SCALING UP POSTHARVEST MANAGEMENT INNOVATIONS FOR GRAIN LEGUMES IN BURKINA FASO

FINAL REPORT

Submitted to the Alliance for a Green Revolution in Africa (AGRA)

By

Institute of Statistical, Social and Economic Research (ISSER), University of Ghana

Contributors:

Robert D. Osei[a], Isaac Osei-Akoto[a], Felix A. Asante[a], Frank Agyire-Tettey[b] and Kwabena Adu-Ababio[a]

[a] Institute of Statistical, Social and Economic Research (ISSER), University of Ghana

[b] Department of Economics, University of Ghana

Email of Corresponding Author: rdosei@yahoo.co.uk

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List Acronyms and Abbreviations

AC	Aggregation Center
AGRA	Alliance for a Green Revolution for Africa
AGRODIA	Association of Wholesalers and Retailers of Agricultural Inputs
BOUATAPA	AGRO-Pastoral Input Shop
BP	Business Plan
CAN	Contour Line Development
CLAPHI	Catalyzing Large Scale Adoption of Cowpea Post-Harvest Innovations
CEAS	Centre Ecologique Albert Schweitzer
COCIMA	Cooperative of Agricultural Equipment's and Inputs
DP	Demonstration Plot
DPAAH	Provincial Directorate for Agriculture
DRAAH	Regional Directorate for Agriculture
FBOs	Farmers Based Organization
FFS	Farmer Field School
GRAD	Group for Research and Action for Development
IFDC	International Fertilizer Development Center
INERA	Institute for Environment and Agronomic Research
MFI	Micro-Finance Institutions
PHT	Post-Harvest Technology
PHL	Post-Harvest Losses
PICS	Purdue Improved Crop Storage (PICS)
SECOPA	Studies and commercialization Society of agricultural products.
UGPCER	Union of Cereal Producers' Groups
UPPN/N	Provincial Union of Cowpea Producers in Nayala
UPPN/S	Provincial Union of Cowpea Producers in Sourou
WFP	United Nations World Food Program

1 Executive Summary

With subsistence agriculture being the one of the major sources of livelihoods on the African continent, it should be imperative that the usual policies that drive the sector be consistently updated to address the long of barriers that stifle the growth in the sector. Usually, progressively tackling bottlenecks and improving key indicators such as yields, land tenure, pre- and post-harvest loses as well as input use go a long way to address and ameliorate the agricultural status quo on the continent. Although most policy makers have seen the need to put in more work to assiduously improve the state of smallholder agriculture, a lot more needs to be done.

Most policies have been geared towards improving staples as they hold the key for not only improving livelihoods but also contributing to the welfare effect through poverty reduction and income generation. Cereals and crop legumes farmers have benefitted from policies like input subsidies and contracts promoting ease of access to markets all in the name of improving agricultural livelihoods in Africa. As these current policies have existed for a while, research has started to wonder why there is not much significant improvements in progressive agricultural indicators. Although, some indicators have improved, others, especially post-harvest losses continue to soar as a result of favourable tropical weather for pests and diseases that thrive in such conditions and continue to inflict damaging harm to crops after harvests.

Research has established that irrespective of the size of input subsidies that are given through policy intervention, bumper harvests will always be affected by poor post-harvest management. This does not only dwindle agriculture produce but equally affects the quality on the market, thus, inhibiting effective competition from imports. Resource-poor smallholders in Africa continually suffer from this plight which is compounded by lack of technological innovations and strict reliance on rudimentary practices. This has reduced food and nutritional security on the continent usually caused by losses of between 14% to 36% of annual harvest. Post-harvest losses also contribute to high food prices by removing portion of the supply from the market. Reducing post-harvest losses is an essential component in any strategy to make more food available without increasing the burden on the natural environment.

However, solving the post-harvest management problems will require cooperation and effective linkage between research and policy, working in synchronization to resolve relative rigidities related to such problems. AGRA in conjunction with IDRC have seen the need for the research policy nexus in tackling many small holder agricultural rigidities in Africa by incorporating scientific research into their various intervention policies. They believe that policies that may have good intentions should not be arbitrarily rolled out for implementation. First, the current situation should be scientifically investigated in order to note the well performing sectors that need to be maintained. Moreover, the non-performing sectors where critical attention has to be paid in order to improve the current situation should be noted.

Recognizing the challenge of post-harvest losses, IDRC and AGRA have tried to apply this approach by implementing a three-year grant support applied research project to bring effective, field-tested post-harvest innovations for increasing productivity and reducing post-harvest loss of cereals and grain legumes to thousands of smallholder farmers in Burkina Faso. In addition to this, these stakeholders seek to develop effective scaling up models and innovation delivery systems for adaptation and use in other countries in the sub region. Burkina Faso just like any country in sub Saharan Africa suffers from poor post-harvest management technologies and sampling from a typical smallholder Burkinabe household will not vary from what one will find elsewhere on the continent. The novel aspect of this intervention is the introduction of post-harvest innovation technologies (PHT's) in the form of Purdue Improved Crop Storage (PICS) as well as mechanised threshers to a section of small holder farmers and observe how this affects level of post-harvest losses as well as their welfare. To observe this scientifically using appropriate monitoring and evaluation tools, the Institute of Statistical Social and Economic Research (ISSER) was contracted to conduct an impact evaluation study on how well such an intervention will behave given it is done on a small scale within the Boucle du Mouhoun province.

To do this, ISSER first conducted a baseline survey of farm households in preparation of the intervention in the Boucle du Mouhoun region as well as the Centre Est region, where no intervention will take place to be used as a yardstick to provide an excellent measure of the intervention impact. Households from these two provinces were comparable through the Propensity Score Matching (PSM) approach to ensure the treatment group did not vary in terms of household size, farm size, post-harvest loses, crop yields etc. from the control group. Subsequently the intervention was rolled out in 2017, with the end-line survey conducted a year later in 2018. Pooling the two datasets gathered over the period, impact evaluation analysis was carried out using Difference in Difference regression estimations. An important question then is whether the introduction of technologies in the form of PICS bags and Threshers is most effective in reducing post-harvest losses, and how does this impact on the specific crops surveyed as well as farm incomes. In order to access the 'true' impact of the technologies we set up an experiment as follows. We originally randomly assigned 320 program households as our experimental group and 100 households as our pure control group: all treatment households received or were exposed to both the PICS bags and Thresher technology. It should be noted that both security threats and contamination in the original design moved the control group from Boucle de Mouhoun to Centre Est.

This design allowed testing the following hypotheses:

H1: Enhancing farmers' knowledge on PICS bags and threshers increases the adoption rate of these technologies.

H2: Adoption of PICS bags and threshers significantly reduces post-harvest losses leading to increase in grain production and sales.

H3: Farm households exposed to PHTs have higher sales and lower food insecurity than those who are not exposed to these technologies.

H4: Farmers using threshers work fewer labour days and use their time for other economic activities.

H5: All delivery channels (agro dears, FOs, Extension and NGOs) have similar impact on the propensity of PICS bags adoption

In addition to these hypotheses the quest to find the channel (Agro Dealers, Cooperatives, Extension officers, etc.) of delivery of PHTs that is the most efficient was sought. Also, case studies were conducted in intervention communities to ascertain the qualitative impacts of the intervention. The impact of the program was assessed using ten indicators. The indicators can be grouped into three categories: (a) behavioural change indicators (the share of land devoted to legumes, plot size cultivated and investments in agrochemicals); (b) impact indicators (technology adoption, total harvest volumes and grain yields); and (c) outcome indicators (crop sales, total man-days, post-harvest losses and improved food security).

The most efficient distribution channel for PICS bags is discussed separately. The main findings are as follows. Out of the ten indicators assessed, the study found that the technology adoption of PICS and threshers had impact on eight indicators – food insecurity; actual crop sales; postharvest losses; total crop yield; total harvest volumes; labour days; chemical use and adoption of PHTs. It is worthy to note that post-harvest losses reduced by on average of 27kg per plot surveyed. There were also positive significant impacts seen on total yields, total output volumes and crop sales. In terms of the most effective distribution channel, the study finds that agro-dealers is probably the best channels for technology propagation.

This study provides lessons for policy and practice in Burkina Faso and similar context in sub-Saharan Africa. The study has shown that sometimes a technology that is known to work in theory can equally work on the field when tested appropriately under proper supervision. Although, adoption may not be guaranteed as this was done on a small-scale level, we cannot ignore the results seen in this programme. Our cautious conclusion is that the intervention has potential for scaling up. Our being cautious in this regard relates to not having enough statistical power to assess the heterogeneity of the impacts in different settings, using regional differences as an example. This notwithstanding, there is no other compelling reason to suggest that the intervention would not succeed elsewhere under similar conditions.

2 Introduction

Agriculture is a major source of livelihood in Burkina Faso, employing about 80% of the economically active population. Agricultural production is a major contributor to GDP, contributing about 34.2% of GDP in 2015. The sector is however characterized mostly by smallholder farmers with an average ownership of land of two hectares or less. Productivity of crops and livestock is generally low with production largely dependent on rainfall, and principally supporting subsistence livelihoods. Productivity in the sector expressed in terms of value added per worker is significantly low, estimated at $308 in constant 2005 US dollars (World Bank 2014). Production of maize, sorghum and millet are the dominant agriculture produce in terms of volumes. However, the value of revenue from cotton dominates all other products. Other agricultural products include peanuts, shea nuts, sesame corn and rice as well as livestock. Use of rudimentary tools coupled with lack of requisite inputs such as fertilizers, irrigation systems and access to qualified agricultural extension officers hindered growth and development of the sector. For instance, the average fertilizer use among farmers in Burkina Faso is estimated at 11 kg/hectare with about 8% to 35% of farmers using fertilizers during cultivation (AGRA, 2015). Furthermore, lack of access to land and finance, poor agricultural infrastructure, lack of appropriate seeds and huge postharvest losses have all impacted on the sector with adverse implications for food security and welfare of smallholder farmers in Burkina Faso.

In spite of the challenges the agriculture sector has recorded marginal improvement over the years playing a major role in reducing the risk of periodic famine and food deficit in Burkina Faso. Estimates by the USAID in 2015 indicates about 20% of the country's population are food insecure with about 50% of rural households unable to produce adequate foodstuff to meet their daily calorie needs. One major element aggravating food deficit in low-income countries, including Burkina Faso, is the problem of postharvest losses (PHL), occurring along the value chain from harvesting, through storage to the time it gets to the final consumer. This leads to a loss in income, with adverse implications for welfare of farmers and consumers. AGRA output data panel (2015) indicates that 30% of agriculture produce are lost along the value chain which have dire implications for food insecurity and household welfare in Burkina Faso. Pest and diseases tend to destroy agriculture produce during harvest as well as storage for sales and consumption. In 2012 and 2013, the government of Burkina Faso spent US$ 130 million and US$64 million, respectively on food for the vulnerable population. Increased migration of rural dwellers to urban areas and conversion of agriculture lands for other uses have exacerbated food insecurity in many low-income countries.

PHL has been an issue of concern since the mid-1970s resulting from the food crisis during that period. However, with the food price declining in the 1980s, the focus of policy in reducing PHL shifted to an emphasis on food security through trade and economic liberalization. In recent times, there is a renewed urgency to reduce PHL as development of agriculture is estimated to have greater impact in poverty reduction, especially in low income countries (Christiaensen, Demery and Kuhl, 2011). In part, the full prospect of agriculture to meet the calorie needs of a population can be realized with a reduction in PHL which in turn will reduce food insecurity of vulnerable countries. Global initiatives for the fight against food insecurity have focused extensively on reducing PHL as an approach of increasing food supply around the globe. Issues related to PHL are critical as approximately about a third of food production, estimated at about 1.3 billion ton and valued at one trillion US Dollars (US$1trillion), is lost annually along the food value chain globally (Gustavsson, Cederberg, Sonesson, Van Otterdijk & Meybeck, 2011). Further, PHL in production of grains in sub-Saharan Africa alone is estimated at US $4 billion annually (Zorya et al., 2011). Postharvest losses in developing countries have largely been as a result of inadequate/obsolete harvest and post-harvest technologies, poor storage and transportation as well as poor processing techniques and marketing schemes. Poor farmers with relatively less access to technologies capable of averting or minimising PHL tend to directly suffer greater losses in terms of income and welfare. Income losses result in households' inability to purchase additional foodstuff needed during lean seasons.

The potential benefits accruing from the use of resources (land, water, energy and fertilizer) for food crop production cannot be realised due to postharvest losses. This is because the lost crops can be quantified in terms of emission of carbon dioxide (CO2). The FAO estimates greenhouse gas emissions from production of food not consumed globally at 3.3 Giga tonnes of CO2 in 2007, in addition to the economic value of postharvest losses. Furthermore, land cultivated for production of crops not consumed are wasted especially in many developing countries where poor land tenure systems restrict access to agricultural lands. Fox and Fimeche (2013) estimates that globally food losses translates to 1.47-1.96 global hectares of arable land in 2007.

Avoidance and significant reduction of PHL have considerable effects on food security in several developing countries both for farmers and consumers. In many of these countries, smallholder farmers face food insecurity, thus improving the PHL can have a positive impact on their livelihood and welfare. In recognition of these issues, IDRC and AGRA aim at developing smallholder agriculture into a productive, efficient, and sustainable system to ensure food security, reduce poverty and achieve inclusive and equitable growth in Burkina Faso. To this end, IDRC-AGRA seek to reduce significantly PHL through the distribution of PHL technologies to 5,000 Burkinabe farmers with the aim of scaling it up to benefit 35,000 farmers by 2020. The purpose of this study, conducted by the Institute of Statistical Social and Economic Research (ISSER), is to help catalyze and sustain large-scale adoption of postharvest value addition innovations for cowpea in Burkina Faso. More specifically this study assesses the effectiveness of select delivery models for the chosen innovations to enable a cost effective scaling up.

2.1 Project and study objectives

2.1.1 Project objectives

The overall objective of the Project is to catalyze and sustain large-scale adoption of postharvest value addition innovations for grain legumes in Mozambique and Burkina Faso.

The specific objectives of the project are to:

a) Scale up innovative post-harvest technologies (PHTs), specifically threshers and PICS bags, to achieve meaningful impacts in the lives of farmers, women and youth;
b) Assess the effectiveness of selected delivery models for the chosen innovations; and
c) Synthesize and disseminate evidence and lessons from the scaling efforts to catalyze the field and inform policy change and investment.

2.1.2 Study objectives

Based on the overall objectives of the project, this study designed a quasi-experiment to analyze the impact of the intervention by AGRA through its implementing partner. Specifically, the study:

a) Examines the impact of introduction of PHT (PICS bags and threshers) on postharvest losses, welfare of small-scale farmers and other socio-economic indicators of small-scale farmers in the intervention region.
b) Ascertain which channel of delivery of PHTs is most efficient (Agro Dealers, Cooperatives, Private mechanized service providers, etc.)

3 Intervention, theory of change and research hypothesis

3.1 Programme Intervention and Implementation Processes

Considerable effort has been dedicated to the production and marketing of grains such as cowpea, maize, rice and sorghum. These form an important component of the cropping systems in Burkina Faso. Increased production and marketing are critical for improving welfare of smallholder farmers, as majority of these farmers depend on grains as their staple food. Cultivation of these grains, which are largely dominated by smallholder farmers, is dependent on the use of rudimentary technique along the entire value chains leading to low production, and inability for production to reach its potential. Huge crop losses occur at farm level contributing to high food prices and food shortages. Typically, the losses emanate from the use of inappropriate threshing, winnowing and storage methods, which in turn hinders the development of grain market and undermines the welfare improvement of smallholder farmers in Burkina Faso. With a common interest of reducing post-harvest losses in cowpea, maize, rice and sorghum, IDRC, AGRA, and GRAD undertook "Catalysing Large-Scale Adoption of Post-Harvest Operations of Cowpeas for Better Food Security in Burkina Faso". The project initially targeted cowpea, however, was expanded to cover rice, maize and sorghum.

According to the project officer, in line with the AGRA objectives, it is by no meagre means that GRAD has taken on this task through the CLAPHI project. The latter has observed that cowpea production and marketing in Burkina Faso is dominated by smallholders, a phenomenon which has not encouraged the performance of cowpea value chains and marketing potential. Three main root causes that have been identified are (i) The lack of adequate threshing machines; (ii) Postharvest losses due to insect's damages causing significant challenges in the cowpea value chain and (iii) Inadequate Roll out/Delivery models.

As a result, the GRAD consulting group acted to ensure that the project produced the expected results. The project "Catalysing Large-Scale Adoption of Post-Harvest Operations of Cowpeas for Better Food Security in Burkina Faso" (CLAPHI), was launched on February 16, 2017 in Tougan which is within one of this study's provinces, Sourou. After the launch, ISSER came to understand that agro dealers in the CLAPHI project area had been identified and discussions had been concluded to define the support they needed to carry out the demonstration plots (PD) in the 2017-2018 cropping season. Moreover, the implementation of a communication strategy on the threshing machine and the development of a procurement strategy for inputs and PICS bags were activated. Training was also provided for farmers, with demonstrations using multifunctional threshing machines, for cowpea crops in irrigated production.

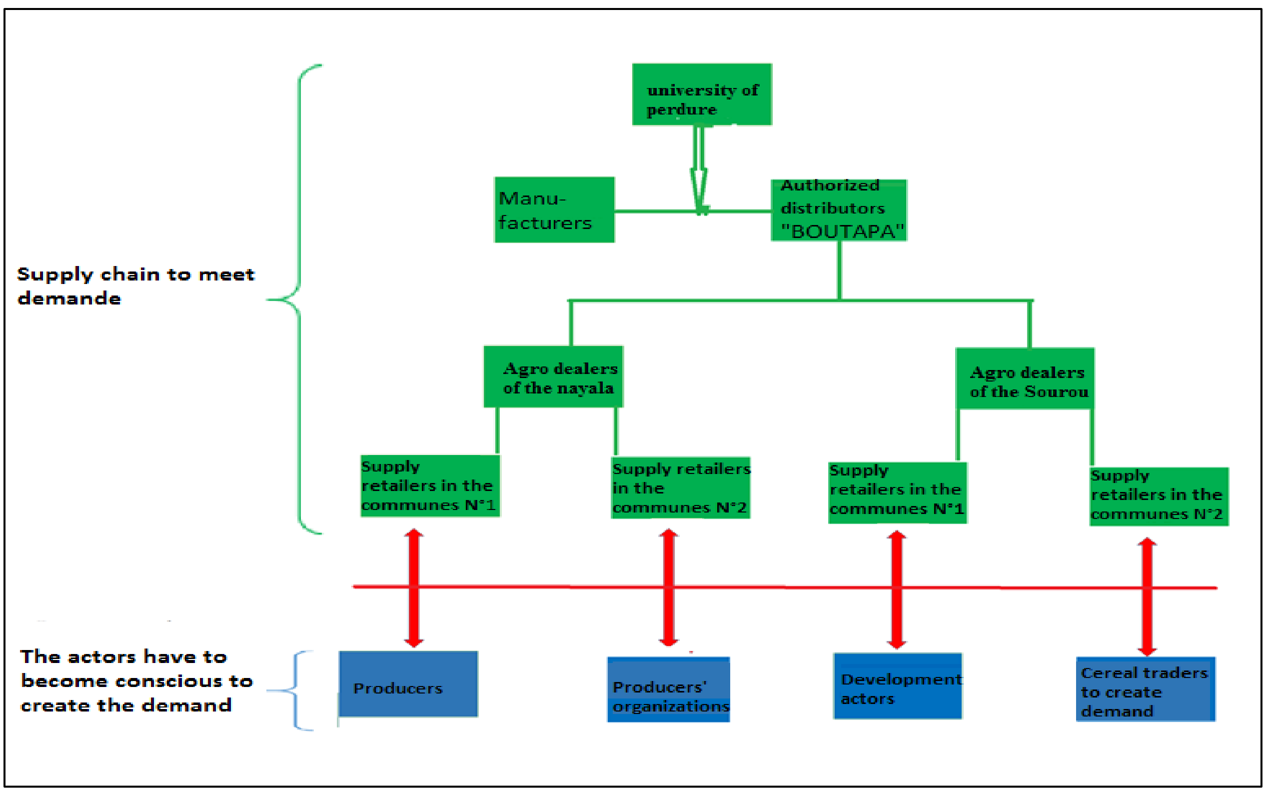
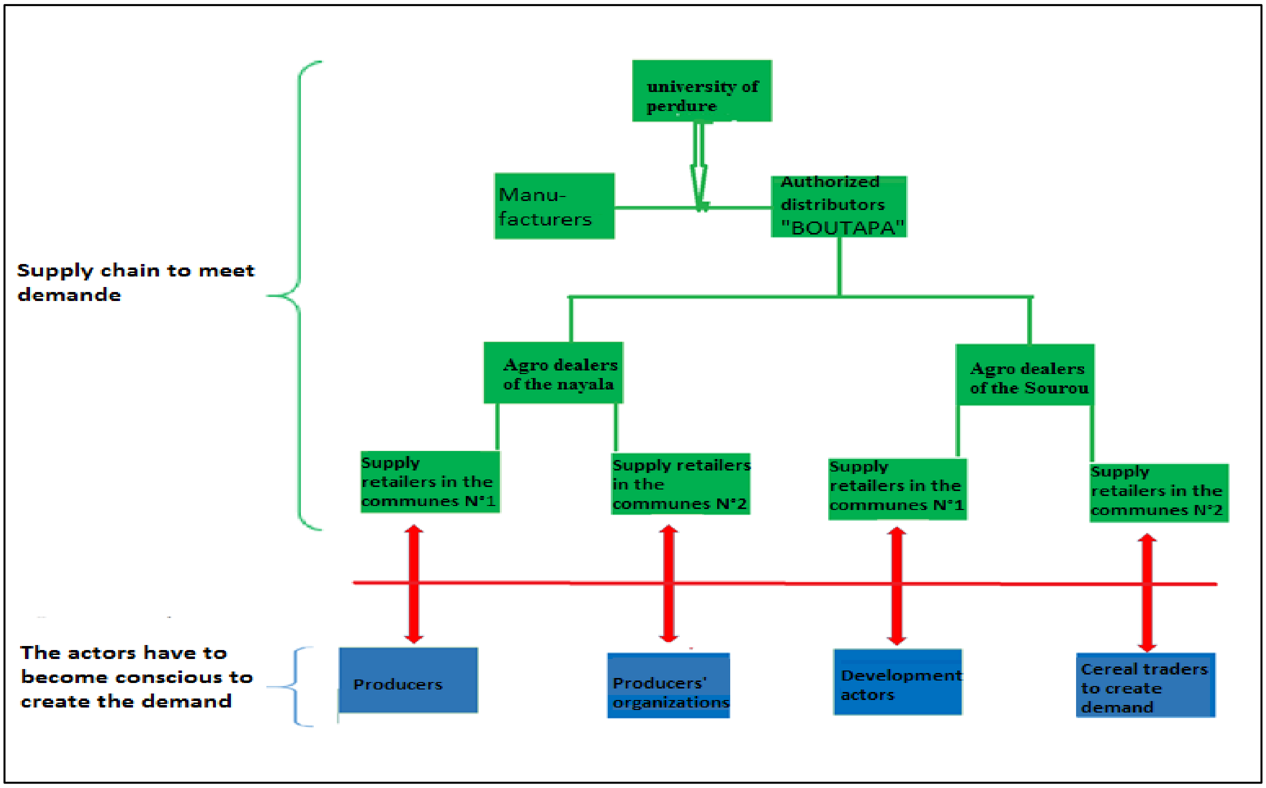


Figure 1. Strategy for the availability of good quality PICS bags
Source: GRAD Interim Report, 2017.

Concerning PICS bags the research team learnt that demonstration of its use to agro dealers was done, not only by GRAD but also by a national consultant, M. Issaka Sankara. The consultant was also contracted by the University of Perdue, to train and demonstrate the use of this storage technology. Moreover, radio commercial spots were developed to advertise the efficacy and reliability of the PICS bag storage technology. It is worth noting that although distribution of PICS bags is done through one main outlet, BOUTAPA Company, the project also facilitated the development of a mechanism for PICS bags distribution in the project/treatment areas. These mechanisms which were deployed, aimed at improving availability and access as illustrated below.

As



shows, the different steps are:

- Awareness-raising among producers, producers' organizations, development actors and cereal traders to create demand;
- Bringing in agro dealers in groups by province (Sourou and Nayala) and implementation of bulk (group) purchases to benefit from economies of scale from authorized distributors. We also note that advocacy continues with the University of Perdue to increase the number of authorized distributors to more than one;
- Enlisting supply retailers in the various communes for food supplies in the villages.

The progress on the threshers on the other hand has seen a lot of support from the Regional Directorate for Agriculture and Hydraulics Development of the Boucle du Mouhoun region. In line with this we understand that agricultural entrepreneurs have been identified and sensitized about agriculture service provision to smallholder farmers. They have positioned themselves as private operators to offer among others post-harvest services to farmers. These operators currently benefit from the support of the CLAPHI team in the development of their business plans. Table 1 gives the list of private operators who had indicated purchase intentions of the threshing machine in 2016.

Table 1: Private Operators intending to purchase threshers

Surname and given name	Localities	Contact	Observations
Moussiani Henri Joel	Nayala	70 38 56 58	Individual
Pare Albert	Nayala	70 71 94 00	Individual
Bicaba Kani	Dedougou		President of the regional union of agricultural entrepreneurs of Boucle du Mouhoun
Tiendrebeogo Celestin	Bobo Dioulasso		Individual/SECOPA
Pare Olivier	Dedougou	70 09 57 66/ 78 46 39 77	President of the regional union of agricultural entrepreneurs of Boucle du Mouhoun
Traore P. Ali	Sourou		
Kombelem Herman	Nayala	70 45 09 23	Nayala Seed Producer and President of the Provincial Union of Nayala Agricultural Contractors
Yameogo Jean Pierre	Koudougou	70 23 90 25	Individual / Cereal / Pulse Trader and Distribution of Agricultural Inputs

Source: GRAD Interim Report, 2017.

Once individuals as above, had indicated their intentions after training, and demonstrations were completed in the intervention provinces, GRAD believed that it was on course to improve thresher usage in especially the subsequent farming seasons. In addition to this, we learnt that local workshops had been set up by trained craftsmen to manufacture the machines and were in the process of finalizing the machines as at the time the study began. As the cost of the machines, although high, had been heavily subsidized by the project (60% of total cost), GRAD believes this helped patronage beyond what would have been the demand.

In trying to understand the challenges that the project encountered so far, we found out that as knowledge of the efficiency and utility of the PICS bags spread, there was the introduction of fake bags onto the market. GRAD noticed that farmers who tried to purchase the bags themselves were sometimes tricked into buying fake ones, not as durable as the authentic ones. This may have influenced farmer's choice in the adoption of the technology due to results observed during use. In addition to this, GRAD also observed the use of other storage technology such as the "ZeroFlies" bag which had been distributed by the WFP and the FAO to some smallholder farmers in the treatment provinces. GRAD however expected that, its sensitization and radio commercial broadcasts of PICS bags will result in better patronage compared to other technologies. Armed with this information following consultations with GRAD, the research team paid visits to some sites to confirm the stories we had been told about the CLAPHI project.

3.2 Theory of Change

In many developing countries farming is the major economic livelihood activity, employing a large section of the population. This is not different for Burkina Faso where farming is characterized by erratic rainfall patterns, low soil fertility, low productivity and huge post-harvest losses. These continue to be major challenge to the profitability of farm enterprises if farming is to be seen to have potentially decreasing effect on poverty. The arid nature of the land in Burkina Faso tends to worsen the problem resulting in poor crop yields, low income and poor agricultural performance in general. Post-harvest losses have played a critical role in reducing quantity of grains produced and as a result reduced the welfare status of smallholder farmers in Burkina Faso.

Addressing the challenges with post-harvest losses in Burkina Faso is seen as a major way of improving the livelihoods of poor farmers. High post-harvest losses (PHL's) in part are a major cause of food shortages, incidence of hunger, low income and worsening of welfare of smallholder farmers in the country. Measures aimed at reducing PHL's potentially have direct consequences for improving food security in several parts of Burkina Faso as many of these smallholder farmers and consumers encounter food insecurity on a continuous basis due to such losses. Thus, PHL mitigation will assist in improving livelihoods and the welfare of both farmers and consumers.

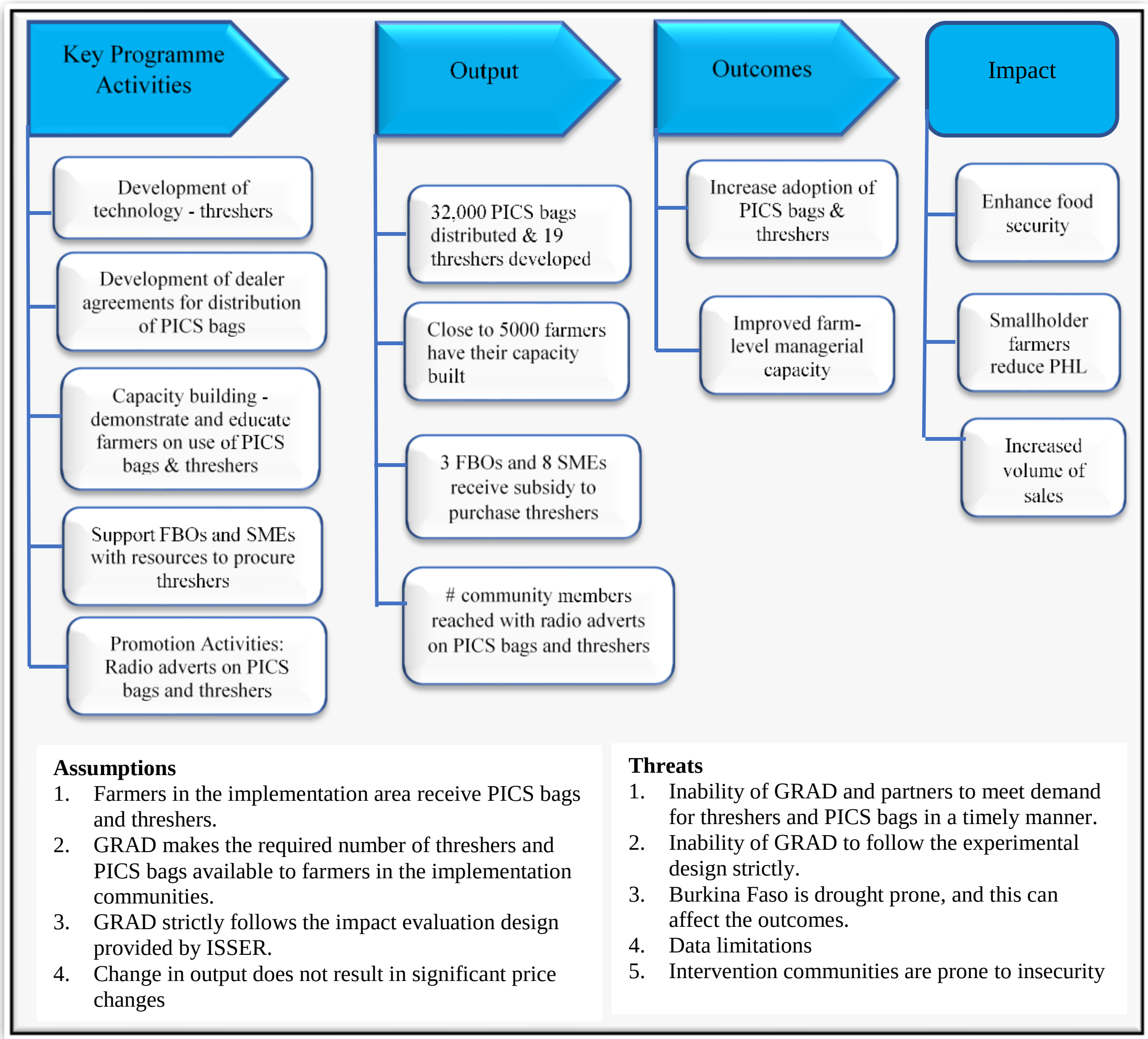


Figure 2: Theory change - CLAPHI project in Burkina Faso
Source: Authors' construct

Reducing food losses, and particularly PHL, contributes to improving food security, fighting hunger and reducing poverty. Smallholder farmers in food deficit areas benefit from increased availability, quality and safety of food as well as more efficient production and post-harvest systems at the farm level which provide additional opportunities to increase household income. The CLAPHI project seeks to address barriers to improved grain productivity of smallholder farmers in Burkina Faso as well as reduce poverty. The programme makes available a set of PHTs – threshers and PICS bags to farmers across the study areas. Provision and access of a mechanized approach to threshing and winnowing is aimed at improving and considerably reducing threshing time, improve on grain quality and significantly reduce crop losses during post-harvest activities. Crop losses occur at every stage of the supply chain from production to the final consumer although losses are more critical at the storage stage in many developing countries. The adoption and usage of PICS bags are therefore essential in reducing PHL among smallholder farmers in Burkina Faso and can have an impact in improving their welfare.

Given this background, awareness of the post-harvest technologies is expected to increase adoption rate of PHTs, reduce crop losses, increase total harvest volumes and crop sales and crop yield. Increases in indicators are consequently expected to have a positive impact on food security and reduce incidence of hunger farmer households as well as increase household income. The program's theory of change is summarized in **Error! Reference source not found.**.

3.3 Research Hypothesis

Reduction of post-harvest losses in critical in the fight again hunger and food insecurity in developing countries. Poor technologies used in post-harvest activities, are expected to lead to low volumes and low sales given the prices. Use of technology during post-harvest activities also reduces the drudgery nature of those activities An important component of the programme under evaluation is to enhance the adoption of post-harvest technologies – PICS bags and threshers, which helps in reducing post-harvest losses and mitigate food insecurity and hunger. However, the theory of change assumes that famers would adopt and use these technologies because it has been shown to work on demonstration fields and elsewhere. However, this is a new technology and farmers need to be convinced before they may use it. Information dissemination about the technology then becomes critical for the success of the project. GRAD resorted to use radio advertisements, FBOs, field demonstrations, among other channels to enhance farmer knowledge about the technologies. This study therefore evaluates the CLAPHI project by testing the hypotheses relating to the impact of PHTs on post-harvest losses and other welfare enhancing indicators, thus assessing the overall success of the CLAPHI project. Thus, this study seeks to test five broad hypotheses:

H1: Enhancing farmers knowledge on PICS bags and threshers increases the adoption rate of these technology.

H2: Adoption of PICS bags and threshers significantly reduces post-harvest losses leading to increase in grain production and sales.

H3: Farm households exposed to PHTs have lower food insecurity than those who are not exposed to these technologies.

H4: Farmers using threshers work fewer labour days and use their time for other economic activities.

H5: All delivery channels (agro dears, FOs, Extension and NGOs) have similar impact on the propensity of PICS bags adoption

We expect famers who receive information and adoption PHTs to increase their grain portfolio investments by allocating more resources (land, for example) to the production of such crops. The assumption here is that the adoption of PHTs would boost farmers' interest in the selected grains production, making them scale up by devoting more farm land to the selected grains relative to other crops, for example.

4 CONTEXT

4.1 Country Background

Burkina Faso is a landlocked country south of the Sahara Desert with a total area of 27.4 million hectares and arable land estimated by both the World Bank and FAO at 6 million hectares in 2014. The climate is mainly dry (starting from October to June) with unimodal rainfall lasting for 4 to 5 months. Though the volume of rainfall differs significantly from month to month and for various. ecological zones, nearly 65% of the country is in the isohyets 500 mm and 800 mm, with the highest rainfall recorded in south Sudanian zone, and the month of August is deemed as the wettest. Farmers in the South and central ecological zones have profited from rich arable lands relative to those in the north Sahelian zone. Cultivation of major cereals (millet, sorghum, fonio and maize) in Burkina Faso accounts for about 3.7 million hectares of arable land, and this is largely dependent on rainfall, with about 98,000 hectares of arable land under rice cultivation. Potentially irrigable land of Burkina Faso is estimated between 165 000 ha (Mee, 2001) and 233 500 hectares (MAHRH, 2004). However, in 2012, it was estimated that only 55,000 hectares of arable land (0.5 percent) was irrigated and these were located near river systems, with a further 500,000 hectares of valley-bottom lands that potentially could lend themselves to small-scale irrigation

4.2 Focus Region and Crops

The Boucle du Mouhoun region (area marked with the deep blue colour in Figure 3) is endowed with major irrigation schemes coupled with artificial lakes and fertile green lands suitable for vegetable cultivation. In addition, there are temporary pond, which are normally created during the wet rainy season.

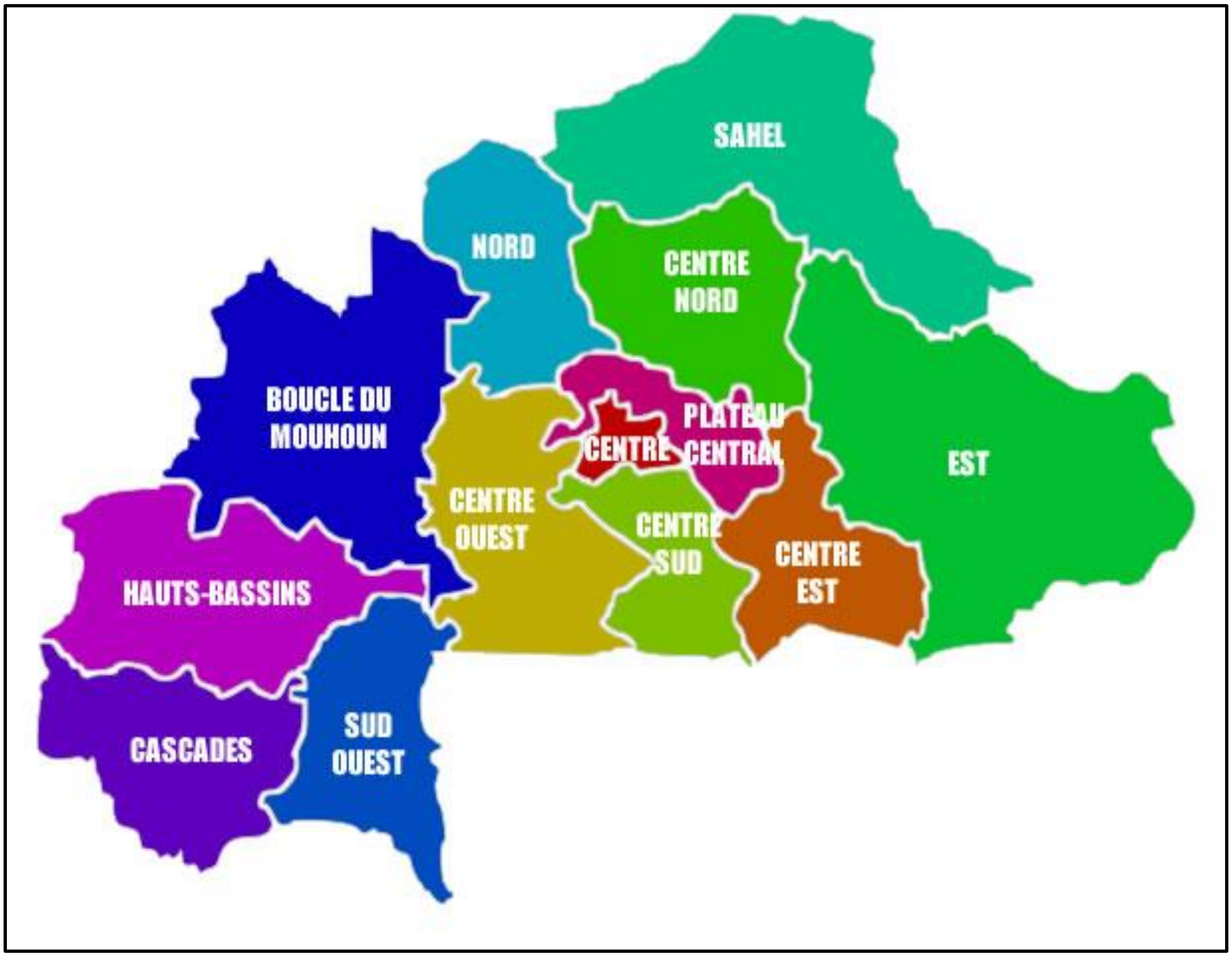


Figure 3: Study Areas - Boucle du Mouhoun (deep blue and Centre Est (deep brown) Region

Although Burkina Faso is not self-sufficient in food, agriculture in Burkina Faso has tremendous potential. The agricultural sector employs the vast majority of workforce contributing about 34.2 percent of the GDP in 2015. However, only an estimated 13 percent of the total land area is under annual or perennial crops. Government attempts to modernize the agricultural sector have met with some success, especially with cotton, whose export accounted for 10.1 percent of total exports in 2018.

Agriculture continue to be critical for improving livelihoods in Burkina Faso. Indeed, food production has significant positive implications for poverty reduction and improvement in welfare. However, key challenges including high PHL, access to fertile lands as well as poor irrigation systems, poor transportations, high cost of inputs, access to credit and poor extension services among others, threaten the growth and development of the sector. Government with assistance from development partners have implemented a series of policies and programmes to reduce the threat that confronts the sector. For instance, government increased its investment in irrigation projects from US $14 million in 2009 to US $29 million in 2010 with the aim of increasing irrigated lands for increased productivity and all year around cultivation.

The objectives of the agricultural sector hinges on establishment of suitable institutional and regulatory framework aimed at attracting private investments in irrigation and the adoption of agricultural land development and use policies that promote the utilization of irrigation systems, and the promotion of value addition in the sector. To this end, agricultural policies of government have targeted raising production per household by encouraging farmers to adopt modern farming practices, technology, efficient soil water and fertility management techniques as well as mechanization.

5 TIMELINES

The activity timeline for the study is shown in Figure 4. The diagram shows the main study activity milestones and note that the study started with the randomization of the households into the different arms from the list of FBOs obtained from GRAD. This was done by the researchers together with the programme implementers, so that we had their agreement from the beginning of the study about the need to keep to this random assignment. The random assignment was preceded by a focus group discussion with some of the farming households as well as opinion leaders in some of the intervention communities to explain the essence of the study design. An inception workshop was organized in July 2016 in Ouagadougou to introduce the project to stakeholders and the potential benefits of the project. Following the random assignment of the households into the different treatment arms, we undertook a baseline survey in November 2016. In February 2018, the researcher embarked on a monitoring activity to ensure that the research design was not contaminated and there was no spill over effects. In December 2018 the end-line survey was conducted. The choice of December was critical to ensure that the survey coincided with the harvest season to avoid recall bias. After this a stakeholder workshop was organized in February 2019 at which the preliminary results were discussed. The draft final report was submitted in February 2019 to AGRA.

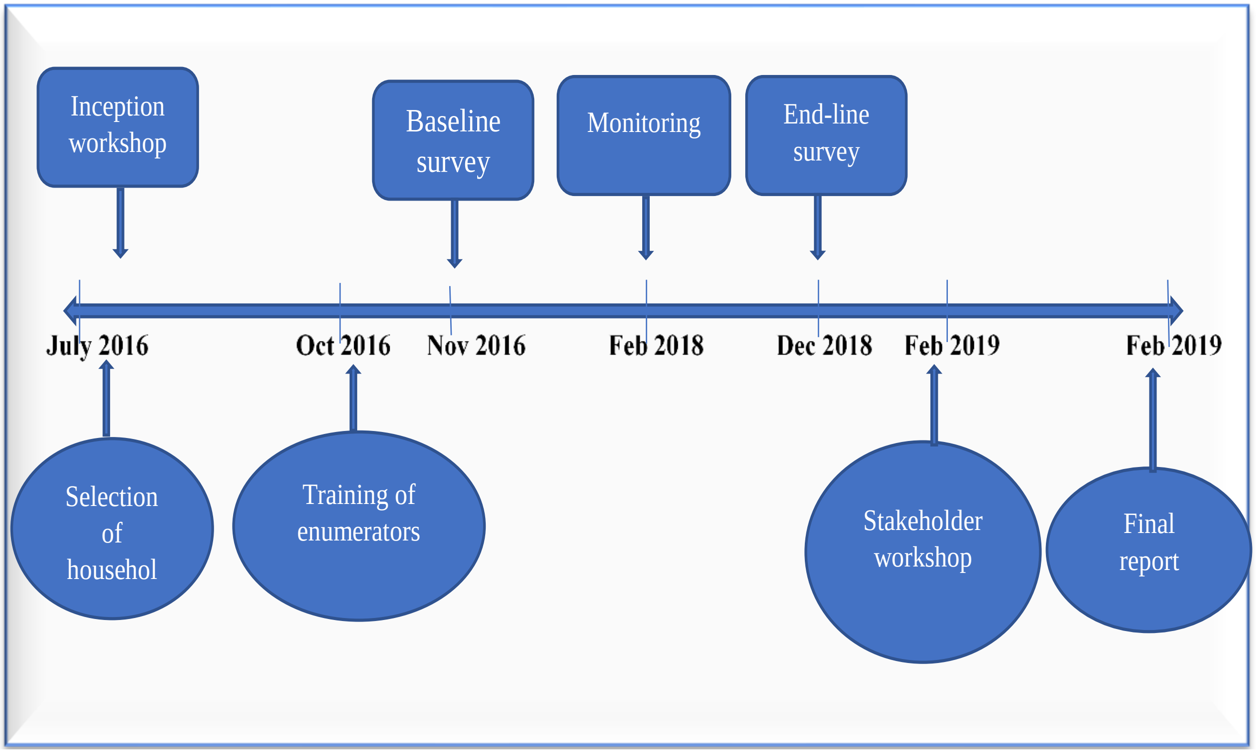


Figure 4: Activity timeline for study
Source: Authors' own construct

6 EVALUATION: DESIGN, METHODS AND IMPLEMENTATION

6.1 Evaluation Design (Including Randomisation)

In trying to attain all the goals for this study, it was agreed that a combination of two methodologies will be appropriate for the work to be done. First, Propensity Score Matching (PSM) techniques were used for the control households. The control household were obtained from the AGRA baseline survey which run concurrently as the IDRC survey in order to allow for strict communities. Moreover, the period and timing for both surveys makes the sampling for treatment and control groups ideal for a baseline survey. Treatment sample was collected in one region (Boucle de Mouhoun) spread across two districts, Nayala and Sourou.

It is worth noting that in selecting the control community for the Propensity Score Matching test, the study sought to create control sample good enough in order to tackle the problem of contamination if it happened. Control samples were selected to match as closely as possible the treatment sample. In addition to other similar characteristics in the treatment, one sample was done based on datasets collected in the same region (Boucle de Mouhoun) but in different districts, Banwa and Mouhoun to ensure that this sample did not deviate so much from our treatment sample. This sample had a high chance of contamination due to the closeness of the survey areas, as well as security in these controlled communities, hence Banwa and Mouhoun were dropped. This therefore necessitated the creation of another control sample which considered respondents selected from 2 districts (Bouglou and Kouritenga) in a different region (Centre-Est).

Combining this latter sample with the treatment sample, balance tests and rankings were done from these control samples which provided some statistical proof which aided in the selection of 100 control respondents.

The goal is after obtaining these control communities the study will use the difference in difference approach after the second wave to ascertain the impact of the Post-Harvest Technologies on farmers in these intervention regions.

6.2 Sample Size Determination

For the purposes of scaling up the intervention, this study sampled farm households from a list of 9000 cereal farmers, provided by the implementers of the project (GRAD), who utilises services rendered by agro-dealers and private mechanisation service providers. The study also sampled from the same group of farm households who are members of co-operatives (farmer-based organisations) from the chosen intervention area, the Boucle de Mouhoun region. As discussed above this approach was considered for the treatment as well as the control sample. It is relevant to note that treatment groups were split into three main intervention channels to ascertain which channel best suits the efficient distribution of some Post-harvest technologies with the main aim of upscaling. Channels split among the treatment group through which the intervention took place were Agro Dealers, Private Mechanization/Service Providers and Cooperatives.

Using a stratified random sampling technique, the study sampled a total of 240 households were considered for the treatment sample. Eighty (80) households for each channel. Thirty-five (35) communities were selected within the two treatment districts with originally ten (10) farmers per community although the study decided on fifteen (15) farmers per community to tackle the expected attrition problem. On the other hand, a sample of 80 households were to be considered for control. However, taking into consideration attrition and cost, the study decided to select a total sample of 419 households, 319 for the treatment sample intervention channels and 100 households for the control sample.

6.3 Survey Methodology: Data Collection and Quality Control

The employed a mixed method approach to research to address the objectives of the study. The research approach consisted of first conducting a baseline survey in December 2016, aimed at collecting quantitative information of the sampled farm households in both regions of Boucle du Mouhoun and Centre Est. This was followed by a field visit to the study areas in November 2017 to ascertain that the non-contamination of the research design. Subsequently, the end-line quantitative survey was conducted in December 2018.

A critical component of the research was the comparison of households in the intervention communities and those in the controlled areas. To ensure the robustness of the results the study employed a matching technique to ensure households in intervention communities and controlled areas are of similar characteristics. This was to ensure that the only difference between the two group of households was access and lack of access to the intervention. In the statistical description of observational data, propensity score matching (PSM) is a statistical matching approach that tries to estimate the impact of a treatment, policy, or other intervention by considering some independent variables or markers that predict receiving the treatment. This is a pseudo experimental design which is not random but provides a score which is the probability of treatment assignment conditional on observed baseline characteristics. The propensity score allows one to design and analyze an observational (nonrandomized) study so that it mimics some of the characteristics of a randomized controlled trial. In particular, the propensity score is a balancing score: conditional on the propensity score that the distribution of observed baseline covariates will be similar between treated and untreated subjects.

The propensity score was defined by Rosenbaum and Rubin (1983a) to be the probability of treatment assignment conditional on observed baseline covariates: ei = Pr(Zi = 1|Xi). Thus, in a set of subjects all of whom have the same propensity score, the distribution of observed baseline covariates will be the same between the treated and untreated subjects.

The propensity score exists in both randomized experiments and in observational studies. In randomized experiments, which is not evident in our case the true propensity score is known and is defined by the study design. In this survey's case which is an observational study, the true propensity score is not, in general, known. However, it can be estimated using the study data which was done using the strict treatment and control samples. In practice, the propensity score is most often estimated using a logistic regression model, in which treatment status is regressed on observed baseline characteristics. The estimated propensity score is the predicted probability of treatment derived from the fitted regression model. Although logistic regression appears to be the most commonly used method for estimating the propensity score, the use of bagging or boosting (Lee, Lessler, & Stuart, 2010; McCaffrey, Ridgeway, & Morral, 2004), recursive partitioning or tree-based methods (Lee, Lessler, & Stuart, 2010; Setoguchi, Schneeweiss, Brookhart, Glynn, & Cook, 2008) random forests (Lee, Lessler, & Stuart, 2010), and neural networks (Setoguchi, Schneeweiss, Brookhart, Glynn, & Cook, 2008) for estimating the propensity score have been examined.

Propensity score matching entails forming matched sets of treated and untreated subjects who share a similar value of the propensity score (Rosenbaum & Rubin, 1983a; Rosenbaum & Rubin, 1985). Propensity score matching allows one to estimate the ATT (Imbens, 2004). The most common implementation of propensity score matching is one-to-one or pair matching, in which pairs of treated and untreated subjects are formed, such that matched subjects have similar values of the propensity score. Although one-to-one matching appears to be the most common approach to propensity score matching, other approaches can be used. Once a matched sample has been formed, the treatment effect can be estimated by directly comparing outcomes between treated and untreated subjects in the matched sample (Austin, 2011).

6.3.1 Baseline Survey

Fieldwork covered an overall period of about 3 weeks, beginning November 28th, 2016, for listing and both quantitative and qualitative surveys. The selected period coincided with the harvest period for the target crops for most farmers, while ensuring that fieldwork ended before the Christmas festivities scheduled for December 24th, 2016. Prior to that, enumerators for the quantitative survey received training on the content and techniques for administering the instrument, after which they deployed to the field.

As mentioned above there were 35 communities from the two districts where enumerators were to find their treatment households. Immediately after listing; enumeration teams purposefully selected households which formed part of the implementers list, with backups, to begin quantitative interviews.

The instruments focused on farming activities of households in both regions, for all stages of production with emphasis on Post-harvest technologies, household welfare, related to income, food security and housing conditions. The questions in the quantitative instrument covered land tenure and use, input adoption, agronomic practices, harvest, post and pre-harvest losses, income and employment, housing conditions and food security. To ensure the quality and integrity of the data captured, a computer-assisted personal interviews (CAPI) programme was deployed. All the instruments were upload unto a tablet and given to the enumerators.

6.3.2 Field Monitoring

The qualitative fieldwork began in February 2017. The interviews took a different format and consisted of Key Informant Interviews with agents of stakeholder organisations such as the Ministry of Agriculture, Water and Water Resources (Ministère de l'Agriculture et des Aménagements Hydrauliques), extension officers and aggregators. Additionally, In Depth Interviews (IDIs) and Focus Group Discussions (FGDs) were also conducted with farmers. The enumerators were assigned based on language proficiency relevant to the areas.

Two data collection instruments were developed to collect data for the qualitative baseline study. These were semi-structured interview and discussion guides. Both instruments focused on areas of the baseline study. Semi-structured interview guides were used as instruments to conduct IDIs and KIIs. A semi-structured discussion guide was also designed to conduct the FGDs. The areas of focus for each interview were:

- Structure, activities and sources of household income
- Asset, wealth, income and food security
- Access and use of agricultural inputs
- The management and use of agricultural output
- Women empowerment in agriculture, and other
- Potential extraneous variables

6.2.3 End-Line Survey

The survey took place in two provinces in the Boucle du Mouhoun region, namely Sourou and Nayala. In total, three (3) teams were formed: one team in Nayala and the other two in Sourou in relation to the knowledge of the environment and the number of households to be researched. In addition, it should be noted that majority of investigators had already participated in the baseline research in 2016. This was a major advantage in the field data collection process. In order to ensure the proper conduct of the data collection, the enumerators and the supervisors each received the following material:

- Physical questionnaires to use if needed;
- GPS, tablets and charger;
- Two Power-Banks to maximize shelf life;
- USB flash drives

For the controllers, in addition to the elements mentioned above, there was a Wi-Fi modem for connection; a letter for the local authorities. For their mobility in the collection areas, a vehicle was made available to each team. Also, each investigator had a motorcycle at his disposal for his mobility within the villages.

All three (3) teams started the data collection on Saturday 8th December 2018. The collection lasted 15 days for the study in the intervention zone. Once in the locality, the objective was to find all the households researched in 2016 during the IDRC study, and to collect the same information except in certain cases. Controllers regularly send (at the end of the day) the data collected to the supervisor for verification. There was opportunity to consider progress and address difficulties encountered. As part of quality control measures, the controller assesses activities and the problems that the team encounters and possibly makes suggestions. Furthermore, the coordination team, especially the supervisor, provides solutions after discussions with the coordinator regarding some specific problems. The data collection did not end at the same time for all teams. This was due to the specific problems faced by each team. Finally, we note that the contribution of the field knowledge by the controllers and the support of the local authorities were decisive in the success of the mission. For the control zone, two teams were sent to the field for a period of seven (7) working days. It was advised that we use the teams that finished earlier, in their area of demarcation. The advantage was that the latter already had the CAPI application in hand, in addition to the knowledge of the questionnaire.

In total, 287 households out of a total of 320 were surveyed, a completion rate of about 90%. Overall, the teams performed well. In the case of team 2, for example, it is pointed out that, thanks to the team's determination and the support of local authorities, 109 households out of a total of 110 households were studied. The single household missing was explained by the fact that the head of a household in Ouori-Baonghin village named GUIRA Soumaila and his entire household had left the village.

Overall, the survey also turned out well with regards to team 3 despite the context of insecurity. Thus, out of 110 households to be surveyed in 11 villages, 98 were carried out in 10 villages. And finally, Team 1, achieved a result of 98 out of 100 households. In general, and mainly for reasons of displacement and insecurity, one of the sample villages (Konga) was not surveyed. Households located in the control area, that could not be surveyed were linked to duplicates in the ISSER sample. Factors such as household shifts as well as deaths meant that some households were unavailable. The result is that 87 households were surveyed out of the 99 households downloaded on the tablets.

7 ANALYTICAL FRAMEWORK

7.1 Estimation of impact of the intervention of key outcomes

The successful implementation of randomization process indicates that the estimates of Average Treatment Effect (ATE) and Average Treatment Effect on the Treated (ATT) is expected to be similar (i.e. ATE = ATT). The randomization process further allows us to use a simple strategy for evaluating the impact of post-harvest technologies on post-harvest losses and aggregation services on key outcomes for smallholder farmers. Therefore, conditional on observed characteristics, X, and treatment, we can write the expected value of an outcome variable of interest (e.g., total volume of crops) as:

$$E(Y_i|X_i,D_i) = D_iY_{1i} + (1\text{-}D_i)Y_{0i} \quad (1)$$

where Di is the treatment variable for household i = 1, 2, …, N such that Di = 1 if household i is located in a treated community or indeed received the given treatment and Di = 0 if household i was assigned to the control group. The impact of the intervention on the ith household, τ, is simply $\tau_i \equiv Y_{1i} - Y_{0i}$. Specifically, we estimate the following regression model:

$$y_{it} = \alpha + \beta_1 Treat_{it} + \beta_2 T + \delta_1(T^*Treat_i) + X_{it}\lambda + \varepsilon_{it} \quad (2)$$

where T denotes time dummy, taking the value 0 for baseline and 1 for end-line. *Treat* is the treatment variable, which equals 1 if the household is in the treatment group and 0 if the household is in the control group. The impact indicator is the interaction between Time and Treat, hence the impact is measured by δ_1. If the intervention has an impact on a given outcome, then δ_1 would differ from zero at less than 5% level of significance. Lastly, *X is* a set of other controls (household characteristics, namely: age, sex of household head and literacy). For the outcomes that are roughly continuous, we modify equation (2) as:

$$\Delta y_i = \alpha + \beta_1 Treat_{it} + \Delta X_1\lambda_1 + X_2\lambda_2 + \varepsilon_i \quad (3)$$

where Δ is the change (or difference) operator, X_1 is the vector of time-varying covariates, X_2 is the vector of time-invariant covariates, and β_1 measures the impact of the intervention.

For each ATE estimate we present results from two equations labelled Eqn1 and Eqn2, respectively, depending on the variables that enter the vector X in equation (2). For Eqn1 estimates, the vector X is null signifying that the equation is estimated without covariates. Eqn2 however has the vector X containing the full complement of standard controls depending on the particular outcome of interest.

The estimations of the ATE comprise of two types of outcome variables: binary and continuous. Each of these types of outcome variables require different types of estimators: probit and ordinary least squares (OLS), respectively. Where the outcome is binary or roughly continuous, we use the linear random effects estimator, which yields a panel data linear probability model in cases where the outcome is binary. The drawbacks of the linear probability model specification are benign in this case because our interest is in the estimate of ATE (Wooldridge 2002 p.445). The added advantage of the linear probability model in this case, apart from the ease in obtaining the ATE, is that it allows us to model unobserved heterogeneity using the correlated random effects approach (Wooldridge 2010). For the nonlinear models, we use the 'contrast' capability of the Stata statistical software package to obtain the correct ATE because in nonlinear models with interactions the coefficient on the interaction term may not represent the correct marginal effect in a similar way as the case is in a linear regression model (Ai and Norton 2003; Norton et al. 2004).

7.2 Balance Test

The study employed a difference-in-difference estimation technique in assessing the impact of postharvest technologies (see section 6.1 for details). The method is founded on a number of assumptions, which must be valid so as to generate appropriate counterfactual for estimating the impact. With the successful random assignment of households to control and treatment groups, and in the absence of any observable contamination issues, it is anticipated that households in the treatment and control communities are similar in observable characteristics prior to the intervention. To ensure that the observed impact of postharvest technologies is largely as a result of the introduction of the intervention, it is imperative to substantiate that the treatment and control groups are similar, at least on observed characteristics. In this regard, we carry out the balance test. The balance test examines the statistical differences between the treatments and the control group at baseline on all the key indicators. This is done by simply regressing each indicator, y_k, on the treatment dummy (Treat). The general form of the regression for this test can be written as:

$$y_{i,k} = a + rTreat + u_i$$

Where *Treat* = 1 if household *i* is in the treatment community and 0 if household is in the control community. The balance test is the test of the null hypothesis that $r = 0$. An indicator is balanced at baseline if we fail to reject the null hypothesis at the 5 per cent level of significance. The balance test results are presented in Table A1. The randomisation exercise was in most cases successful, however, a number of the key indicators the null hypothesis could not be rejected at 5% level of significance. We therefore also tested the average treatment effect (ATE) by estimating ANCOVA.

8 FINDINGS

8.1 Descriptive Statistics

Table 2 present descriptive statistics of the adoption variables, the impact variable of interest and the control variables. The demographic indicators provide important explanations of observed economic and social trends of the population under study and serves as a critical component in public policy analysis and development. Thus, in this section the indicators offer an understanding of the characteristics of the treated and control households from the study sample. Most of the household members are males (see Table *2*). Within the two set of groups, both the control and treatment were dominated by males, constituting about 52.5% of the control sample.

Table 2: Summary statistics of selected variables

Variable	Unit	Baseline		End-line	
		Treatment districts	Control districts	Treatment districts	Control districts
Adoption variables					
Heard PICS	%	25	90.91	44.05	94.37
Use PICS	%	48	68.79	18.92	44.4
Heard Threshers	%	17	44.2	76.41	38.1
Use Threshers		11.76	9.35	15.63	6.91
Impact variables					
PHL	Kg	28.23	1.28	16.46	5.39
Actual Sales	CFA	11514.52	20833.33	16424.75	751
Food Security	%	32.92	35	44.01	27.38
Total labour days	Man days	82.11	194.01	92.38	85.71
Control variables					
Female	%	49.2	52.5	48.78	48.64
Age Household	years	23.99	23.99	25.58	26.97
Read	%	30.7	26.1	34.97	23.06
Write	%	30.5	25.9	33.24	22.64

8.2 Impact Evaluation Results

Farming, specifically grain production, is the main economic livelihood activity for the majority of households Burkina Faso. However, in spite of progress in grain production and marketing, output continue to fall far below the production and marketing potential. Two main challenges are identified as the root causes of the country's inability to realize its potential in grain production – lack of appropriate threshing and storage technologies. In this regard, the CLAPHI project sort to provide these technologies to enhance grain production. Thus, CLAPHI theory of change indicates that the provision of postharvest technologies, such as threshing machines and storage facilities (PICS bags) will reduce postharvest losses in cowpea, rice, sorghum and maize as well as improve grain quality, allowing farmers to access better markets, and thereby improving their living standards. The intervention was to introduce threshers and PICS bags and resort to training of farmers and radio announcement to disseminate and spread the importance of these postharvest technologies in reducing postharvest losses. We anticipate that these technologies and knowledge on their efficiency will impact on a number of indicators. First, the impact of the intervention on adoption of PHTs, which may be observed through indicators such as number of farmers who have heard of, as well as use the technologies as a means of adopting improved storage methods. The second level of impact is on crop output and marketing, captured by indicators such as postharvest losses (at the threshing, winnowing and storage levels), expected and actual sales, total harvest volumes and crop yields. Impact on expected and actual sales are projected to arise due to the expected improvement in grain quality and increase in output. The third level of impact indicators concerns the goal of improving smallholder farmers' welfare and food security. The is captured by indicators such as incidence of hunger and total work days saved due to the adoption and use of these technologies. We anticipate a reduction in the incidence of hunger and improvement in food security situation emanating from the intervention through channels other than just the expected increase in grain production and increased sales, ceteris paribus. Given that the technology of the thresher has been modified to accommodate other crops that were originally not part of the four crops – rice, sorghum, maize and cowpea – it is likely there could be a spill over effect on other crops that will in turn improve the hunger situation at the household.

8.2.1 **Adoption of Post-harvest technology services**

An overarching objective of the CLAPHI project was to enhance the adoption of PHTs to improve the post-harvest losses, improve the quality of grains, increase smallholder farmers returns and welfare of farmers. We expect that the CLAPHI will trigger adoption of PICS bags and Threshers in the treated communities, hence we test this hypothesis by assessing the impact on the proportion of farmers who have heard of and use PICS bags and threshers. We employed two variables to measure adoption PICS bags – "heard of PICS bags" and "used PICS bags". A similar approach is used in the measurement of adoption of threshers ("heard of threshers" and use of threshers"). The data shows that at baseline 90.9% and 44% of treated household indicated they had heard of PICS bags and threshers, respectively and increasing to 94% and 76%, respectively at end-line (see Figure 5). The impact results from a probit model are reported in Table 3.

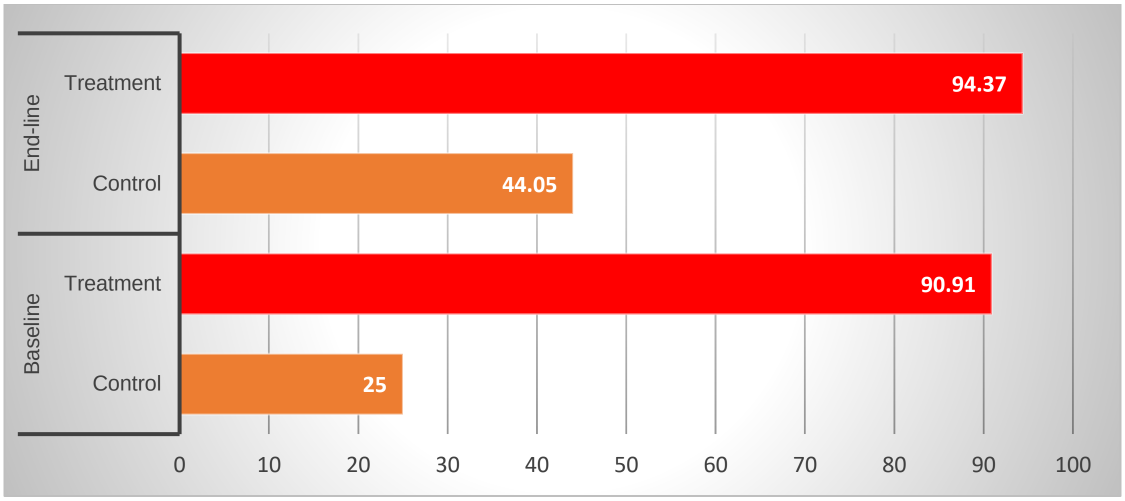


Figure 5: Percentage of households PICS bags

Table 3: Impact of intervention on adoption of post-harvest technologies

Variables	Heard of PICS bags		Use of PICS bags		Heard of Threshers		Use of Threshers	
	Eqn1	Eqn2	Eqn1	Eqn2	Eqn1	Eqn2	Eqn1	Eqn2
Time	0.072***	0.074***	-0.248***	-0.254***	0.298***	0.297***	-0.009	-0.006
	(0.022)	(0.022)	(0.037)	(0.037)	(0.029)	(0.029)	(0.025)	(0.025)
Treatment	0.583***		0.234***		0.318***		-0.053	
	(0.038)		(0.064)		(0.040)		(0.051)	
sex		-0.034		0.084		-0.016		0.047
		(0.044)		(0.077)		(0.068)		(0.053)
age		0.001		0.004***		-0.002		0.002*
		(0.001)		(0.002)		(0.001)		(0.001)
read		0.060		2.173		0.109		0.031
		(0.174)		(300.253)		(0.191)		(0.108)
write		0.052		-2.029		0.141		0.055
		(0.175)		(300.254)		(0.192)		(0.109)
Observations	787		612		787		405	

Robust standard errors in parentheses. *** and ** show statistical significance at the 1 per cent and 5 per cent levels, respectively.

Table 2 shows that the intervention has significantly impacted on the adoption of PHTs. Specifically, the results indicate that overtime, the intervention increased the probability of households' awareness of the importance of PICS bags and threshers. This is corroborated by the reports received on the ground during field monitoring as well as in the case study presented in Appendix 12.1. On the other hand, though the intervention impacted on use of PICS bags, it reduced the proportion of household using the technology over time. This might be surprising given the number of farmers who indicated their awareness of PICS bags and its superiority over other such technologies. However, during the monitoring, farmers were of the view that the price of the PICS was quite high, especially as NGOs were distributing similar bags at no cost. This was further corroborated by farmer interview for the case studies. Further, it is plausible that the shortage and lack of PICS bags may explain this outcome. The results further suggest the lack of evidence that the intervention had any significant impact on use of threshers. This is not surprising as only nineteen (19) of the mechanised threshers were deployed in the intervention area, furthermore, the threshers were deployed just two months prior to the end-line survey. This is thus, unlikely to record any significant impact on adoption of threshers. Additionally, the network of mechanized threshing service providers is yet to be set up. It should also be pointed out that generally, farmers are risk averse and hence the uptake of these technologies would take time, in which case this result is not surprising.

8.2.2 **Post-Harvest losses**

A major object of the CLAPHI project is a substantial reduction in postharvest losses of grains, and this goal was to be achieved via adoption of postharvest technologies – threshers and PICS – by smallholder farmers. Here, we assess the impact of the intervention on total postharvest losses as well as postharvest losses at the threshing, winnowing and storage stages. It is expected that the introduction and subsequent adoption and usage of postharvest technologies will have a dampening effect on the overall postharvest losses and at the various stages of the postharvest process, especially in light of adoption and usage of these technologies, as discussed above.

Overall, there was a decline in the postharvest losses between baseline and end-line. Total postharvest losses of the grains were observed to decline from an average of 20.87kg at baseline to 14.13kg at end-line. Controlling all other factors, the decline can be attributed to the high adoption and usage of PHTs over the two periods. Significantly, the reduction in postharvest losses at the storage stage was more pronounced, an indication of the success of PICS bags usage across the treatment communities. Table 4 provides results from the difference-in-difference regression estimation.

Table 4: Impact of postharvest technologies on postharvest losses

Variables	Threshing Losses		Winnowing Losses		Storage Losses	
	Eqn1	Eqn2	Eqn1	Eqn2	Eqn1	Eqn2
Treatment	10.396**	10.495**	9.031**	9.331**	48.973***	49.912***
	(4.089)	(4.189)	(3.789)	(3.910)	(10.193)	(10.535)
Time	0.000	-0.553	0.000***	0.507	1.143	0.973
	(0.000)	(1.400)	(0.000)	(0.531)	(1.140)	(2.184)
Treatment x Time	5.660	6.186	-8.746**	-9.571**	-49.936***	-51.293***
	(13.608)	(14.898)	(3.800)	(4.211)	(10.261)	(11.280)
Sex		-11.17**		-4.028**		-18.276***
		(5.507)		(1.866)		(5.244)
Age		0.072		0.031		0.629**
		(0.267)		(0.113)		(0.274)
Can Read		-4.166		4.700		19.120
		(9.374)		(4.113)		(14.104)
Can Write		2.173		3.171		9.061
		(6.844)		(4.545)		(15.100)
Observations	742	742	742	742	742	742

Robust standard errors in parentheses. *** and ** show statistical significance at the 1 per cent and 5 per cent levels, respectively.

Results indicate that PHTs reduces the quantity of the farm produce lost at the postharvest stage. The intervention is estimated to have reduced total postharvest losses by appropriately 27kg per an average household plot size of 3 hectares, which is quite a substantial reduction. Further evidence shows that household in the control communities experienced lower postharvest losses at baseline relative to households in treatment communities. However, at end-line treatment communities registered a substantial reduction (45%) in postharvest losses, while controlled communities witness an increased in postharvest losses.

Looking at the broad array of the postharvest process, the result indicates that the impact of the intervention on post-harvest losses at the threshing stage was not statistically significant. The situation was different at the winnowing and storage levels, where the difference-in-difference results show that the intervention impacted significantly on the crop losses. At the winnowing stage, the intervention reduced crop losses by approximately 9.6Kg on average, and further reduced postharvest storage losses by 51Kg on average. This can be largely attributed to the large proportion of farmers who have adopted and are using the PICS bags.

8.2.3 Cultivation Plot Size

We expect adoption of post-harvest technology services to reduce post-harvest losses and thus reduce the necessity to increase plot sizes under cultivation in order to increase farm output. The evidence in developing countries indicate that farmers would usually increase areas of land under cultivation to compensate for productivity challenges. Granted the positive impact of post-harvest technology on farm output, we do not expect the cultivation of plot size to change significantly for the treated, either at the individual or household level. In the long term, we do not expect the size of plots cultivated in treated communities significantly different from than those in control communities, other things being equal. In columns 1 and 2 of Table 5, the difference-in-differences estimates suggest the plot sizes cultivated by individuals in treated communities did not change. In general, the difference in plot size between treatment and control communities is not statistically different from zero across all specifications.

Table 5: Impact of PHTs on cultivated plot size

Variables	Individual cultivated plot size		Household cultivated plot size	
	Eqn1	Eqn2	Eqn1	Eqn2
Treatment	-0.571	-0.592	-2.883	-2.920
	(0.859)	(0.869)	(1.948)	(1.966)
Time	-0.219	-0.234	-1.601	-1.626
	(1.003)	(0.997)	(1.824)	(1.820)
Treatment x Time	-0.331	-0.294	0.857	0.908
	(1.013)	(0.990)	(1.841)	(1.835)
Sex		0.521		1.534
		(1.401)		(2.846)
Age		-0.001		0.001
		(0.012)		(0.019)
Can Read		-0.409		-0.445
		(0.330)		(0.496)
Can Write		0.015		-0.032
		(0.382)		(0.584)
Observations	782	782	782	782

Robust standard errors in parentheses. *** and ** show statistical significance at the 1 per cent and 5 per cent levels, respectively.

8.2.4 Changes in size of plot cultivation

In line with the discussion in with section 6.3.3, we do not expect changes in plot sizes to increase in treatment communities relative to control communities. This expectation is also weighed by the fact that there are larger shares of households cultivating more plots in control communities than in treatment communities. Reduction in post-harvest losses should positively impact on productivity on each plot and therefore lessen the need to extend plot sizes, at least in the short run. The difference-in-difference regression results of a reduction in changes in plot size in treated communities compared to control communities in most of the specifications in Table 6 is therefore consistent with what we expect. Once again, this effect is imprecisely estimated.

Table 6: Impact of PHTs on change of cultivated plot

Variables	Individual cultivated plot size		Household cultivated plot size	
	Eqn1	Eqn2	Eqn1	Eqn2
Treatment	0.060	0.042	-0.195	-0.210
	(0.241)	(0.242)	(0.224)	(0.224)
Time	0.183	0.157	0.141	0.119
	(0.252)	(0.254)	(0.237)	(0.238)
Treatment x Time	-0.056	-0.016	-0.017	0.020
	(0.278)	(0.282)	(0.263)	(0.265)
Sex		-0.360		-0.333
		(0.300)		(0.299)
Age		0.000		-0.001
		(0.005)		(0.005)
Can Read		-0.605***		-0.426
		(0.231)		(0.273)
Can Write		0.332		0.177
		(0.226)		(0.271)
Observations	657	657	698	698

Robust standard errors in parentheses. *** and ** show statistical significance at the 1 per cent and 5 per cent levels, respectively.

8.2.5 Share of land devoted to grains

In general, access to post-harvest technology services should incentivize grain production as individuals and households stand a chance of cutting their losses. The prospect of increasing returns on the farm should therefore encourage the share of land devoted to grains relative to other crops. If this substitution effect is strong, the share of land devoted to all grains should increase. Results in columns 5 to 8 of Table 7 point to this positive response for cowpea and all grains albeit not statistically significantly different from zero. We however see a statistically significant effect for the share of land devoted to maize production. Postharvest technology services increased the share of land devoted to maize production by about 0.7 percentage points more in treatment communities that in control communities. The share of land devoted to the cultivation of sorghum however fell by about 0.8 percentage points in treatment communities compared to control communities. A potential explanation could be the fact that sorghum already enjoys a larger share of grains cultivated per hectare. Farmers in treated communities may therefore be substituting towards other grains such as maize in a bid to improving their yields (see results on crop yields).

Table 7: Impact of PHTs on share of land devoted to grains

Variables	Maize		Sorghum		Cowpea		Grains	
	Eqn1	Eqn2	Eqn1	Eqn2	Eqn1	Eqn2	Eqn1	Eqn2
Treatment	-0.693	-0.719	0.768***	0.768***	-1.752	-1.776	-2.162	-2.194
	(0.628)	(0.641)	(0.193)	(0.191)	(1.226)	(1.234)	(1.945)	(1.966)
Time	0.545***	0.533***	0.328*	0.273	-0.022	-0.055	-2.647	-2.697
	(0.190)	(0.185)	(0.195)	(0.195)	(0.248)	(0.251)	(1.861)	(1.856)
Treatment x Time	0.648**	0.683**	-0.831***	-0.773***	0.035	0.062	0.797	0.867
	(0.323)	(0.334)	(0.234)	(0.235)	(0.295)	(0.300)	(1.891)	(1.885)
Sex		1.369		-0.769***		0.851		0.756
		(1.807)		(0.139)		(1.809)		(2.773)
Age		0.005		0.005		0.021		0.011
		(0.007)		(0.004)		(0.013)		(0.020)
Can Read		-0.875**		-0.343		-0.531		-0.241
		(0.427)		(0.254)		(0.348)		(0.561)
Can Write		0.727		0.248		0.451		-0.224
		(0.505)		(0.264)		(0.351)		(0.646)
Observations	541	541	744	744	606	606	781	781

Robust standard errors in parentheses. *** and ** show statistical significance at the 1 per cent and 5 per cent levels, respectively.

8.2.6 **Chemical use**

In most parts of Burkina Faso, farm lands are arid in nature and hence use of chemicals, especially fertilizers, are essential for soil enhancement as well as assist in mitigating crop losses. Overall, chemical use among our sample is very low, with only 23% of farmers indicating at baseline, that they use chemicals. Though the percentage of household using chemicals increased at end-line, it remains low. It must be indicated that the use of chemical does not necessary guarantee increase in produce as efficiency of these chemicals is largely dependent on appropriately storing, handling and application of the chemicals. Chemical usage is measured using two variables – chemical adoption measured as the probability that a household applies at least one type of chemical on the farm, and quantity of chemicals (in kilograms) used by the farmers.

The results for chemical adoption show that the intervention did not have a statistically significant impact on the proportion of households that use chemical on their farms as shown in Table 8. This is against the backdrop that we observed an increase in the amount of fertilizers used between baseline and end line. Households at baseline used an average of 13kg of chemical by farmers within the treatment communities while at end-line chemical usage by farmers increased to 21.5kg.

Table 8: Impact estimates of PHTs on chemical use

Variables	Chemical use		Quantity of chemical use	
	Eqn1	Eqn2	Eqn1	Eqn2
Treatment			-1.406	-0.872
			(6.230)	(6.294)
Time	0.088**	0.093**	-6.273	-5.513
	(0.037)	(0.037)	(5.879)	(6.048)
Treatment x Time			1.441	0.710
			(6.900)	(6.918)

Sex		-0.045		-5.919***
		(0.074)		(1.769)
Age		0.000		-0.178**
		(0.001)		(0.083)
Can Read		-0.144		-0.637
		(0.181)		(3.116)
Can Write		0.292		-1.155
		(0.179)		(3.930)
Observations	606	606	606	606

Robust standard errors in parentheses. *** and ** show statistical significance at the 1 per cent and 5 per cent levels, respectively.

8.2.7 Crop yields

The project's theory of change posits that the introduction of post-harvest technology should be positively associated with crops yields through two channels: the incentive effect and the salvage effect. The incentive effect stems from farmers being more committed to investing in their farms due to the future anticipated benefits from the technology services. Farmers are more willing to spend on other inputs. The salvage effect is the direct benefit of improving farm yields due to the reduced probability of loss to pests and other factors that contribute to post-harvest losses. Our difference-in-difference regression results in Table 9 below suggest a positive and statistically significant effect of post-harvest technology services on crop yields. In both columns 1 and 2 of our model specifications, average crop yields in treated communities were about 0.1 percentage points higher than in treated communities.

Table 9: Impact on total crop yield

Variables	Eqn1 All crops	Eqn2 All crops
Treatment	0.063**	0.061**
	(0.030)	(0.030)
Time	0.042	0.038
	(0.035)	(0.035)
Treatment x Time	0.098*	0.106*
	(0.057)	(0.058)
Sex		-0.014
		(0.056)
Age		-0.001
		(0.001)
Can Read		-0.016
		(0.083)
Can Write		-0.063
		(0.080)
Observations	788	788

Robust standard errors in parentheses. *** and ** show statistical significance at the 1 per cent and 5 per cent levels, respectively.

Once we disaggregate the crop yields by type, we find the same pattern although effects for maize, sorghum and cowpea are not economically and statistically significantly different from zero. We, however, see a positive and statistically significant effect for rice (See Table 9).

Table 10: Impact on individual crop yields

	Rice		Maize		Sorghum		Cowpea	
Variables	Eqn1	Eqn2	Eqn1	Eqn2	Eqn1	Eqn2	Eqn1	Eqn2
Treatment	0.000	0.000	0.000	0.000	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Time	0.001**	0.001**	0.000**	0.000**	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Treatment x Time	0.001*	0.002*	0.000	0.000	0.000	0.000	-0.000	-0.000
	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Sex		-0.001*		0.000		0.000		0.000
		(0.000)		(0.000)		(0.000)		(0.000)
Age		0.000		-0.000		-0.000		0.000
		(0.000)		(0.000)		(0.000)		(0.000)
Can Read		-0.001		-0.000		0.000		0.000
		(0.001)		(0.000)		(0.000)		(0.000)
Can Write		0.000		-0.000		-0.000		-0.000
		(0.001)		(0.000)		(0.000)		(0.000)
Observations	788	788	788	788	788	788	788	788

Robust standard errors in parentheses. *** and ** show statistical significance at the 1 per cent and 5 per cent levels, respectively.

8.2.8 Total harvest volumes

In line with the project's theory of change, we expect the adoption of post-harvest technology services to have a direct effect on total volume of crops harvested. The total output per hectare is expected to be higher in treated communities. The regression results in **Error! Not a valid bookmark self-reference.** below indicate that total output of all harvested grain (i.e. rice, maize, sorghum and cowpea) exceeded those harvested in control communities at baseline by between 88 kilograms and 100 kilograms. Except for sorghum, the effect for individual crops is not statistically significantly different from zero. The total volume of sorghum harvest increased in treated communities compared to control communities by between 83 and 89 kilograms.

Table 11: Impact on total harvest volumes

	All crops	All crops
	Eqn1	Eqn2
Treatment	92.889***	89.917***
	(22.618)	(22.301)
Time	89.627***	83.223**
	(33.958)	(34.385)
Treatment x Time	88.157*	99.862**
	(48.628)	(49.028)
Sex		-57.344
		(39.901)
Age		-0.885
		(1.153)
Can Read		-97.345
		(80.494)
Can Write		-16.846
		(80.139)
Observations	788	788

Robust standard errors in parentheses. *** and ** show statistical significance at the 1 per cent and 5 per cent levels, respectively.

Table 12: Impact of intervention on total harvest volumes by crop type

	Rice		Maize		Sorghum		Cowpea	
Variables	Eqn1	Eqn2	Eqn1	Eqn2	Eqn1	Eqn2	Eqn1	Eqn2
Treatment	9.503	9.493	2.107	1.600	40.60***	38.90***	40.65***	40.38***
	(8.377)	(8.328)	(1.482)	(1.812)	(12.852)	(12.836)	(9.110)	(8.889)
Time	-2.82	-2.839	41.82***	39.998***	46.318	43.817	5.203	3.777
	(2.164)	(2.234)	(10.628)	(10.665)	(29.105)	(29.363)	(3.515)	(3.855)
Treatment x Time	5.598	6.119	9.211	12.004	83.029**	88.932**	-10.161	-8.994
	(9.134)	(9.354)	(17.785)	(18.571)	(36.430)	(36.623)	(10.547)	(9.528)
Sex		-13.323*		-23.435***		-23.385		3.212
		(7.232)		(6.864)		(27.122)		(13.118)
Age		-0.210		-0.050		-1.107		0.430
		(0.189)		(0.255)		(0.730)		(0.421)
Can Read		-5.519		-24.683		-52.163		8.861
		(5.186)		(17.761)		(50.350)		(16.601)
Can Write		-3.394		3.755		-24.063		-7.185
		(3.247)		(16.948)		(49.997)		(17.540)
Observations	788	788	788	788	788	788	788	788

Robust standard errors in parentheses. *** and ** show statistical significance at the 1 per cent and 5 per cent levels, respectively.

8.2.9 Expected crop sales versus actual crop sales

An uptake of post-harvest technology services is expected to be positively correlated with the amount of expected sales. Given that more crops would be salvaged from destruction, waste or loss, average sales would be expected to go up. Table 13 and Table 14 below show our difference-in-difference regression results for expected and actual sales. We find that delivery of post-harvest technology services impacted on crop sales by between 67,000 and 101,000 FCFA compared to control communities. The translation of expected sales would however be mediated by several factors including effective demand, price of crops and access to markets. It is therefore not surprising that our difference-in-difference regression results for actual sales is more than halved although the effect is statistically significant at conventional levels. Actual crop sales for the average household is between 28,000 and 32,000 FCFA higher in treatment communities than in control communities.

Table 13: Impact of intervention on expected crop sales

	Expected crop sales (values)		Expected crop sales (log values)	
Variables	Eqn1	Eqn2	Eqn1	Eqn2
Treatment	-28,579.73	-48,582.85***	-3.60*	-3.77*
	(17,656.60)	(16,524.70)	(2.02)	(2.04)
Time	-48,912.07***	-61,648.11***	-4.22**	-4.81**
	(16,950.03)	(16,904.55)	(1.99)	(2.07)
Treatment x Time	67,355.80***	100,726.98***	4.39**	5.24**
	(24,470.71)	(31,483.80)	(2.01)	(2.09)
Sex		-40,955.17***		-1.99
		(11,755.70)		(1.47)
Age		-448.76		0.02

		(388.65)		(0.03)
Can Read		-69,892.71***		-11.07***
		(21,653.64)		(0.953)
Can Write		31,259.44**		10.00***
		(14,333.92)		(0.999)
Observations	108	108	107	107

Robust standard errors in parentheses. *** and ** show statistical significance at the 1 per cent and 5 per cent levels, respectively.

We also find evidence to suggest that relative to male counterparts, females are expected to derive higher revenue from the sales of their farm produce. Specifically, females are expected to earn about CFA 41,000 more than the male counter after controlling for all other characteristics. This also supported by the results from actual sales, which shows that females earn a little above CFA 17,000 more than the male counterparts. This is an indication of females' capacity to improve on the welfare and that of the household.

Table 14: Impact of intervention on actual sales of crops

Variables	Actual crop sales (monetary values)		Actual crop sales (log values)	
	Eqn1	Eqn2	Eqn1	Eqn2
Treatment	-9,468.33	-14,074.53	-0.41	-2.05**
	(9,997.35)	(9,455.27)	(0.67)	(0.932)
Time	-20,082.33**	-25,557.35***	-4.74*	-5.92*
	(9,733.54)	(9,244.69)	(2.51)	(3.038)
Treatment x Time	28,246.93**	31,515.82***	5.66**	7.19**
	(11,012.10)	(10,200.11)	(2.568)	(3.092)
Sex		-17,326.38***		-1.70**
		(4,746.37)		(0.718)
Age		294.67		0.16***
		(210.153)		(0.062)
Can Read		6,729.78		0.16
		(10,683.813)		(1.088)
Can Write		-		-
Observations	51	51	51	51

Robust standard errors in parentheses. *** and ** show statistical significance at the 1 per cent and 5 per cent levels, respectively.

8.2.10 **Food security**

One fundamental goal of the CLAPHI project is to improve on food security of households through the reduction in postharvest losses. We employ two variables as a measure of food security – incidence of food insufficiency and incidence of hunger. Essentially, attainment of food security is at the core of the project. We anticipate a reduction in the incidence of food insufficiency situation emanating from the intervention through increased output, improvement in crop yield as well as proper storage of grains. This is particularly essential given the semi-arid conditions and the unimodal rainfall pattern in Burkina Faso. Furthermore, the adoption of improved storage technologies is expected to make it possible for households to have access to more grains over a longer period and thus reduce food insufficiency and the incidence of hunger.

The hunger experience variable is constructed as binary, taking on the value 1 if a household indicates it experienced hunger in the past year, and zero (0) otherwise. We expect the programme to reduce the likelihood of these negative experiences. Both baseline and end-line surveys asked households about the following food insecurity experiences:

- In the last 12 months, is/were there a month(s) that you feel/felt as though you had insufficient food resources?
- If YES which months in the past 12 months did your household experience food shortages?

A household is categorised as having suffered food insufficiency or hunger if they responded 'yes' to the first question above and the number of months the household experienced insufficiency of food gives an indication of the severity of food insecurity.

The data shows that at baseline 33% of households indicated they experienced food insufficiency in the past 12 months, with 67% of the sampled household indicating they did not encounter food insufficiency. The situation worsened at end-line, with 40% of households experiencing shortage of food. The impact estimates for food security are reported in **Error! Reference source not found.**Table 15. The results show that the intervention had no impact on reducing the likelihood of hunger. However, over time there has been a reduction in hunger. The situation is the same for incidence of food insufficiency. This at first glance is surprising, however, a detail assessment revealed that in the past 12 months Burkina Faso experience a drought and this maybe a plausible explanation for this finding.

Table 15: Impact of PHTs on food security

Variables	Incidence of Hunger			Incidence of insufficient food		
	Eqn1	Eqn2	Eqn3	Eqn1	Eqn2	Eqn3
Treatment	0.017			0.017		
	(0.041)			(0.041)		
Time	-0.063*	-0.063*	-0.066**	-0.063*	-0.063*	-0.066**
	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)
sex			-0.025			-0.025
			(0.067)			(0.067)
age			0.002			0.002
			(0.001)			(0.001)
read			0.201			0.201
			(0.196)			(0.196)
write			-0.216			-0.216
			(0.197)			(0.197)
Observations	788	788	788	788	788	788

Robust standard errors in parentheses. *** and ** show statistical significance at the 1 per cent and 5 per cent levels, respectively.

8.2.11 Total workdays

It is without doubt that the thresher machine reduces the amount of time spent on post-harvest activities as discussed in the Case Studies in the appendix. Although, we expected the number of labour days to reduce, the high positive impact on the number of days worked on the farm can be explained by the following. We point out that not every household in our treatment sample used mechanical thresher. End-line (baseline) results show that about 6.9% (9.4%) of farmer households in our treatment sample confirmed usage of the technology. One would naturally expect that if a higher proportion of smallholders were using threshers during post-harvest then time spent on these activities would significantly reduce but this is not the case in our study. Moreover, the location of the thresher machine and its associated costs could have been a hindrance to usage. We note that after the demonstration exercise by CLAPHI, the thresher machines were procured by some FBO’s and placed it in the town or market centres for farmers who wanted to use then. Smallholders who cultivate usually for family consumption as our sample suggests, may be deterred from making seemingly long journeys just to thresh few grains. They may resort to traditional methods which are usually time consuming. As such groups of households feature most in our sample it is not surprising that labour days do not reduce. The study also finds that the number of total days women are engaged in work reduces relative to their male counterparts and this is supported by our findings from the case studies, as the women pointed that with the use of threshers, they save time and reduces the drudgery nature of postharvest activities.

Table 16: impact of the intervention on total man days

Variables	Total man days		Communal man days		Hired man days		Family man days		Female man days	
	Eqn1	Eqn2	Eqn1	Eqn2	Eqn1	Eqn2	Eqn1	Eqn2	Eqn1	Eqn2
Treatment	-111.895***	-110.976***	-58.349***	-58.232***	-0.718	-0.552	-53.676***	-52.940***	-65.069***	-64.709***
	(15.452)	(15.313)	(8.676)	(8.662)	(2.125)	(2.132)	(7.983)	(7.778)	(7.688)	(7.699)
Time	-108.296***	-108.331***	-56.989***	-57.438***	0.105	0.317	-52.612***	-52.209***	-62.002***	-61.746***
	(16.878)	(16.904)	(9.295)	(9.362)	(2.962)	(2.970)	(7.667)	(7.565)	(8.348)	(8.375)
Treatment x Time	118.395***	117.241***	64.435***	64.392***	2.836	2.406	53.332***	52.350***	69.421***	68.588***
	(17.470)	(17.453)	(9.466)	(9.505)	(3.241)	(3.273)	(8.203)	(8.072)	(8.698)	(8.698)
Sex		-26.643**		-0.991		-2.548		-24.070***		-5.205
		(12.556)		(5.617)		(2.147)		(8.237)		(5.704)
Age		0.206		0.191*		-0.016		0.057		0.071
		(0.220)		(0.113)		(0.050)		(0.140)		(0.116)
Can Read		48.964**		26.336		14.051**		5.203		28.796**
		(24.958)		(16.629)		(6.471)		(6.551)		(11.919)
Can Write		-36.905		-23.057		-11.943*		5.142		-21.950*
		(24.911)		(16.702)		(6.403)		(6.762)		(11.990)
Observations	739	739	739	739	739	739	739	739	739	739

Robust standard errors in parentheses. *** and ** show statistical significance at the 1 per cent and 5 per cent levels, respectively.

8.3 Distribution Channels

A critical objective of the CLAPHI project is the scaling-up of innovative PHTs across Burkina Faso, specifically, threshers and PICS bags. The project aimed at enhancing adoption of these technologies in a meaningful manner to achieve the most impact on the livelihood of farmers, women and youth. In this regard, the project sought to ascertain the effectiveness of selected distribution channels of PICS bags and which channel enhances adoption of the technology. The project targeted four distributional channels for PICS bags in the intervention districts – farmer-based organisations (FBOs); agro-dealers; agriculture directorates (through extension services) and non-governmental organisations (NGOs).

To determine the most effective distribution channel, the study asks households to indicate the source of acquisition of PICS bags with the listed delivery channel as possible options. Using a linear probability model[1] (LPM) we assess the most effective mode of delivery of PICS bags. The study estimates the impact of the four distribution channels on adoption of PICS bags, with each indicating the source of acquisition of PICS bags. Dummies for each of the source of acquisition is created in such a way that the sources do not vary over time. Also, to access the impact of a specific source we interact the treatment term with the source of acquisition. This will provide us with information of the effectiveness of a particular source of acquisition relative to other sources.

The results presented in Table 16 indicate significant differences in the impact of the channels of acquisition on adoption of PICS bags in the intervention communities. The results suggest that acquisition from FBO has no impact on adoption of PICS bags among households in the intervention communities. Furthermore, overtime FBO channel of acquisition has not influence households' decision to use PICS bags. In fact, distribution of PICS bags through FBO has negative impact on the probability that a household gets information of PICS bags in the intervention communities ($p<0.1$). This is contrary to the positive effect of FBO channel observed overall, indicating that over the study period within the treatment community household acquired the information on PICS bags from FBOs. This may be due to the lack of trust on the part of farmers in with these farmer-based organisations. In relation to the distribution of the technology by the district agriculture directorate, through its extension officers, the results indicate this channel has no significant impact on adoption. However, the agriculture directorate is an important source of information on PICS bags, as the results show it impact on the probability of the household hearing about the bags. We find that NGOs and agro-dealers are important sources of PICS bags acquisition, with both sources having impact on adoption ($p<0.05$). The probability of PICS bags adoption is relatively greater when sourced from agro-

[1] We acknowledge that probit and logit models are more appropriate in estimating binary outcomes, however, in cases where membership of a group is binary, and every member of the group has a matching value as the variable of interest, logit or probit models are inappropriate in estimating the parameters. Linear probability model is superior over logit and probit in this situation.

dealers relative to NGOs. Again, in relation to sources of information on PICS bags, agro-dealers have greater impact on the probability of household hearing of the technology. The study therefore concludes that PICS bags acquisition through agro-dealers has the potential to enhance adoption of the technology relative to other sources of acquisition.

Table 17: Impact of distributional channels on adoption of PICS bags

Variables	Adoption of PICS bags - Use of PICS					Adoption of PICS bags - Heard of PICS				
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 1	Model 2	Model 3	Model 4	Model 5
Treatment	-0.211**	-0.120	-0.056	-0.073	-0.048	-0.659***	-0.554***	-0.470***	-0.517***	-0.516***
	(0.104)	(0.270)	(0.215)	(0.268)	(0.270)	(0.046)	(0.184)	(0.174)	(0.185)	(0.185)
Time	0.287**	-0.344	-0.264	-0.344	-0.348	-0.200***	-0.579***	-0.504***	-0.578***	-0.579***
	(0.113)	(0.270)	(0.215)	(0.268)	(0.270)	(0.065)	(0.187)	(0.179)	(0.187)	(0.187)
Time x Treatment	-0.044	0.127	-0.024	0.080	0.055	0.167**	0.574***	0.446**	0.535***	0.534***
	(0.120)	(0.275)	(0.224)	(0.273)	(0.275)	(0.068)	(0.187)	(0.182)	(0.188)	(0.187)
Female		-0.003	-0.056	-0.007	-0.004		-0.031**	-0.047**	-0.035**	-0.035**
		(0.081)	(0.099)	(0.092)	(0.090)		(0.016)	(0.020)	(0.017)	(0.016)
Age		-0.001	-0.003	-0.001	-0.001		-0.001	-0.002*	-0.001	-0.001
		(0.002)	(0.002)	(0.002)	(0.002)		(0.001)	(0.001)	(0.001)	(0.001)
Read		-0.003	-0.133***	-0.003	-0.004		-0.015	-0.043*	-0.014	-0.015
		(0.018)	(0.050)	(0.017)	(0.018)		(0.013)	(0.026)	(0.014)	(0.014)
Write		0.014	0.132*	0.017	0.008		-0.034	-0.015	-0.034	-0.037
		(0.052)	(0.075)	(0.056)	(0.052)		(0.022)	(0.023)	(0.024)	(0.023)
FBO – impact		-0.158					-0.102*			
		(0.101)					(0.057)			
FBO – channel		0.153					0.095*			
		(0.102)					(0.054)			
Agro – impact			0.259**					0.081*		
			(0.101)					(0.043)		
Agro- channel			-0.099					-0.046		
			(0.083)					(0.036)		
Extension- impact				-0.036					0.056**	
				(0.156)					(0.025)	
Extension- channel				0.028					-0.046**	
				(0.160)					(0.023)	
NGO – impact					0.220**					0.059**
					(0.094)					(0.025)
NGO – channel					-0.213**					-0.057**
					(0.095)					(0.024)
Observations	**612**	**219**	**241**	**219**	**219**	**787**	**232**	**256**	**232**	**232**

Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Note: The impact of the distribution channel is measured by the interaction between the channel of distribution and the treatment dummy. While the channel variable measures the effect of the channel over the study period within the treatment community.

9 Further Discussion

9.1 Threats to Validity

Initially, the selected control communities experienced possible contamination and civil unrest issues. The possible contamination was as a result of the closeness of the intervention and control communities. It is for this reason that we changed our control communities as indicated in earlier sections of this report. The process monitoring done after the revisions, revealed that contamination was less of a problem. Though sample attrition was encountered, this was not a challenge because the study had over sampled during the baseline survey and so, at the endline the study successfully interviewed 374 households, exceeding the targeted sample of 320 households, that was required for reasonable power.

In the case where households in intervention communities are cognizant that they are being observed to ascertain the impact of the interventions on their behaviour and outcomes (Hawthorne effects), then it is possible that they could adjust their behaviours to either impress or protest. We do not believe that the farm households were under the impression that their behaviour and outcomes were being observed. For the control communities, the geographical dispersion between them and the treatment communities makes it only remotely possible that they were aware some farmers in the treatment communities are being treated in order to evaluate the impact of the CLAPHI programme. Therefore, we do not believe that the John Henry Effect biased the estimates that we have presented.

10 Specific findings for policy and practices

This study has evaluated the impact of the CLAPHI project on adoption of PHTs and how adoption impact on other key socio-economic indicators. Specifically, this study has tested five broad hypotheses:

i. Enhancing farmers' knowledge on PICS bags and threshers increases the adoption rate of these technology.
ii. Adoption of PICS bags and threshers significantly reduces post-harvest losses leading to increase in grain production and sales.
iii. Farm households exposed to PHTs have lower food insecurity than those who are not exposed to these technologies.
iv. Farmers using threshers work fewer labour days and use their time for other economic activities.
v. All delivery channels (agro dears, FOs, Extension and NGOs) have similar impact on the propensity of PICS bags adoption

We found evidence that the intervention by GRAD through the CLAPHI project impacted on adoption of PHTs, which in turn reduced post-harvest losses. Further, the study found evidence to support the hypothesis that the use of PICS bags reduced post-harvest losses significantly at the storage stage. The adoption of the technologies also increased both expected and actual sales for farm households. This lead to a reduction in food insufficiency and lowered the likelihood of the household experiencing hunger. It also reduced reduce female labour days.

Even though there is a growing nonfarm sector in Burkina Faso, the agricultural sector continues to be the most dominant source of livelihood for the majority of households in the country. The majority of households are involved in grain production despite significant post-harvest losses which works against profitability of farm enterprises. Any intervention that helps address these constraints and improve the welfare of farm households provides lessons for policy and practice. We have shown that even where a technology is known to work under 'laboratory conditions' adoption is not guaranteed and that using the appropriate channels of distribution of the technology is critical for adoption. Our results have shown that a more appropriate approach of distributing PICS bags to realize the utmost impact is through agro-dealers.

The study concludes that the intervention was successful and has potential for scaling up. However, we make this conclusion with an important caveat. The limited number of districts over which the study was undertaken meant that we had limited district and regional differences to enable us assess the heterogeneity of the impacts in different settings. This notwithstanding, we still are of the opinion that this is a scalable intervention.

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12 Appendix

12.1 Case Study

Case Studies on Treatment Communities for Scaling up Post-Harvest Management Innovations for Grain Legumes in Burkina Faso

Individual experiences with adoption of Post-Harvest Management innovations within the treatment communities are captured in a case study conducted by the research team. This enabled the researchers to provide individual specific stories on how the introduction of these technologies have directly impacted on farmers' produce and wellbeing. In this regard, the research team solicited views of specific small holder farmers on the use of these innovative technologies and their impact on yield. Case studies were to narrate the specific benefits accrued from reductions in Post-Harvest loss since innovative technology adoption in post-harvest management.

The notion was to randomly sample four (4) farmers in the Boucle de Mouhoun region where the intervention had been implemented, specifically in Sourou and Nayala. Purposively, these farmers should have adopted both PICS bags and Threshers as a means to effectively reduce their post-harvest loses. The survey team also ensured a gender balance in the selection of the respondents by sampling a man and a woman from each of the two intervention communities. This was to enhance the knowledge on how the post-harvest innovations impacted on gender. To ensure the women voice their opinion freely and not be intimidated by their male counterparts, the women were interviewed separately from the men. It should, however, be noted that the level and extent of probing was the same for both sexes. Since the post-harvest technology relates primarily to grains, the small holder farmers interviewed were mainly engaged in cowpea and millet production. On the average farm size for each farmer ranged between 0.5 to 1 hectare, with the women farm size averaging between 0.5 to 0.7 hectare.

In relation to the duration of use since adoption, both males and females in the intervention region attested to the fact that they have been using the PICS bags for about two and half years since its introduction by the Agricultural Directorate through GRAD's CLAPHI project. Although they got to know about the technology in 2015, actual usage started in mid-2016. The usage of the threshing innovation introduced by GRAD, however, started much later, mainly due to procurement challenges. The farmers indicated that they had knowledge of the technology prior to its procurement, but its usage actual began during the 2017/2018 agricultural season.

Probing on the state of affairs in terms of post-harvest losses prior to adoption revealed similar responses among both sexes. Huge post-harvest losses were recorded prior to adoption as a result of traditional storage in silos. First, it is evident that in the absence of PICS bags, the farmers suffered from huge losses emanating from the method of storage, which mainly involves the use of various traditional approaches. According to the women, losses began immediately after harvest through to storage. In addition to this, their main concern was that traditional chemicals that were sometimes used as preservatives usually had side effects on humans. The men confirmed the enormous quantities that were lost due to pest invasions as well as domestic animal scattering. Grains that were not lost to pests lacked the quality required by clients, inadvertently affecting the sale price of produce. The storyline is different after the introduction and adoption of the PICS bags technology. Additionally, use of the PICS bags has increased the shelf life of harvest from one month to at least a year and has effectively reduced post-harvest losses primarily linked to storage.

Second, the effect of the absence of threshers prior to adoption had mixed reactions by gender. Females did not attest to actual post-harvest losses from winnowing and threshing but raised issues on duration required of them to thresh their produce as well as costs related to use of traditional method of threshing. In addition to these pre-adoption challenges, men on the other hand revealed that prior to adoption there were some post-harvest losses during threshing and winnowing. This was linked specifically to the process of deshelling which involved manually beating the stem of the crop usually on the ground to expel the fruit. This traditional process of threshing tends to scatter the grains and male respondents saw this as a major loss no matter how small. Although maximum efforts are made to gather the scattered grains, to them this could never be done effectively. Aside the losses, the quality of the grain reduces due to broken grains resulting from such traditional processes. The adoption of the thresher machine innovation has led to a rise in the quality of grain produced and reduced the amount of time involved in that process.

Case studies tried to ascertain the actual amount of cost, in monetary terms as well as time, saved by the farmers as a result of adopting the thresher machine technology. Due to their natural lack in physical strength, the understanding was that women harvest in smaller quantities relative to their male counterparts and as such threshing of the harvest required an average working time of three days with an average of ten (10) labour hands assisting in the process (beating, winnowing, threshing) prior to adopting the threshers machine technology. Men took twice the time; an average working time of six days to thresh about ten 100kg bags of produce from a 1-hectare plot. This was achieved with an average of twenty (20) to twenty-five (25) hired labour assisting in the same process. Moreover, time spent could be greater than anticipated as the whole threshing processes depended on how quick one could mobilise labour hands to help. The process of beating, winnowing and threshing grain cannot be undertaken by a single farmer. The farmers, both men and women, indicated enormous cost saving due to this innovation and this is quite interesting. Prior to its introduction, farmers in the intervention region were paying about FCFA1000[2] per labour hand hired to assist in the post-harvest processes for a day, including winnowing and threshing. On average women and men incurred daily labour cost of FCFA10,000 and FCFA25,000, respectively to undertake post-harvest activities. Costs for the latter are higher as it leads to an average production of a tonne of grain.

[2] $1=FCFA576

Thus, the greater the harvest, the greater the cost as more labour hands are required. Farmers who do not have this amount of money in cash would have to pay an equivalent amount in produce, usually measured in bowls. The absolute cost for women is however greater as sometimes hired labour may demand that food is prepared for them from the same produce, they are threshing. This significantly reduces quantity harvested especially for women as compared to men, although men might pay more due to relative size of their farms and higher produce. However, farmers indicated that currently with the introduction of the new technology they pay a fee of FCFA1000 per 100kg bag when they use the thresher machine.

Due to the drudgery nature of traditional threshing process as described in the above paragraph, case studies gathered that some extra time has been gained as a result of technology adoption. The technology has the capacity to thresh one tonne of cowpea in an hour according to the farmers, however threshing the same quantity manually will require an average of 4 to 5 working days. Thus, the farmers attested to the fact the technology has been beneficial in saving time that could be used for other activities. In terms of the use of this extra time gained from using the thresher machine, women pointed out that they have more time to engage in non-farm activities which also supplements household income for agriculture. Also, they can now spend more time with the family by taking on extra household activities. “The extra time gained has made me engage more in the activities of my Farmer Based Organization (FBO)” one female respondent revealed. This has allowed her to gain a deeper understanding of the activities within her FBO and how their respective activities assist member farmers. Overall, the women indicated an improvement in their welfare. The men on the other hand pointed out that, the extra time has helped them expand the size of their farms. According to them, in times past, mixed cropping was the order of the day. Usually male farmers would grow millet and cowpea on the same plot of land due to the laborious nature of post-harvest activities for such crops. Currently with the adoption of the above innovation, there is some surety in the reduction of losses from as well as extra time gained. Due to this, farmers commit separate plots for different crops in order to benefit fully from specific cash or household crops. Moreover, as grain quality has increased due to this technology adoption, profit margins are assured due to the increase in market price. Females do not have this advantage to extend farm size since from a social and cultural notion of a typical Burkinabe community, farm inputs are kept by the head of the households who are predominantly males.

Automatic increases in yield have also been recorded in the intervention regions. As a result of removing the element of in-kind payments to labour and the reduction in post-harvest losses, both males and females in Sourou and Nayala have observed automatic increases in quantity harvested with regards to the size of their farms. This has translated to more income for households who cannot consume all that they produce as well as for those who grow specifically for selling and marketing purposes.

12.2 Appendix 2: Field notes and other information from formative work

The IDRC 2018 endline survey, like the baseline in 2016, was conducted by Y2S MEASURE consulting firm. This study aims at conducting an evaluation of the implementation to scale up Post Harvest Management Innovation for grain legumes in Burkina Faso which started in 2016.
After five days of training, three teams composed of 3 enumerators and a supervisor were formed to cover the areas concerned, namely Sourou and Nayala. Subsequently, a team of six enumerators was dispatched to the control study area (Kouritenga and Boulgou) to investigate the control households surveyed in 2016. This report describes the distribution of the teams, the progress of the field data collection, the results obtained, the difficulties encountered, and the solutions provided and the observations and comments.

The objective of the study is the collection of panel data on the households studied in 2016 based on the same questionnaire and in CAPI. The specificity of the panel study lies in the obligation to find exactly the same households as in 2016 and to convince them to answer the same questionnaire a second time. This is a significant challenge in terms of demographic movements and the availability in terms of time of these people.

It should be noted that the investigation took place against a backdrop of insecurity in the Boucle du Mouhoun region, which raised fears of the abandonment of some villages. This was achieved by the abandonment of a village for reasons of insecurity in Sourou (KONGA) in the municipality of GOMBORO).

In general, the results of the collection were achieved in terms of samples. As a reminder, the targets given are 240, targeted for the intervention zone and 80, for the control zone. For reasons of prudence related to the possible loss of the 2016 sample has counted on larger numbers of all 320 households surveyed in 2016 and 100 households for the control area. The final results gave: 287 households in the intervention zone against 87 households in the control zone.

The survey took place in two provinces in the Boucle du Mouhoun region, namely Sourou and Nayala. In total, three (3) teams were formed: one team in Nayala and the other two in Sourou in relation to the knowledge of the environment and the number of households to be researched. In addition, it should be noted that the majority of investigators had already participated in the baseline research in 2016. This was a major advantage in the field data collection process. In order to ensure the proper conduct of the collection, the enumerators and the supervisors each received the following material:

- Physical questionnaires to use if needed;
- GPS, tablets and charger;
- Two Power-Banks to maximize shelf life;
- USB flash drives.

For the controllers, in addition to the elements mentioned above, there was a Wi-Fi modem for connection; a letter for the local authorities. For their mobility in the collection areas, a vehicle was made available to each team. Also, each investigator had a motorcycle at his disposal for his mobility within the villages.

All three (3) teams started the collection on Saturday 08 December 2018. The collection lasted 15 days for the study in the intervention zone.

Once in the locality, the objective was to find all the households researched in 2016 during the IDRC study, and to collect the same information except in certain particular cases. Controllers regularly send (at the end of the day) the data collected to the supervisor for verification and to draw the controller's attention to the progress and difficulties encountered. Thus, the controller assesses his activities, the problems that the team encounters and possibly makes suggestions. To these problems, the coordination team, especially the supervisor, provides solutions after discussions with the coordinator regarding some specific problems. The investigation did not end at the same time for all teams. This is due to the specific problems faced by each team. Finally, we note that the contribution of the field knowledge by the controllers and the support of the local authorities were decisive in the success of the mission.

For the control zone, two teams were sent to the field for a period of seven (7) working days. It was advised that we use the teams that finished earlier, in their area of demarcation. The advantage was that the latter already have the CAPI application in hand in addition to the knowledge of the questionnaire.

In total, 287 households out of a total of 320 were researched, a completion rate of about 90%. Overall, the teams performed well. For team 2, for example, it is pointed out that thanks to the team's determination and the support of local authorities, 109 households out of a total of 110 households were studied. The single household missing is explained by the fact that the head of a household in Ouori-Baonghin village named GUIRA Soumaila and his entire household had left the village.

As for team 3, the survey went well overall despite the context of insecurity. Thus, out of 110 households to be surveyed in 11 villages, 98 were carried out in 10 villages. Finally, Team 1, managed to interview a total of 98 out of 100 households. In general, households that not surveyed at end-line is attributed to displacement and insecurity in one of the sample villages (Konga). For those control households that were not surveyed was due to movement of the household or death. The result is that 87 households were surveyed out of the 99 households downloaded on the tablets.

The surveyed encountered some challenges and difficulties and these include:

- There was no opportunity to drop members who were present in 2016 and were no longer there in 2018 either for reasons of death, marriage, travel, etc. This equally applies to the plots as old plots could not be replaced with new plots.
- The length of the questionnaire forced the respondents to abandon some of their activities. In such instances the enumerator had to wait for the participants' consent. This undoubtedly impacted the length of the survey.
- Increasing insecurity in the area, especially in the Lankoue and Gomboro areas, was a major obstacle. Indeed, among the teams present in these areas, some were forced to return to sleep in Gourcy several times on the instruction of local authorities. This resulted in a surplus of fuel consumption estimated at around

25000 F by the supervisor of team 2. For the supervisor of team 3, the household members with Case ID 100024 was no longer resident in the village. Also, he adds that for very specific security reasons the ten (10) households of the village of Gomboro have not been surveyed.

- In the CAPI application, the update of household members was missing. This lack of update does not reflect the characteristics of household members and may impact labour force analyzes that affect areas and crop yields.
- The constraint also imposed on the parcels which prevents to take new parcels is likely to play on the quality of the information. In fact, in the impossibility of registering the new parcels, the crop rotation and set-aside strategy for certain parcels of the household will not be recorded. It may also be a failure in the quality of the information collected.

Recommandations

- The timely programming of the study to allow a greater awareness of the people involved;
- The preparation of the CAPI application and its test to avoid bugs in the field which cause wastes of time;
- The timely payment of the remaining funds to facilitate the settlement of field staff after the completion of the work.

Conclusion

The data collection by the different teams was satisfactory despite the difficulties encountered. Indeed, solutions to the many difficulties were addressed through effective communication between the teams and the coordination.

The databases were sent to ISSER and the firm's assistance was made for a good understanding of these databases and also for the conversion of certain variables into physical quantities.

Y2S-MEASURE thanks ISSER for the trust placed in it for the conduct of this final evaluation operation.

Coordination

Name	**Post**
Mr. Namaro YAGO	Coordinator of the survey
Mr. Abdoul Aziz OUEDRAOGO	Supervisor
Ms. Jacqueline ZIDA	Manager of the consultant’s office.

Investigators / Controllers

Team leader	Name of enumerator	First name	Phone Number
	ZONON	Herman	70952814
	BAGRE	PHILIPPE	70805560
	SOMDA	EVARICE	70892760
Victor SIMBORO 70854287/66492168	BAKYONO	IDJA Michel	70191611
	OUEDRAOGO	ISSA	79189363
	GANGO	SENI	76870671
NIAMPA Noufou 71023696	BOUDA	FREDERIC	70334776
	KAFANDO	Abdoulaye	70128286
	SANDAOGO	BAPIO	70350902

Spatial distribution of teams

	TEAM 1		
Nayala	Gossina	Kalabo	10
		Koayo	10
	Toma	Toma Sect1	9
		Toma	11
		Koin	10
		Goussi	10
	Kougny	Kougny	10
		Sebere	10
	Gassan	Teri-Samo	10
Sourou	Di	Debe	10
	TEAM 2		
	Kiembara	Kiembara	10
		Gorgare	10
		Sissili	10
	Lankoue	Gourbala	11
		Komyargo	20
		Lankoue	10
		Ouori-Baonghin	20
		Peterkoue	9
		Rimaibé	10
	TEAM 3		
	Gomboro	Konga	10
	Toeny	Damani	10
		Gon	10
		Kwaretackel	10
		Louta	10
		Ouorou	10
	Tougan	Kassan	10
		Dioroum	10
		Kouy	11
	Di	Koromi	10
		Poura	10