structure
- ☐ Soil pH adjustment
- ☐ Colonization of effective microbes
- ☐ Temperature keeping effect
- ☐ Strengthen cell walls and support plant growth by silicon (Si) of biochar
- ☐ Reduction of risk from soil borne diseases
- ☐ Pot weight saving by mixing with nursery soil
- ☐ For deodorant. (e.g. cattle shed)
- ☐ Don't know

L2a. Have you heard about Mulching?

- ◯ Yes
- ◯ No

L2b. What are the benefits of mulching? Please list all the benefits you know ? *

- ☐ Enhancing warming up or keeping soil temperature
- ☐ To control undesirable seeds
- ☐ To keep moisture in surface soil
- ☐ Supplement materials for soil structure and character renovation
- ☐ Don't know

L3. If a person uses clear plastic sheets for mulching, what cautionary points this person needs to consider? Please list all the cautionary points you know. *

- ☐ No natural decomposition
- ☐ Not possible to control weeds
- ☐ Heat damage to seeds and roots.
- ☐ Other – indicate
- ☐ Don't know

Other – indicate *

L4a. Have you heard about Bokashi? *

- ◯ Yes
- ◯ No

L4b. What are the possible uses of bokashi? Please list all the uses you know. *

- ☐ As a fertilizer
- ☐ As soil sterilization starter
- ☐ For disease control
- ☐ For pest control
- ☐ As composting enhancer
- ☐ For feed grade
- ☐ Don´t know

L5. How can you evaluate the quality of Bokashi that has been made from rice bran? *

- ☐ By observing the consistency of the mix
- ☐ By observing the color of the mix
- ☐ By smelling the inside of the bucket
- ☐ By constantly checking the temperature of the mix
- ☐ Others- indicate
- ☐ Don't know

Others- indicate *

____

L6. What is the optimal location for a water harvesting pond? *

- ☐ Close to the rice area in the farm
- ☐ At low areas in the farm
- ☐ At the top of the farm in any type of soil
- ☐ At the top of the farm in stable soils
- ☐ At any area in the farm
- ☐ Others – indicate
- ☐ Don´t know

Others – indicate *

____

L7. What is the minimum height required for the fence of the water harvesting pond? *

Indicate height in meters allow for decimals:

____

L8a. Have you heard about the Hydroponic system? *

- ◯ Yes
- ◯ No

L8b. What are the common disease management practices that farmers can adopt in hydroponic systems? Please list all the ones you remember. *

- ☐ Wear clean clothes
- ☐ Clean up spills and runoff
- ☐ Keep plants clean
- ☐ Use of fungicides
- ☐ Other – indicate
- ☐ Don´t know

Other – indicate *

____

L9. What are the preventive measures that are useful for maintaining proper sanitation for avoiding pest and disease in the greenhouse? *

- [ ] Avoiding sites with previous record of high pests and disease incidence
- [ ] Using pest and disease-free growing meadow and seeds/ seedlings
- [ ] Keeping the area free from weeds as they are known host to most pests and diseases
- [ ] Regulating entry of people into the greenhouse
- [ ] Adopting a practice of sanitizing tools/implements before and after use
- [ ] Following recommended crop management practices
- [ ] Don´t know

L10. Which other resilient practices do you know apart from those mentioned above? Specify

....

Phone number of respondent *

(If the respondent does not have phone, ask the phone number of any member)

....

Any other remarks

....

Thank You

....

Appendix B – Female headed household regressions

Table B.1 – Perceived knowledge of climate resilient and sustainable agricultural practices						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of Individuals who indicates their HHs have the necessary knowledge to fully implement climate resilient and sustainable agricultural practices .	278	0.162	292	0.14	-0.025	-0.001
		(0.03)		(0.02)	(0.04)	(0.03)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors are clustered at the chiwog level.						

Table B.2 - Knowledge of mulching, biochar, bokachi, water harvesting ponds and greenhouses management as assessed by objective test						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Overall test score	278	1.04	292	1.0	-0.037	-0.031
		(0.09)		(0.05)	(0.11)	(0.09)
Test components						
Proportion of HHs who have heard about biochar	278	0.022	292	0.05	0.026	0.022
		(0.01)		(0.01)	(0.02)	(0.02)
Average number of biocahr benefits identified.	278	0.029	292	0.05	0.023	0.015
		(0.01)		(0.02)	(0.02)	(0.03)
Proportion of HHs who have heard about mulching	278	0.108	292	0.12	0.015	-0.003
		(0.03)		(0.02)	(0.03)	(0.03)
Average number of muching benefits identified.	278	0.176	292	0.15	-0.029	-0.052
		(0.05)		(0.03)	(0.05)	(0.05)
Proportion of HHs who identify at least one risk related to the uses of clear plastic sheets for mulching	278	0.068	292	0.07	-0.003	-0.005
		(0.02)		(0.01)	(0.03)	(0.03)
Proportion of HHs who have heard about bokachi	278	0.022	292	0.06	0.040*	0.030
		(0.01)		(0.01)	(0.02)	(0.02)
Average number of possible uses of bokashi identified.	278	0.036	292	0.08	0.046	0.033
		(0.02)		(0.02)	(0.04)	(0.04)
Proportion of HHs who know how to evaluate quality of bokashi made from rice bran	278	0.004	292	0.01	0.010	0.009
		(0.00)		(0.01)	(0.01)	(0.01)
Proportion of HHs who correctly identify the optimal location for a water harvesting pool	278	0.223	292	0.22	-0.007	-0.022
		(0.03)		(0.02)	(0.04)	(0.04)
Proportion of HHs who have heard about hydroponic systems	278	0.601	292	0.56	-0.043	-0.018
		(0.05)		(0.03)	(0.07)	(0.06)
Average number of common disease management practices in hydroponic systems identified	278	0.022	292	0.07	0.050**	0.047**
		(0.01)		(0.02)	(0.02)	(0.02)
Average number of preventive measures for proper sanitation to avoid pest and disease and greenhouse identifeid.	278	0.014	292	0.03	0.020	0.025
		(0.01)		(0.01)	(0.02)	(0.02)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors are clustered at the chiwog level.						

Table B.3 – Implementation of SLM practices						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of HHs who consider that they have fully implemented or implemented some climate resilient and sustainable land practices.	278	0.439	292	0.44	-0.000	0.025
		(0.04)		(0.03)	(0.05)	(0.05)
Proportion of HHs who consider than more than half theri neighbors adopt climate resilient agricultural practices.	278	0.464	292	0.46	-0.005	0.036
		(0.05)		(0.03)	(0.06)	(0.05)
Proportion of HHs who have implemented dry land Bench terracing .	278	0.284	292	0.24	-0.044	-0.043
		(0.05)		(0.03)	(0.06)	(0.06)
Proportion of HHs who have implemented wet land Terrace consolidation.	278	0.363	292	0.34	-0.021	-0.028
		(0.06)		(0.03)	(0.08)	(0.07)
Proportion of HHs who have implemented Orchard terracing .	278	0.147	292	0.06	-0.086**	-0.077**
		(0.03)		(0.01)	(0.04)	(0.03)
Proportion of HHs who have implemented contour hedgerows.	278	0.259	292	0.14	-0.119**	-0.092**
		(0.04)		(0.02)	(0.05)	(0.04)
Proportion of HHs who have implemented contour stone bunds.	278	0.248	292	0.18	-0.067	-0.060
		(0.07)		(0.02)	(0.07)	(0.06)
Proportion of HHs who have implemented check dams/buffer zone .	278	0.032	292	0.04	0.005	0.002
		(0.01)		(0.01)	(0.02)	(0.02)
Proportion of HHs who have implemented creation/plantation.	278	0.194	292	0.2	0.008	0.026
		(0.06)		(0.02)	(0.08)	(0.04)
Proportion of HHs who have implemented Land Stabilization.	278	0.169	292	0.13	-0.042	-0.035
		(0.05)		(0.02)	(0.05)	(0.04)
Proportion of HHs who have implemented Water source protection.	278	0.313	292	0.39	0.074	0.082
		(0.06)		(0.03)	(0.09)	(0.05)
Average Total number of agricultural practices implemented by HHs	278	2.011	292	1.72	-0.292	-0.226
		(0.28)		(0.11)	(0.33)	(0.27)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors are clustered at the chiwog level.						

Table B.4 – Adoption of poly houses/greenhouses – aerobic/hydroponic/vertical garden techniques - water storage and water saving technologies						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of HHs who have a poly house or greenhouse.	278	0.169	292	0.154	-0.015	-0.038
		(0.04)		(0.02)	(0.05)	(0.05)
Proportion of HHs who have implemented, aerobic, hydroponic or vertical garden techniques.	278	0.011	292	0.007	-0.004	-0.007
		(0.01)		(0.005)	(0.01)	(0.02)
Proportion of HHs who have a water storage technology (earthen ponds, concrete tanks, syntax tanks, others) .	278	0.029	292	0.034	0.005	-0.002
		(0.01)		(0.01)	(0.02)	(0.02)
Proportion of HHs who have water saving technology (drip irrigation / sprinkler)	278	0.036	292	0.038	0.002	-0.011
		(0.01)		(0.01)	(0.02)	(0.02)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors are clustered at the chiwog level. Yes=1						

Table B.5 – Adoption of improved rice seeds						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of HHs that use improved / climate resilient locally produced rice seeds	195	0.369	232	0.5	0.126	0.090
		(0.07)		(0.03)	(0.10)	(0.09)
Proportion of HHs that use improved / climate resilient not locally produced rice seeds	195	0.082	232	0.05	-0.030	-0.042
		(0.03)		(0.01)	(0.03)	(0.03)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors are clustered at the chiwog level.						

Table B.6 – Access to and adoption of weather information systems						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of HHs that eceived any weather/climate information in last 12 months.	278	0.662	292	0.67	0.009	0.004
		(0.05)		(0.03)	(0.06)	(0.05)
Proportion of HHs that this information to inform agricultural decisions in last 12 months.	184	0.701	196	0.66	-0.038	-0.034
		(0.06)		(0.03)	(0.07)	(0.06)
Proportion of HHs that received forecast/warning information in 2022.	278	0.597	292	0.64	0.043	0.050
		(0.04)		(0.03)	(0.05)	(0.04)
Proportion of HHs that accessed a weather forecast in 2022.	278	0.637	292	0.71	0.076	0.074
		(0.04)		(0.03)	(0.05)	(0.05)
Proportion of HHs that had to predict weather forecast during last cropping season.	278	0.435	292	0.51	0.072	0.100
		(0.05)		(0.03)	(0.07)	(0.06)
Proportion of HHs that made farm decisions based on weather prediction during last cropping season.	278	0.335	292	0.41	0.076	0.087
		(0.04)		(0.03)	(0.06)	(0.05)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors are clustered at the chiwog level.						

Table B.7 - Impacts on rice cultivated area, total production and productivity during last cropping season						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of HHs that cultivated rice during the last cropping season.	278	0.701	292	0.795	0.093	0.081
		(0.06)		(0.02)	(0.07)	(0.06)
Average total rice area cultivated in acres	278	0.707	292	0.66	-0.050	-0.033
		(0.08)		(0.05)	(0.09)	(0.08)
Percentage irrigated area	154	0.883	180	0.78	-0.104*	-0.014
		(0.04)		(0.03)	(0.06)	(0.06)
Percentage rainfed area	154	0.006	180	0.01	0.006	0.007
		(0.01)		(0.01)	(0.01)	(0.01)
Percentage mixed-type area	154	0.071	180	0.19	0.123**	0.061
		(0.03)		(0.03)	(0.06)	(0.05)
Percentage upland cultivation area	154	0.039	180	0.01	-0.026	-0.054
		(0.02)		(0.01)	(0.03)	(0.04)
Average total production obtained in kg	278	330.288	292	336.99	6.699	3.366
		(42.74)		(45.36)	(51.44)	(52.71)
Aveage rice productivity kg -acre (production obtained / total area cultivated)	154	558.047	180	688.6	130.551	91.696
		(50.52)		(57.95)	(86.01)	(81.03)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Table B.8 – Impacts on rice loses during last cropping season						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Total amount of rice lost in kg during last cropping season	195	78.108	232	77.99	-0.116	1.013
		(9.59)		(6.53)	(12.61)	(9.09)
Percentage lost due to wildlife depredation	195	42.528	232	44.69	2.157	4.406
		(4.90)		(5.02)	(6.54)	(5.25)
Percentage lost due to extreme weather	195	20.354	232	18.38	-1.975	-1.799
		(4.33)		(3.52)	(5.38)	(4.34)
Percentage lost due to pest and diseases	195	14.995	232	14.65	-0.348	-1.597
		(3.40)		(3.14)	(4.39)	(4.03)
Percentage lost due to post harvest losses	195	0.231	232	0.28	0.049	0.002
		(0.07)		(0.15)	(0.12)	(0.14)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Table B.9 – Impact on rice production last 12 months						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average total rice production in kg	278	480.576	292	617.74	137.164*	89.660
		(54.83)		(34.68)	(71.29)	(56.09)
Average total rice area	278	0.826	292	0.79	-0.033	-0.033
		(0.09)		(0.05)	(0.10)	(0.07)
Average rice productivity kg per acre	191	709.171	229	889.36	180.188**	128.078*
		(48.25)		(51.29)	(76.24)	(74.39)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Table B.10 – Use of improved seeds in rice land area						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average total rice area with improved / climate resilient locally produced rice seeds in acres	195	0.343	232	0.3	-0.045	-0.042
		(0.06)		(0.03)	(0.08)	(0.08)
Average total rice area with improved / climate resilient not locally produced rice seeds in acres	195	0.004	232	0.002	-0.002	-0.004
		(0.00)		(0.00)	(0.00)	(0.00)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Table B.11 – Inputs expenses related rice production last cropping season						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average total amount spent on herbicides	195	336.967	232	325.69	-11.279	7.200
		(75.43)		(42.1)	(109.18)	(74.69)
Average total amount spent on insecticides	195	16.795	232	18.66	1.860	3.537
		(5.70)		(5.19)	(8.22)	(7.13)
Average total amount spent on fungicides	195	0	232	2.37	2.371	3.570
		(0.00)		(2.37)	(2.30)	(3.16)
Average totalquantity of chemical fertilizer used	195	87.231	232	407.12	319.890	214.170
		(76.49)		(237.98)	(263.81)	(231.51)
Average total amount spent on chemical fertilizer	195	463.051	232	346.58	-116.474	-48.497
		(181.50)		(59.04)	(211.43)	(224.71)
Average totall amount spent on compost manure	195	54.99	232	36.55	-18.444	6.395
		(16.94)		(8.12)	(21.14)	(16.67)
Average total amount spent on power tiller hire	195	1,647.96	232	1733.87	85.902	290.607
		(276.38)		(203.09)	(415.42)	(367.35)
Average total amount spent on tractor hire	195	163.077	232	402.59	239.509	205.306
		(83.35)		(140.32)	(177.88)	(146.75)
Average total amount spent on labor	195	3,967.44	232	3686.85	-280.582	-539.149
		(916.99)		(464.94)	(1,057.40)	(1,336.05)
Average totall amount spent on rice inputs	195	6,737.51	232	6960.26	222.753	143.137
		(970.21)		(591.01)	(1,306.27)	(1,390.28)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Table B.12 – Cultivated area for other crops last cropping season						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average maize area grown (Acres)	278	0.474	292	0.29	-0.180	-0.130
		(0.11)		(0.03)	(0.13)	(0.10)
Average wheat area grown (Acres)	278	0.056	292	0.06	0.004	-0.001
		(0.02)		(0.01)	(0.02)	(0.02)
Average potatoes area grown (Acres)	278	0.039	292	0.03	-0.011	-0.015
		(0.01)		(0.01)	(0.01)	(0.01)
Average chillies area grown (Acres)	278	0.051	292	0.05	0.003	0.005
		(0.01)		(0.01)	(0.01)	(0.01)
Average oranges area grown (Acres)	278	0.245	292	0.15	-0.092	-0.041
		(0.06)		(0.03)	(0.07)	(0.06)
Average cardamom area grown (Acres)	278	0.17	292	0.09	-0.076*	-0.053
		(0.04)		(0.01)	(0.05)	(0.04)
Average arecanut area grown (Acres)	278	0.011	292	0.03	0.014	0.012
		(0.00)		(0.01)	(0.01)	(0.01)
Average ginger area grown (Acres)	278	0.022	292	0.02	-0.005	-0.006
		(0.01)		(0.01)	(0.01)	(0.01)

*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.

Table B.13 – Cultivated area for other crops last winter cropping season						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average maize area grown (Acres)	278	0.048	292	0.02	-0.024	-0.024
		(0.03)		(0.01)	(0.03)	(0.03)
Average wheat area grown (Acres)	278	0.031	292	0.05	0.022	0.011
		(0.01)		(0.01)	(0.02)	(0.02)
Average potatoes area grown (Acres)	278	0.055	292	0.03	-0.028	-0.044
		(0.04)		(0.01)	(0.04)	(0.05)
Average chillies area grown (Acres)	278	0.011	292	0.02	0.006	0.004
		(0.00)		(0.00)	(0.01)	(0.01)
Average oranges area grown (Acres)	278	0.048	292	0.02	-0.027	-0.016
		(0.02)		(0.01)	(0.03)	(0.02)
Average cardamom area grown (Acres)	278	0.056	292	0.02	-0.041	-0.037
		(0.03)		(0.01)	(0.03)	(0.03)
Average arecanut area grown (Acres)	278	0.005	292	0.01	0.000	-0.001
		(0.00)		(0.00)	(0.00)	(0.00)
Average ginger area grown (Acres)	278	0.004	292	0.01	0.001	0.000
		(0.00)		(0.00)	(0.00)	(0.00)

*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.

Table B.14 – Cultivated crops under poly house or green house						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average total crop area cultivated under green house or poly house - acres	278	0.034	292	0.03	-0.006	-0.007
		(0.01)		(0.01)	(0.01)	(0.01)
Average total value of sales from production obtained in green house or poly house - Un	278	272.77	292	164.43	-108.335	-109.127
		(87.94)		(78.3)	(116.76)	(132.99)

*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.

Table B.15– Impacts on income, expenses and investments in farm equipment and tools						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average total HH income - Nu.	278	74905	292	117775.13	42,870.129	52,614.621
		(6,293.23)		(41389.86)	(42,427.04)	(53,712.92)
Average income earned from agriculture products - Nu.	277	34238.086	289	29367.58	-4,870.509	-3,198.908
		(4,216.90)		(2225.24)	(5,359.61)	(4,500.03)
Average total expenditures - Nu.	278	63059.328	292	67797.52	4,738.197	3,643.970
		(3,131.72)		(2764.09)	(5,080.39)	(4,188.99)
Average food expenditures - Nu.	278	5687.259	292	5640.87	-46.389	110.911
		(200.91)		(167.47)	(291.06)	(279.88)
Average non-food expenditures - Nu.	278	57372.066	292	62156.65	4,784.586	3,533.058
		(3,047.83)		(2728.45)	(4,978.09)	(4,073.20)
Proportion of HHs that invested in farm equipment and tools.	278	0.047	292	0.04	-0.002	0.003
		(0.02)		(0.01)	(0.03)	(0.02)
Average amount invested in farm equipment and tools - Nu.	278	1769.784	292	938.18	-831.599	-377.858
		(731.59)		(359.54)	(830.82)	(708.09)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Table B.16 – Impacts on perceived wellbeing, food security and water access						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Household ladder position	278	6.209	292	6.55	0.339	0.218
		(0.19)		(0.13)	(0.27)	(0.20)
Proportion of HHs ataht t one point of time in last 12 months worried about food self-sufficiency.	278	0.173	292	0.19	0.019	0.031
		(0.02)		(0.02)	(0.04)	(0.03)
Proportion of HHs that experienced a situation in which they did not have sufficient food to ensure that every HH member could have at least two meals in one day.	278	0.065	292	0.03	-0.031	-0.037
		(0.02)		(0.01)	(0.02)	(0.02)
Proportion of HHs that have access to water by pipe in dwelling/compound.	278	0.471	292	0.5	0.029	0.057
		(0.04)		(0.03)	(0.06)	(0.05)
Average number of days HH did not have access to drinking water in last moth	278	2.27	292	2.79	0.518	0.418
		(0.33)		(0.32)	(0.50)	(0.50)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Table B.17 – Impacts on vulnerability and vulnerability perceptions						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of HHs that have lost land to soil erosions since April 2021	278	0.068	292	0.11	0.038	0.031
		(0.02)		(0.02)	(0.03)	(0.03)
Proportion of HH that consider that in an extreme weather event they will lose less than half of next year rice production.	278	0.579	292	0.64	0.058	0.060
		(0.05)		(0.03)	(0.06)	(0.04)
Proportion of HH that consider that in an extreme weather event their neighbors will lose less than half of next year rice production.	278	0.568	292	0.65	0.082	0.086**
		(0.05)		(0.03)	(0.06)	(0.04)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Appendix C – Male headed household regressions

Table C.1 – Perceived knowledge of climate resilient and sustainable agricultural practices						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of Individuals who indicates their HHs have the necessary knowledge to fully implement climate resilient and sustainable agricultural practices .	552	0.1290	521	0.16	0.031	0.044
		(0.03)		(0.02)	(0.04)	(0.04)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors are clustered at the chiwog level.						

Table C.2 - Knowledge of mulching, biochar, bokachi, water harvesting ponds and greenhouses management as assessed by objective test						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Overall test score	552	1.469	521	1.38	-0.086	-0.072
		(0.06)		(0.04)	(0.09)	(0.08)
Test components						
Proportion of HHs who have heard about biochar	552	0.027	521	0.04	0.011	0.015
		(0.01)		(0.01)	(0.02)	(0.01)
Average number of biocahr benefits identified.	552	0.042	521	0.05	0.010	0.016
		(0.02)		(0.01)	(0.02)	(0.02)
Proportion of HHs who have heard about mulching	552	0.183	521	0.15	-0.029	-0.037
		(0.02)		(0.02)	(0.03)	(0.03)
Average number of muching benefits identified.	552	0.301	521	0.22	-0.084	-0.098**
		(0.05)		(0.03)	(0.06)	(0.05)
Proportion of HHs who identify at least one risk related to the uses of clear plastic sheets for mulching	552	0.158	521	0.13	-0.031	-0.034
		(0.03)		(0.02)	(0.03)	(0.03)
Proportion of HHs who have heard about bokachi	552	0.011	521	0.02	0.012	0.013
		(0.01)		(0.01)	(0.01)	(0.01)
Average number of possible uses of bokashi identified.	552	0.013	521	0.03	0.022	0.024
		(0.01)		(0.01)	(0.01)	(0.01)
Proportion of HHs who know how to evaluate quality of bokashi made from rice bran	552	0.002	521	0	0.002	0.003
		(0.00)		(0.00)	(0.00)	(0.00)
Proportion of HHs who correctly identify the optimal location for a water harvesting pool	552	0.384	521	0.38	-0.004	0.007
		(0.03)		(0.02)	(0.04)	(0.03)
Proportion of HHs who have heard about hydroponic systems	552	0.036	521	0.04	0.000	-0.003
		(0.01)		(0.01)	(0.01)	(0.01)
Average number of common disease management practices in hydroponic systems identified	552	0.04	521	0.02	-0.015	-0.016
		(0.01)		(0.01)	(0.01)	(0.01)
Average number of preventive measures for proper sanitation to avoid pest and disease and greenhouse identifeid.	552	0.572	521	0.56	-0.012	0.004
		(0.06)		(0.04)	(0.08)	(0.08)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors are clustered at the chiwog level.						

Table C.3 – Implementation of SLM practices						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of HHs who consider that they have fully implemented or implemented some climate resilient and sustainable land practices.	552	0.399	521	0.46	0.066	0.071
		(0.04)		(0.02)	(0.05)	(0.05)
Proportion of HHs who consider than more than half theri neighbors adopt climate resilient agricultural practices.	552	0.415	521	0.49	0.073	0.085
		(0.04)		(0.02)	(0.06)	(0.06)
Proportion of HHs who have implemented dry land Bench terracing .	552	0.46	521	0.39	-0.067	-0.039
		(0.05)		(0.02)	(0.07)	(0.06)
Proportion of HHs who have implemented wet land Terrace consolidation.	552	0.377	521	0.31	-0.062	-0.056
		(0.04)		(0.02)	(0.05)	(0.05)
Proportion of HHs who have implemented Orchard terracing .	552	0.138	521	0.14	0.001	0.001
		(0.03)		(0.02)	(0.04)	(0.04)
Proportion of HHs who have implemented contour hedgerows.	552	0.248	521	0.24	-0.008	0.006
		(0.03)		(0.02)	(0.04)	(0.04)
Proportion of HHs who have implemented contour stone bunds.	552	0.237	521	0.25	0.008	0.018
		(0.03)		(0.02)	(0.05)	(0.04)
Proportion of HHs who have implemented check dams/buffer zone .	552	0.078	521	0.05	-0.024	-0.021
		(0.02)		(0.01)	(0.02)	(0.02)
Proportion of HHs who have implemented creation/plantation.	552	0.225	521	0.22	-0.000	-0.008
		(0.03)		(0.02)	(0.05)	(0.04)
Proportion of HHs who have implemented Land Stabilization.	552	0.232	521	0.18	-0.050	-0.047
		(0.04)		(0.02)	(0.05)	(0.05)
Proportion of HHs who have implemented Water source protection.	552	0.342	521	0.38	0.041	0.050
		(0.04)		(0.02)	(0.06)	(0.05)
Average Total number of agricultural practices implemented by HHs	552	2.337	521	2.18	-0.160	-0.095
		(0.24)		(0.1)	(0.32)	(0.30)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors are clustered at the chiwog level.						

Table C.4 – Adoption of poly houses/greenhouses – aerobic/hydroponic/vertical garden techniques - water storage and water saving technologies						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of HHs who have a poly house or greenhouse.	552	0.167	521	0.132	-0.034	-0.038
		(0.02)		(0.015)	(0.03)	(0.03)
Proportion of HHs who have implemented, aerobic, hydroponic or vertical garden techniques.	552	0.007	521	0.002	-0.005	-0.007
		(0.00)		(0.002)	(0.00)	(0.00)
Proportion of HHs who have a water storage technology (earthen ponds, concrete tanks, syntax tanks, others) .	552	0.045	521	0.04	-0.005	-0.002
		(0.02)		(0.01)	(0.02)	(0.02)
Proportion of HHs who have water saving technology (drip irrigation / sprinkler)	552	0.091	521	0.117	0.027	0.033
		(0.03)		(0.014)	(0.04)	(0.04)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors are clustered at the chiwog level. Yes=1						

Table C.5 – Adoption of improved rice seeds						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of HHs that use improved / climate resilient locally produced rice seeds	370	0.389	375	0.39	-0.003	-0.004
		(0.04)		(0.03)	(0.07)	(0.06)
Proportion of HHs that use improved / climate resilient not locally produced rice seeds	370	0.135	375	0.15	0.012	0.012
		(0.03)		(0.02)	(0.04)	(0.04)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors are clustered at the chiwog level.						

Table C.6 – Access to and adoption of weather information systems						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of HHs that eceived any weather/climate information in last 12 months.	552	0.563	521	0.61	0.045	0.041
		(0.04)		(0.02)	(0.05)	(0.04)
Proportion of HHs that this information to inform agricultural decisions in last 12 months.	311	0.82	317	0.8	-0.019	-0.000
		(0.03)		(0.02)	(0.04)	(0.03)
Proportion of HHs that received forecast/warning information in 2022.	552	0.524	521	0.55	0.023	0.028
		(0.03)		(0.02)	(0.05)	(0.04)
Proportion of HHs that accessed a weather forecast in 2022.	552	0.618	521	0.64	0.023	0.027
		(0.03)		(0.02)	(0.05)	(0.04)
Proportion of HHs that had to predict weather forecast during last cropping season.	552	0.433	521	0.51	0.076	0.090*
		(0.04)		(0.02)	(0.06)	(0.05)
Proportion of HHs that made farm decisions based on weather prediction during last cropping season.	552	0.353	521	0.4	0.046	0.061
		(0.04)		(0.02)	(0.06)	(0.05)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors are clustered at the chiwog level.						

Table C.7 - Impacts on rice cultivated area, total production and productivity during last cropping season						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of HHs that cultivated rice during the last cropping season.	552	0.67	521	0.720	0.049	0.058
		(0.04)		(0.02)	(0.06)	(0.05)
Average total rice area cultivated in acres	552	0.616	521	0.64	0.027	0.048
		(0.05)		(0.04)	(0.07)	(0.06)
Percentage irrigated area	312	0.872	300	0.87	-0.003	0.032
		(0.03)		(0.02)	(0.04)	(0.03)
Percentage rainfed area	312	0.022	300	0.02	0.002	0.001
		(0.01)		(0.01)	(0.01)	(0.01)
Percentage mixed-type area	312	0.071	300	0.09	0.016	0.005
		(0.02)		(0.02)	(0.03)	(0.03)
Percentage upland cultivation area	312	0.035	300	0.02	-0.015	-0.038*
		(0.02)		(0.01)	(0.02)	(0.02)
Average total production obtained in kg	552	395.913	521	361.72	-34.197	-22.566
		(33.87)		(22.29)	(44.22)	(37.45)
Aveage rice productivity kg -acre (production obtained / total area cultivated)	312	716.645	300	628.09	-88.557*	-94.435*
		(40.56)		(28.74)	(51.56)	(50.97)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Table C.8 – Impacts on rice loses during last cropping season						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Total amount of rice lost in kg during last cropping season	370	103.105	375	90.02	-13.089	-12.542
		(7.76)		(5.18)	(9.56)	(8.88)
Percentage lost due to wildlife depredation	370	56.027	375	48.47	-7.558	-6.682
		(4.90)		(4.23)	(6.01)	(5.98)
Percentage lost due to extreme weather	370	21.776	375	23.3	1.520	1.550
		(2.84)		(3.07)	(4.12)	(3.84)
Percentage lost due to pest and diseases	370	25.014	375	17.94	-7.070*	-7.423**
		(2.96)		(2.35)	(3.76)	(3.55)
Percentage lost due to post harvest losses	370	0.289	375	0.31	0.017	0.014
		(0.09)		(0.09)	(0.12)	(0.11)

*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.

Table C.9 – Impact on rice production last 12 months						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average total rice production in kg	552	471.1	521	507.32	36.225	43.127
		(41.22)		(23.57)	(57.26)	(49.36)
Average total rice area	552	0.71	521	0.77	0.057	0.073
		(0.05)		(0.04)	(0.08)	(0.06)
Average rice productivity kg per acre	366	924.539	369	722.85	-201.686	-206.540
		(189.32)		(29.54)	(192.39)	(189.60)

*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.

Table C.10 – Use of improved seeds in rice land area						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average total rice area with improved / climate resilient locally produced rice seeds in acres	370	0.255	375	0.24	-0.013	-0.009
		(0.04)		(0.03)	(0.06)	(0.06)
Average total rice area with improved / climate resilient not locally produced rice seeds in acres	370	0.012	375	0.01	0.001	0.001
		(0.00)		(0.00)	(0.01)	(0.01)

*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.

Table C.11 – Inputs expenses related rice production last cropping season						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average total amount spent on herbicides	370	65.207	375	116.57	51.359	49.298**
		(24.14)		(17.68)	(35.40)	(24.57)
Average total amount spent on insecticides	370	10.659	375	8.83	-1.833	-1.136
		(3.82)		(2.79)	(4.83)	(4.35)
Average total amount spent on fungicides	370	0	375	1.2	1.200	1.306
		(0.00)		(1.2)	(1.18)	(1.25)
Average totalquantity of chemical fertilizer used	370	56.992	375	10.71	-46.280	-46.235
		(53.80)		(8.03)	(54.41)	(51.66)
Average total amount spent on chemical fertilizer	370	141.524	375	134.66	-6.868	-14.312
		(45.84)		(28.23)	(57.15)	(45.03)
Average totall amount spent on compost manure	370	38.009	375	22.02	-15.993	-13.673
		(11.52)		(4.63)	(13.66)	(13.63)
Average total amount spent on power tiller hire	370	988.67	375	979.04	-9.630	-38.372
		(177.69)		(117.05)	(238.16)	(214.66)
Average total amount spent on tractor hire	370	652.111	375	648.8	-3.311	26.396
		(315.52)		(128.21)	(380.05)	(379.83)
Average total amount spent on labor	370	3,173.92	375	3252.48	78.561	157.665
		(422.83)		(327.62)	(584.96)	(603.67)
Average totall amount spent on rice inputs	370	5,127.10	375	5174.3	47.204	120.937
		(621.93)		(385.81)	(833.69)	(849.15)

*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.

Table C.12 – Cultivated area for other crops last cropping season						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average maize area grown (Acres)	552	0.467	521	0.41	-0.054	-0.046
		(0.05)		(0.03)	(0.06)	(0.05)
Average wheat area grown (Acres)	552	0.032	521	0.03	-0.002	-0.007
		(0.01)		(0.01)	(0.01)	(0.01)
Average potatoes area grown (Acres)	552	0.065	521	0.07	0.005	0.005
		(0.01)		(0.01)	(0.01)	(0.01)
Average chillies area grown (Acres)	552	0.049	521	0.06	0.011	0.010
		(0.01)		(0.01)	(0.01)	(0.01)
Average oranges area grown (Acres)	552	0.232	521	0.23	-0.006	-0.005
		(0.06)		(0.03)	(0.07)	(0.06)
Average cardamom area grown (Acres)	552	0.204	521	0.14	-0.060	-0.048
		(0.03)		(0.02)	(0.05)	(0.05)
Average arecanut area grown (Acres)	552	0.081	521	0.09	0.011	0.018
		(0.02)		(0.01)	(0.02)	(0.02)
Average ginger area grown (Acres)	552	0.048	521	0.07	0.025	0.017
		(0.02)		(0.01)	(0.03)	(0.02)

*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.

Table C.13 – Cultivated area for other crops last winter cropping season						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average maize area grown (Acres)	552	0.111	521	0.15	0.035	0.028
		(0.02)		(0.02)	(0.04)	(0.04)
Average wheat area grown (Acres)	552	0.009	521	0.01	0.005	0.002
		(0.00)		(0.01)	(0.01)	(0.01)
Average potatoes area grown (Acres)	552	0.039	521	0.05	0.010	0.010
		(0.01)		(0.01)	(0.01)	(0.01)
Average chillies area grown (Acres)	552	0.027	521	0.04	0.016	0.015*
		(0.01)		(0.00)	(0.01)	(0.01)
Average oranges area grown (Acres)	552	0.06	521	0.07	0.008	0.008
		(0.02)		(0.02)	(0.03)	(0.03)
Average cardamom area grown (Acres)	552	0.033	521	0.02	-0.015	-0.014
		(0.01)		(0.01)	(0.01)	(0.01)
Average arecanut area grown (Acres)	552	0.048	521	0.07	0.018	0.020
		(0.02)		(0.01)	(0.02)	(0.02)
Average ginger area grown (Acres)	552	0.021	521	0.02	0.004	-0.001
		(0.01)		(0.01)	(0.01)	(0.01)

*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.

Table C.14 – Cultivated crops under poly house or green house						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average total crop area cultivated under green house or poly house - acres	552	0.055	521	0.04	-0.014	-0.018
		(0.01)		(0.01)	(0.02)	(0.01)
Average total value of sales from production obtained in green house or poly house - Un	552	317.043	521	167.27	-149.769	-155.309
		(112.89)		(46.58)	(126.70)	(138.04)

*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.

Table C.15– Impacts on income, expenses and investments in farm equipment and tools						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average total HH income - Nu.	552	81629.75	521	90222.41	8,592.661	8,409.744
		(4,429.91)		(3986.9)	(6,577.49)	(6,471.00)
Average income earned from agriculture products - Nu.	549	41,291.535	517	40,329.35	-962.182	-332.966
		(3,369.96)		(2054.16)	(4,861.33)	(4,699.52)
Average total expenditures - Nu.	552	47,257.645	521	50,075.59	2,817.948	693.449
		(2,610.58)		(2044.96)	(3,910.76)	(3,121.39)
Average food expenditures - Nu.	552	5,130.832	521	5196.64	65.810	43.289
		(140.28)		(120.16)	(204.66)	(204.93)
Average non-food expenditures - Nu.	552	42,126.813	521	44,878.95	2,752.138	650.160
		(2,564.74)		(2014.94)	(3,857.78)	(3,075.75)
Proportion of HHs that invested in farm equipment and tools.	552	0.036	521	0.04	0.006	0.009
		(0.01)		(0.01)	(0.02)	(0.02)
Average amount invested in farm equipment and tools - Nu.	552	1,156.522	521	1,323.13	166.607	310.717
		(373.87)		(402.39)	(615.67)	(594.19)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Table C.16 – Impacts on perceived wellbeing, food security and water access						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Household ladder position	552	5.969	521	5.86	-0.113	-0.152
		(0.09)		(0.08)	(0.15)	(0.13)
Proportion of HHs ataht t one point of time in last 12 months worried about food self-sufficiency.	552	0.125	521	0.14	0.011	0.012
		(0.02)		(0.02)	(0.03)	(0.03)
Proportion of HHs that experienced a situation in which they did not have sufficient food to ensure that every HH member could have at least two meals in one day.	552	0.031	521	0.04	0.013	0.015
		(0.01)		(0.01)	(0.01)	(0.01)
Proportion of HHs that have access to water by pipe in dwelling/compound.	552	0.538	521	0.57	0.030	0.044
		(0.03)		(0.02)	(0.05)	(0.04)
Average number of days HH did not have access to drinking water in last moth	552	2.446	521	2.83	0.384	0.329
		(0.30)		(0.26)	(0.55)	(0.55)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Table C.17 – Impacts on vulnerability and vulnerability perceptions						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of HHs that have lost land to soil erosions since April 2021	552	0.087	521	0.11	0.019	0.019
		(0.02)		(0.01)	(0.02)	(0.02)
Proportion of HH that consider that in an extreme weather event they will lose less than half of next year rice production.	552	0.611	521	0.64	0.027	0.037
		(0.03)		(0.02)	(0.04)	(0.03)
Proportion of HH that consider that in an extreme weather event their neighbors will lose less than half of next year rice production.	552	0.6	521	0.65	0.049	0.058*
		(0.02)		(0.02)	(0.04)	(0.03)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Appendix D – GPS restricted data.

Table D.1 – Perceived knowledge of climate resilient and sustainable agricultural practices						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of Individuals who indicates their HHs have the necessary knowledge to fully implement climate resilient and sustainable agricultural practices .	308	0.1300	687	0.17	0.040	0.026
		(0.03)		(0.01)	(0.04)	(0.03)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors are clustered at the chiwog level.						

Table D.2 - Knowledge of mulching, biochar, bokachi, water harvesting ponds and greenhouses management as assessed by objective test						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Overall test score	308	1.208	687	1.247	0.039	0.058
		(0.09)		(0.04)	(0.11)	(0.09)
Test components						
Proportion of HHs who have heard about biochar	308	0.032	687	0.038	0.005	0.004
		(0.01)		(0.01)	(0.02)	(0.01)
Average number of biocahr benefits identified.	308	0.052	687	0.051	-0.001	-0.004
		(0.02)		(0.01)	(0.03)	(0.02)
Proportion of HHs who have heard about mulching	308	0.136	687	0.147	0.011	0.014
		(0.03)		(0.01)	(0.03)	(0.02)
Average number of muching benefits identified.	308	0.24	687	0.192	-0.048	-0.039
		(0.06)		(0.02)	(0.07)	(0.05)
Proportion of HHs who identify at least one risk related to the uses of clear plastic sheets for mulching	308	0.078	687	0.109	0.031	0.034
		(0.02)		(0.02)	(0.03)	(0.03)
Proportion of HHs who have heard about bokachi	308	0.003	687	0.041	0.038***	0.034***
		(0.00)		(0.01)	(0.01)	(0.01)
Average number of possible uses of bokashi identified.	308	0.006	687	0.057	0.050***	0.048***
		(0.01)		(0.01)	(0.02)	(0.02)
Proportion of HHs who know how to evaluate quality of bokashi made from rice bran	308	0.003	687	0.007	0.004	0.004
		(0.00)		(0.02)	(0.00)	(0.00)
Proportion of HHs who correctly identify the optimal location for a water harvesting pool	308	0.266	687	0.317	0.051	0.047
		(0.04)		(0.02)	(0.04)	(0.04)
Proportion of HHs who have heard about hydroponic systems	308	0.049	687	0.044	-0.005	-0.005
		(0.01)		(0.01)	(0.02)	(0.02)
Average number of common disease management practices in hydroponic systems identified	308	0.052	687	0.025	-0.027	-0.030
		(0.02)		(0.01)	(0.02)	(0.02)
Average number of preventive measures for proper sanitation to avoid pest and disease and greenhouse identifeid.	308	0.588	687	0.591	0.003	-0.011
		(0.09)		(0.04)	(0.11)	(0.10)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors are clustered at the chiwog level.						

Table D.3 – Implementation of SLM practices						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of HHs who consider that they have fully implemented or implemented some climate resilient and sustainable land practices.	308	0.396	687	0.459	0.062	0.065
		(0.05)		(0.02)	(0.06)	(0.05)
Proportion of HHs who consider than more than half theri neighbors adopt climate resilient agricultural practices.	308	0.422	687	0.492	0.070	0.049
		(0.06)		(0.02)	(0.07)	(0.06)
Proportion of HHs who have implemented dry land Bench terracing .	308	0.325	687	0.344	0.019	-0.005
		(0.06)		(0.02)	(0.07)	(0.07)
Proportion of HHs who have implemented wet land Terrace consolidation.	308	0.315	687	0.33	0.015	-0.018
		(0.05)		(0.02)	(0.06)	(0.06)
Proportion of HHs who have implemented Orchard terracing .	308	0.14	687	0.109	-0.030	-0.019
		(0.03)		(0.01)	(0.04)	(0.04)
Proportion of HHs who have implemented contour hedgerows.	308	0.237	687	0.197	-0.041	-0.033
		(0.04)		(0.02)	(0.05)	(0.04)
Proportion of HHs who have implemented contour stone bunds.	308	0.26	687	0.208	-0.052	-0.048
		(0.05)		(0.02)	(0.06)	(0.05)
Proportion of HHs who have implemented check dams/buffer zone .	308	0.062	687	0.044	-0.018	-0.022
		(0.03)		(0.01)	(0.03)	(0.03)
Proportion of HHs who have implemented creation/plantation.	308	0.231	687	0.186	-0.044	-0.003
		(0.06)		(0.01)	(0.06)	(0.04)
Proportion of HHs who have implemented Land Stabilization.	308	0.201	687	0.146	-0.056	-0.036
		(0.04)		(0.01)	(0.05)	(0.05)
Proportion of HHs who have implemented Water source protection.	308	0.308	687	0.348	0.039	0.065
		(0.06)		(0.02)	(0.07)	(0.06)
Average Total number of agricultural practices implemented by HHs	308	2.078	687	1.911	-0.167	-0.120
		(0.30)		(0.08)	(0.35)	(0.32)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors are clustered at the chiwog level.						

Table D.4 – Adoption of poly houses/greenhouses – aerobic/hydroponic/vertical garden techniques - water storage and water saving technologies						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of HHs who have a poly house or greenhouse.	308	0.143	687	0.156	0.013	0.005
		(0.03)		(0.01)	(0.04)	(0.03)
Proportion of HHs who have implemented, aerobic, hydroponic or vertical garden techniques.	308	0.013	687	0.004	-0.009	-0.009
		(0.01)		(0.00)	(0.01)	(0.01)
Proportion of HHs who have a water storage technology (earthen ponds, concrete tanks, syntax tanks, others) .	308	0.016	687	0.044	0.027**	0.024*
		(0.01)		(0.01)	(0.01)	(0.01)
Proportion of HHs who have water saving technology (drip irrigation / sprinkler)	308	0.029	687	0.095	0.065***	0.065***
		(0.01)		(0.01)	(0.02)	(0.02)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors are clustered at the chiwog level. Yes=1						

Table D.6 – Access to and adoption of weather information systems						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of HHs that eceived any weather/climate information in last 12 months.	308	0.604	687	0.656	0.053	0.057
		(0.04)		(0.02)	(0.05)	(0.05)
Proportion of HHs that this information to inform agricultural decisions in last 12 months.	186	0.71	451	0.756	0.046	0.039
		(0.06)		(0.02)	(0.07)	(0.05)
Proportion of HHs that received forecast/warning information in 2022.	308	0.513	687	0.6	0.087*	0.090**
		(0.04)		(0.02)	(0.04)	(0.04)
Proportion of HHs that accessed a weather forecast in 2022.	308	0.591	687	0.674	0.083*	0.087**
		(0.03)		(0.02)	(0.04)	(0.04)
Proportion of HHs that had to predict weather forecast during last cropping season.	308	0.386	687	0.509	0.123**	0.143***
		(0.05)		(0.02)	(0.06)	(0.05)
Proportion of HHs that made farm decisions based on weather prediction during last cropping season.	308	0.266	687	0.402	0.136***	0.143***
		(0.04)		(0.02)	(0.05)	(0.05)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors are clustered at the chiwog level.						

Table D.7 - Impacts on rice cultivated area, total production and productivity during last cropping season						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of HHs that cultivated rice during the last cropping season.	308	0.636	687	0.751	0.115*	0.073
		(0.05)		(0.02)	(0.06)	(0.05)
Average total rice area cultivated in acres	308	0.58	687	0.658	0.078	0.050
		(0.06)		(0.03)	(0.08)	(0.06)
Percentage irrigated area	165	0.809	401	0.85	0.041	0.064
		(0.05)		(0.02)	(0.06)	(0.05)
Percentage rainfed area	165	0.024	401	0.019	-0.005	-0.007
		(0.01)		(0.01)	(0.01)	(0.02)
Percentage mixed-type area	165	0.094	401	0.109	0.015	-0.005
		(0.03)		(0.02)	(0.04)	(0.04)
Percentage upland cultivation area	165	0.073	401	0.021	-0.052	-0.052*
		(0.04)		(0.01)	(0.04)	(0.03)
Average total production obtained in kg	308	355.779	687	355.706	-0.073	-23.529
		(40.80)		(16.9)	(48.24)	(38.19)
Aveage rice productivity kg -acre (production obtained / total area cultivated)	165	711.203	401	610.285	-100.918	-103.517
		(55.96)		(26.09)	(64.32)	(65.56)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Table D.8 – Impacts on rice loses during last cropping season						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Total amount of rice lost in kg during last cropping season	196	93.163	516	80.992	-12.171	-9.952
		(8.79)		(4.17)	(10.33)	(8.97)
Percentage lost due to wildlife depredation	196	53.872	516	46.44	-7.433	-5.907
		(4.60)		(2.58)	(5.62)	(5.25)
Percentage lost due to extreme weather	196	19.964	516	20.337	0.373	0.460
		(3.42)		(2.07)	(4.25)	(3.88)
Percentage lost due to pest and diseases	196	19.122	516	13.882	-5.241	-4.658
		(3.47)		(1.42)	(3.85)	(3.33)
Percentage lost due to post harvest losses	196	0.204	516	0.333	0.129	0.152
		(0.07)		(0.05)	(0.10)	(0.10)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Table D.9 – Impact on rice production last 12 months						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average total rice production in kg	308	425.162	687	539.188	114.025*	68.730
		(49.43)		(20.78)	(61.19)	(51.27)
Average total rice area	308	0.671	687	0.798	0.127	0.085
		(0.07)		(0.03)	(0.08)	(0.06)
Average rice productivity kg per acre	194	754.262	509	740.98	-13.283	-33.185
		(54.76)		(26.05)	(64.55)	(66.99)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Table D.10 – Use of improved seeds in rice land area						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average total rice area with improved / climate resilient locally produced rice seeds in acres	196	0.336	516	0.27	-0.066	-0.075
		(0.06)		(0.02)	(0.07)	(0.07)
Average total rice area with improved / climate resilient not locally produced rice seeds in acres	196	0.012	516	0.009	-0.003	-0.001
		(0.01)		(0.00)	(0.01)	(0.01)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Table D.11 – Inputs expenses related rice production last cropping season						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average total amount spent on herbicides	196	153.393	516	215.292	61.899	39.735
		(51.69)		(22.46)	(71.72)	(44.27)
Average total amount spent on insecticides	196	3.643	516	12.264	8.621**	7.897**
		(1.51)		(2.69)	(3.54)	(3.21)
Average total amount spent on fungicides	196	0	516	1.938	1.938	1.868
		(0.00)		(1.37)	(1.33)	(1.23)
Average totalquantity of chemical fertilizer used	196	82.903	516	186.729	103.826	60.480
		(75.14)		(107.32)	(136.24)	(128.05)
Average total amount spent on chemical fertilizer	196	229.679	516	243.647	13.969	16.551
		(85.06)		(33.40)	(107.20)	(94.61)
Average totall amount spent on compost manure	196	36.372	516	28.737	-7.635	-8.229
		(13.89)		(4.69)	(16.04)	(13.09)
Average total amount spent on power tiller hire	196	1,111.74	516	1386.618	274.878	145.301
		(225.55)		(121.53)	(307.37)	(241.83)
Average total amount spent on tractor hire	196	828.577	516	564.729	-263.848	-174.826
		(536.49)		(106.67)	(563.28)	(572.89)
Average total amount spent on labor	196	2,800.26	516	3357.616	557.361	599.707
		(532.30)		(290.63)	(651.76)	(649.76)
Average totall amount spent on rice inputs	196	5,246.56	516	5997.57	751.009	688.484
		(657.50)		(362.47)	(858.50)	(854.63)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Table D.12 – Cultivated area for other crops last cropping season						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average maize area grown (Acres)	308	0.496	687	0.385	-0.112	-0.055
		(0.08)		(0.02)	(0.10)	(0.06)
Average wheat area grown (Acres)	308	0.043	687	0.044	0.002	-0.006
		(0.01)		(0.01)	(0.01)	(0.01)
Average potatoes area grown (Acres)	308	0.066	687	0.057	-0.009	-0.014
		(0.01)		(0.01)	(0.02)	(0.02)
Average chillies area grown (Acres)	308	0.039	687	0.062	0.024**	0.023**
		(0.01)		(0.00)	(0.01)	(0.01)
Average oranges area grown (Acres)	308	0.27	687	0.204	-0.066	-0.033
		(0.07)		(0.02)	(0.08)	(0.06)
Average cardamom area grown (Acres)	308	0.247	687	0.115	-0.132**	-0.138***
		(0.06)		(0.01)	(0.06)	(0.05)
Average arecanut area grown (Acres)	308	0.026	687	0.069	0.043**	0.042**
		(0.01)		(0.01)	(0.02)	(0.02)
Average ginger area grown (Acres)	308	0.051	687	0.059	0.008	0.024
		(0.02)		(0.01)	(0.02)	(0.03)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Table D.13 – Cultivated area for other crops last winter cropping season						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average maize area grown (Acres)	308	0.082	687	0.11	0.028	0.056
		(0.03)		(0.01)	(0.04)	(0.04)
Average wheat area grown (Acres)	308	0.018	687	0.029	0.011	0.002
		(0.01)		(0.01)	(0.01)	(0.01)
Average potatoes area grown (Acres)	308	0.059	687	0.046	-0.013	-0.017
		(0.03)		(0.01)	(0.03)	(0.03)
Average chillies area grown (Acres)	308	0.018	687	0.036	0.019**	0.022***
		(0.01)		(0.00)	(0.01)	(0.01)
Average oranges area grown (Acres)	308	0.079	687	0.056	-0.023	-0.016
		(0.03)		(0.01)	(0.04)	(0.04)
Average cardamom area grown (Acres)	308	0.074	687	0.014	-0.059**	-0.061**
		(0.03)		(0.01)	(0.03)	(0.03)
Average arecanut area grown (Acres)	308	0.02	687	0.051	0.031*	0.033*
		(0.01)		(0.01)	(0.02)	(0.02)
Average ginger area grown (Acres)	308	0.021	687	0.021	-0.000	0.007
		(0.01)		(0.00)	(0.01)	(0.01)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Table D.14 – Cultivated crops under poly house or green house						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average total crop area cultivated under green house or poly house - acres	308	0.049	687	0.041	-0.008	-0.003
		(0.01)		(0.01)	(0.02)	(0.01)
Average total value of sales from production obtained in green house or poly house - Un	308	172.266	687	196.237	23.971	20.103
		(71.29)		(48.42)	(91.94)	(98.16)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Table D.15– Impacts on income, expenses and investments in farm equipment and tools						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Average total HH income - Nu.	308	81,809.875	687	106,218.725	24,408.852	23,733.119
		(6,397.92)		(17805.95)	(19,705.71)	(18,878.92)
Average income earned from agriculture products - Nu.	308	40,923.219	683	37,232.804	-3,690.414	-2,506.151
		(4,790.99)		(1720.47)	(5,761.64)	(4,877.62)
Average total expenditures - Nu.	308	56,987.352	687	58,228.418	1,241.067	168.667
		(3,371.59)		(1833.09)	(4,657.85)	(3,654.38)
Average food expenditures - Nu.	308	5,406.964	687	5,364.066	-42.899	-3.506
		(207.27)		(106.32)	(250.11)	(226.77)
Average non-food expenditures - Nu.	308	51,580.387	687	52,864.352	1,283.966	172.172
		(3,293.75)		(1809.07)	(4,572.86)	(3,593.17)
Proportion of HHs that invested in farm equipment and tools.	308	0.023	687	0.047	0.024	0.020
		(0.01)		(0.01)	(0.02)	(0.01)
Average amount invested in farm equipment and tools - Nu.	308	725.487	687	1,299.272	573.785	629.220
		(429.33)		(334.67)	(588.64)	(531.78)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Table D.16 – Impacts on perceived wellbeing, food security and water access						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Household ladder position	308	6.117	687	6.146	0.029	-0.091
		(0.12)		(0.08)	(0.19)	(0.15)
Proportion of HHs at aht t one point of time in last 12 months worried about food self-sufficiency.	308	0.156	687	0.143	-0.013	-0.004
		(0.03)		(0.01)	(0.03)	(0.03)
Proportion of HHs that experienced a situation in which they did not have sufficient food to ensure that every HH member could have at least two meals in one day.	308	0.039	687	0.041	0.002	-0.001
		(0.01)		(0.01)	(0.01)	(0.01)
Proportion of HHs that have access to water by pipe in dwelling/compound.	308	0.529	687	0.525	-0.004	-0.007
		(0.05)		(0.02)	(0.05)	(0.04)
Average number of days HH did not have access to drinking water in last moth	308	2.208	687	2.879	0.671	0.739
		(0.38)		(0.23)	(0.54)	(0.52)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						

Table D.17 – Impacts on vulnerability and vulnerability perceptions						
	Control Obs	Control mean	Treatment Obs	Treatment mean	Raw difference T-C	FE difference T-C
Proportion of HHs that have lost land to soil erosions since April 2021	308	0.078	687	0.102	0.024	0.021
		(0.02)		(0.01)	(0.02)	(0.02)
Proportion of HH that consider that in an extreme weather event they will lose less than half of next year rice production.	308	0.578	687	0.652	0.074	0.033
		(0.04)		(0.02)	(0.05)	(0.03)
Proportion of HH that consider that in an extreme weather event their neighbors will lose less than half of next year rice production.	308	0.562	687	0.665	0.104**	0.065*
		(0.04)		(0.02)	(0.05)	(0.04)
*,**, and *** indicate statistical significance at the 10%, 5% and 1% levels. In all regressions standard errors, in parenthesis, are clustered at the chiwog level.						