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A Pathway to Adoption of Yield-Enhancing Agricultural Technologies among the Rural Poor: Evidence from a Randomized Control Trial in Benin

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Abstract

We tested a novel way of encouraging the adoption of improved maize seeds in Benin. In the treatment group, farmers were provided with intensive agricultural-extension support and a full package of inputs to test on one of their plots. In the control group, farmers were offered improved seeds, and agricultural-extension agents gave them only limited support. Our treatment was designed to encourage farmers to experiment with improved seeds by providing intensive technical support and free inputs throughout the maize crop season. Using a cluster randomized design and data on farmers' experimental plots, we found a 23% increase in maize yields with our intervention as compared to the less resource-intensive policy solution. Further analyses suggested that it was not enough to expose farmers to a one-time resource-intensive model because the impact on their production was not long-lasting.

Keywords: Adoption, agricultural technologies, maize production, randomized control trial, Benin.

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List of abbreviations

FFS	Farmer Field School
GAFSP	Global Agriculture and Food Security Program
GOB	Government of Benin
OLS	Ordinary Least Squares
PAPVIRE-ABC	Project to Support Food Production and Build Resilience in the departments of Alibori, Borgou, and Collines
T&V	Training and Visits

I. Introduction

Adoption of new agricultural technologies is central to growth, rural economies, food security and the well-being of households in many developing countries. The diffusion of innovations (new production techniques, use of improved seeds and fertilizers) from the lab to the farm, however, may be hampered by information failures. The supply of agricultural-extension services to rural communities is considered a key component to enable adoption of new agricultural technologies and contribute to boosting crop productivity (Ragasa & Mazunda, 2018; Haile & Abebaw, 2012; Davis et al., 2012).

Agricultural extension was heavily promoted in the 1970s and 1980s through implementation of large-scale training and visit programs by agricultural technicians (Ragasa & Mazunda, 2018). Training and Visits (T&V) typically took place in the fields of lead farmers[1] and consisted of teaching rural producers how to farm with adequate inputs and technology. This system has been the cornerstone of the extension system in West Africa since the 1980s (Moumouni, Nouatin & Baco, 2011).

However, the T&V model has been criticized because of its high cost and mixed results (Laajaj & Macours, 2017; Larsen & Lilleør, 2014; Kondylis, Mueller & Zhu, 2017; Davis et al., 2012). As a result, there was a decline in investment in agriculture extension in the 1980s by the governments of sub-Saharan African countries. In the 2000s, the extension system was reintroduced during the development of agricultural policies. In Benin, the farmer-field-school (hereafter, FFS)[2] approach was adopted and considered the main agricultural-extension service. The FFS was a training activity that took place in a demonstration field during an entire crop season. In that setting and together with a trained facilitator, farmers asked questions, experimented, and talked about what they were learning, (Conant & Fadem, 2008). That mechanism was expected to enhance farmers' knowledge and encourage them to adopt new technologies, which, as a result, would increase crop productivity. The final objective was to increase production and agricultural income and help farmers move out of poverty. The reality fell short of this objective, however, because farmers did

[1] A lead farmer was one who was provided a demonstration package (seeds, fertilizers) to encourage adoption and transmission of knowledge to other farmers (Kondylis, Mueller & Zhu, 2017) and support technology dissemination objectives.

[2] The main difference between the T&V and the FFS implemented in Benin is that producers in the T&V model were taught farming techniques and were given a package of inputs (seeds and fertilizers). The FFS approach, conversely, values local knowledge and encourages farmers to make their own decisions.

not sustainably apply the technologies they were taught at the FFS, progress in yields remained slow compared to other regions of the world, and there was very little effect in moving farmers out of poverty (Ragasa & Mazunda, 2018; Larsen & Lilleør, 2014).

One reason for these limited effects was that farmers did not adequately apply what they learned at FFS because of financial constraints that limited their ability to purchase agricultural inputs (improved seeds, fertilizers, herbicides, and pesticides). A growing literature (Ragasa & Mazunda, 2018; Laajaj & Marcours, 2017; Kondylis, Mueller & Zhu, 2017; Conley & Udry, 2010; Bandiera & Rasul, 2006; Munshi, 2004) has suggested information failure as an impediment to the adoption of agricultural technology.

In early 2004, following a review of its agricultural-extension system, the Benin government designed a new extension system that organized farmers into small groups of less than twenty. An extension agent taught them best practices for crop production in FFS style on the group leader's farmland. Subsequently, an extension agent would visit and support each farmer on his own land upon request throughout the agricultural season. This, in theory, represented a standard extension delivery model. In practice, farmers faced constraints such as lack of affordable credit and high prices (Debbie & Murielle, 2003; Arshad et al., 2010) that limited their access to improved production inputs. In addition, they did not regularly attend FFS activities because they preferred to spend time working on their farmland or in paid jobs to cover the costs of fertilizers and harvesting (Debbie & Murielle, 2003). Extension agents did not go to their farmland systematically for several reasons: the lack of equipment, facilities, funds, and availability, among others (Arshad et al., 2010). Those factors did not contribute to increased production and therefore, it is fair to infer that they did not fulfil the expectation that they would alleviate rural poverty.

In recent years, amid the food crises of 2008 and following severe climate events, Northern Benin suffered extreme climate shocks (uneven rainfall, pest attacks, very low productivity, etc.) which led to food shortages, exposing Ghanaians to risks of food and humanitarian crises. In that context, PAPVIRE-ABC[3] project was designed by the Ministry of Agriculture to relieve the constraints farmers faced and unleash the potential of agricultural development in the region. As such, the project gave us an opportunity to focus on the role of information failure in explaining low adoption

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[3] The project operates in several agricultural development aspects, including access to production water, training of farmers on management and cash-flow aspects, access to banking and credit, access to markets, connections with brokers, etc.

of yield-enhancing agricultural technologies. We decided to upgrade the standard agricultural-extension delivery model by addressing farmers' needs and considering recommendations that emerged from the failure of the FFS and the T&V models. This process generated an innovative extension-delivery model that we refer to as a "resource-intensive model."[4] This model was related to the literature (Ragasa & Mazunda, 2018; Macours, 2017; Kondylis, Mueller & Zhu, 2017) in the sense that it combined a learning-by-doing approach (direct training on individual farmer's land) with the FFS approach to stimulate and encourage adoption of technology.

The resource-intensive model of delivery of agricultural-extension services consisted of organizing farmers into small groups and teaching them best practices for maize production in a FFS style. Thereafter farmers received a free package of inputs (improved seeds, fertilizer, herbicides and pesticides) necessary for them to produce maize on a 500m2 plot which was set-up on their own farmland. An extension agent was assigned and financially incentivized to visit and support them regularly during all the main phases of the production season (from soil preparation to maize harvesting).

Following our review of the literature, we found no study that used an experimental approach to evaluate the impact of an intervention that combined FFS, free inputs to farmers, and financial incentives to extension agents. Considering the willingness of the implementing agency to evaluate the impact of the resource-intensive delivery model and learn lessons from the first phase of the project, we designed a randomized control trial with a pure control group. However, that initial impact evaluation design was not approved by policymakers for several reasons, including ethical concerns: some farmers would not receive any support from the project, risks of social tension existed, and there was a likelihood that such a pure control group design would fail during implementation.

We thus moved on to offer the standard T&V, including free improved seeds, as the default scenario for the comparison group. This allowed us to address ethical issues and minimize the risk of design-implementation failure that had been feared with a pure control group. An important remark is in order. Free delivery of improved seeds in a quantity designed for experimentation was common to both the treatment and control groups. We thus referred to this augmented T&V model, which was offered to the control group, as a hybrid-model of agricultural-extension service

[4] The resource-intensive model of agricultural-extension delivery combines the strength of the FFS and the T&V models and adds a few components to mitigate their shortcomings.

delivery.

The impact of T&V, FFS, or free inputs on the adoption of technologies and crop production have already been evaluated in the literature, with mixed results (Kondylis, Mueller & Zhu, 2017; Diab, 2015; Niu & Ragasa, 2018; Haile & Abebaw, 2012 ; Davis et al., 2012) but not the suite of approaches that we combined in our resource-intensive extension.

We used a randomized control trial conducted over one agricultural season, with the object of, first, evaluating the short-term impact of a resource-intensive-extension delivery model in comparison to a hybrid model on farmers' adoption of agricultural technologies and on experimental plot yield. We collected data in a subsequent agricultural season, after the resource-intensive model and the hybrid-model ceased, and when both treatment and control group farmers were exposed to the standard agricultural-extension model to evaluate if any differential impact of treatment arms during the first season persisted over time.

Our units of assignment were eligible villages clustered at the level of communes. Only one group of farmers in each village was randomly assigned to the treatment. All the farmers in a group were systematically assigned to the status of their village. The units of observation were farmers in the evaluation sample groups. We used two types of data in the analyses, but no baseline data were collected. The first dataset came from the 500m2 plot set-up of each participant's farmland during the first agricultural season. The second dataset was based on total maize production of the households during the first and second agricultural seasons.

We analyzed the data using pooled OLS regression to estimate the relative effects of the resource-intensive model vs. the hybrid-model. We showed that, when farmers received the resource-intensive model, they were more likely to increase maize production by a margin of 23% compared with those who had been offered the hybrid model. Hence, the resource-intensive model was more effective on maize production compared with the hybrid-model. In the subsequent agricultural season, when the same farmers receive neither the resource-intensive model nor the hybrid-model, but only the standard delivery model, the impact observed in the first year vanished. This second main result suggests that a one-time exposure to a resource-intensive agricultural delivery model was not enough to produce a lasting impact on their production.

This study makes an important contribution to the policy discussion (Agwu, Dimelu & Madukwe, 2008; Asiabaka, 2002) regarding the best ways for extension service delivery to affect production and contribute to poverty reduction in sub-Saharan Africa. It builds on existing academic knowledge as a randomized control trial that made a clean estimation of the impact of different agricultural-extension services on yield, production, and food security. We also used a theory-based analysis that contributes to the mixed-method methodological literature, shedding light on the mechanisms through which the impact of extension models is felt over time and on whether nor not those models are sustainable.

II. Context, Intervention and Theory of Change

2.1 Context of the study

The Republic of Benin made an appreciable effort in food production for decades through public investment and support from donors and other development partners. Maize production was particularly and positively impacted. As a result, Benin was quite self-sufficient in maize production, which reached a million metric tons after the implementation in 2008 of a special project designed to address the crises of high prices that were observed from 2007 onward.

In general, Benin was once in a non-critical food and nutrition security situation. The global hunger index at the national level showed the extent of the effort that had been made, one result of which was a more than 50% reduction in hunger between 1990 and 2014. Despite that, due to severe climate shocks, which cause drought and floods with serious consequences since 2010, some parts of the country have reached an alarming level of food and nutrition insecurity. As a result, household income has been affected, precarious living conditions have increased, and rural exodus and social conflicts over the use of land and transhumance corridors have been exacerbated.

Benin has recorded low productivity in agriculture for decades, mainly in food production. Agronomic research has shown that maize yield could reach seven tons per hectare, but in practice is barely 1.4 tons/hectare (Hodonou, 2014; Ministry of Agriculture, Livestock Farming and Fishery, 2014; Ministry of Agriculture, Livestock Farming and Fishery, 2015). In addition, maize varieties used in Benin are frequently not climate-smart because the production cycle sometimes lasts longer than 105 days—in other words, crops cannot be harvested before drought or flood hit—and the use of a non-resilient variety of maize leads to production losses and to a negative impact on household income. Other problems faced by food producers in Benin are lack of credit to purchase high-yield food crop seeds, lack of access to adequate fertilizers and pesticides, and the absence of a well organized way to reach markets. Other crucial problems are lack of training for use of climate-smart technologies in agriculture and for farm management in the context of climate change. The consequences for productivity and food security are well-known.

To begin to solve these problems, the Government of Benin (GOB) applied for Global Agriculture and Food Security Program (GAFSP) funding through the project named "Project to Support Food Production and Build Resilience in the departments of Alibori, Borgou, and Collines (PAPVIRE-ABC)." As stated by the African Development Bank in 2015, "The specific project objective is to increase food production in the three administrative departments of Alibori, Borgou and Collines. This will happen [through] improving productivity, building resilience to climate change, ensuring sustainable management of agriculture and natural resources, reducing gender inequalities, and increasing household incomes, particularly the income of the most vulnerable segments of the population in the project impact area."

The project was to be implemented over a five-year-period and included three components: (i) Support for Rural Infrastructures; (ii) Development of Agriculture Value Chains and Resilience; and (iii) Project Management. The second component, "Development of Agriculture Value Chains and Resilience," was the basis for this study. This component aimed to increase agricultural productivity, engender more added value, stimulate entrepreneurship among youth and women, alleviate food and nutrition insecurity, and reinforce household resilience. It focused mainly on (a) improving farm productivity and technological innovations; (b) building stakeholder capacity; (c) developing agricultural value chains; (d) promoting agricultural entrepreneurship and employability among youth and women; and (e) supporting nutrition-oriented activities.

The project in the three departments was intended to directly benefit 50,000 people (40% of whom were women), including 25,445 smallholder farmers who received support to cultivate maize, rice, and vegetables. On average, each smallholder farmer received support for 1.5 hectares of maize, 0.5 hectare of rice, and 0.25 hectare of vegetables. In the long run, the project made inputs available for purchase by farmers, but they were not provided for free. Agricultural advisory service was to be offered to farmers as usual.

The three departments where the project was implemented covered an area of 66,029km^2, equivalent to 58% of the national territory, with a population of 2,786,699 inhabitants, equivalent to 28% of the total population. In view of the size of the intervention area and the population, some communes were targeted for priority intervention, nine of which were identified in all three departments: Banikoara, Gogounou, and Karimama in Alibori; Kalalé, Ndali, and Tchaourou in Borgou; and Bantè, Ouèssè, and Glazoué in Collines.

These communes were chosen on the basis of several cross-checked criteria: the existence of exploitable lowlands and of permanent surface or underground water resources, the exploitation rate of the lowlands or market place, the degree of ownership with respect to land tenure, the capacity of farmers to organize themselves around dry sites and crops, the existence of synergy and complementarity with other projects, the degree of concentration of projects, the rate of severe and moderate food insecurity; the incidence of income poverty, and the overall underemployment rate. Most of these indicators were provided by each municipality. During the targeting process, participants were asked to score the communes from 1 to 3. The scores were then averaged, and the communes were ranked to determine the nine communes of the project. The final list was submitted to the General Secretariat of the Ministry of Agriculture, and each was validated.

The communes in Borgou and Alibori were very similar in terms of agro-ecological, environmental and socioeconomic conditions, compared with the other three communes in Collines. The communes in Alibori and Borgou were influenced by the Sudan-zone climate. They received one season of rainfall from May to September, compared to communes in the Collines that were influenced by a Guineo-Sudanian transition climate. Those communes received two periods of rain from March to July and September to November, though the shorter rainy season has been especially brief or absent in recent years. The socioeconomic conditions in all nine communes targeted by the project were quite similar and maize was one of the main crops produced.

The PAPVIRE-ABC was managed by a coordination team recruited on a skills-and-competency-based procedure, with technical support from the African Development Bank and financial support from the GAFSP administered by the World Bank.

2.2 Description of the Treatment Arms

We evaluated the impact on maize producers, who were randomly assigned to either of the treatment arms, of a resource-intensive agricultural-extension delivery model vs. a hybrid-extension delivery model.

2.2.1 Resource-Intensive Agricultural-Extension-Delivery Model

In this arm, farmers were organized into small groups of less than twenty in their villages. Each group appointed a lead farmer who offered a piece of land that would serve as the demonstration plot for members of that group during trainings. A professional agricultural-extension agent was assigned to each group, who assembled them for training on the best maize production technologies and on management of their production systems. The trainings took place throughout the agricultural season and were very similar to a FFS approach. During those trainings, farmers learned new technologies and improved their knowledge and skills regarding the use of improved seeds; application of fertilizers, pesticides, herbicides; and post-harvest activities such as conservation of production, access to market, access to credit, etc. The model also allowed farmers to share personal experiences and concerns with their peers.

In addition to attending the FFS in groups, each farmer in resource-intensive extension group received, free of charge, the inputs (improved seeds, fertilizer, herbicides and pesticides) necessary to produce maize on a $500m^2$ plot set-up on their own farmland. Table 1 gives details on the quantities of input used.

As part of the resource-intensive extension model, the extension agent that worked with the farmers in each group was financially incentivized to visit and support each farmer during all the main phases of the production season: soil preparation, sowing, growth, application of fertilizer, use of pesticides and herbicides when necessary, harvesting, storage technics, etc. Because the extension agent was financially incentivized to cover his transportation for a regular visit to each farmer in the resource-intensive group, this was expected to ensure the advisory service would be delivered.

Table 1: Quantity of Inputs Given to Each Farmer for Maize Production on 500m2 plot

Inputs	Quantity	Units
Improved seeds	20	kg
Fertilizer_1 (Urea)	2,5	Kilogram (kg)
Fertilizer_2 (NPK)	5	Kilogram (kg)
Fertilizer_3 (TECAMIN RAIZ)	0,05	Liter (L)
Pesticide (neem oil)	0,075	Liter (L)
Herbicide (NICOMAIS)	0,05	Liter (L)

Providing free inputs to support production on the 500m2 plot was meant to remove the barriers farmers had mentioned during the inception phase of the project. This also gave each farmer the opportunity to apply, independently and on his own farmland, what he'd learned in group and was therefore intended to positively influence perception of the technology, contributing to behavior change and adoption of the technology.

III. A hybrid-model of agricultural-extension-service delivery

The second treatment arm was the alternative treatment that we referred to as a hybrid-model of agricultural-extension-service delivery. It consisted of organizing farmers into small groups of less than twenty and, on the group leader's land, teaching best practices for maize production in a FFS style. Thereafter they received, free of charge, only improved seeds (no other input was offered) necessary to produce maize on a 500m2 plot set-up on their own farmland. An extension agent was also assigned to visit and support them during the production season, but no incentive was offered to the extension agent. With this treatment arm, farmers were not guaranteed the visits because extension agents only visited farmers when they were not otherwise occupied. Visits sometimes do not take place in a standard agricultural advisory system because the supply of service providers is lower than demand and, in some instances, extension agents lack incentives (such as financial resources to fuel their motorbikes) to go to farmers and support them.

The hybrid extension model was fundamentally different from the resource-intensive model in the sense that it did not provide any financial incentives to extension agents apart from their salaries and therefore farmers were not guaranteed visits and training during each of the main phases of the production cycle. Furthermore, the model did not provide any of the free inputs that determine flowering, fructification, and high productivity. Theoretically, then, we expected that both models would produce different impacts on the outcomes of interest.

IV. Timeline of the Research

The two treatments described above took place at only one point in time during the agricultural season (June-December 2017). In theory, it was expected that, if the resource-intensive-extension delivery model, which was the main treatment arm of interest, took place during one season, farmers would change their behavior and adopt the technologies on all their farmlands in subsequent seasons. To maintain this change and its impact on productivity and production, exposure to the standard extension model during the subsequent season (June-December 2018) was believed to be sufficient even after the resource-intensive extension model was no longer offered.

In that logical process, only the standard agricultural-extension-delivery model was offered to all the farmers irrespective of their being in the treatment or comparison groups in the previous year.

V. The Standard Agricultural-Extension-Delivery model

The standard model consists of organizing farmers into small groups of less than twenty for training and visit. On a demonstration plot provided by their leader, a professional extension agent gave trainings on production technologies and farm management. Thereafter, the extension agent would visit and support each farmer on his farmland from time to time throughout the agricultural season. However, farmers were not guaranteed these visits and support, however, because the agent would visit only according to the agent's availability. This extension model was provided to all farmers in the second year, irrespective of whether they were in the treatment or comparison group during the first year's experiment.

Figure 1 shows the timeline, what happened to farmers in each group during the first and second year of the research, the treatment they received, data collected (or not collected), and important dates.

Figure 1 : Timeline and Details of Treatment for the Treatment and Comparison Groups, Year 1 and Year 2

	RESEARCH PREPARATION PHASE	KEY ACTIVITIES						
	Randomization of eligible villages with farmers' group in place	Baseline survey	500m² set-up on each farmer's land	Treatment arm 1: Resource-intensive extension model	Treatment arm 2: Hybrid extension model	Standard extension model	Plot-level data: Maize production at the level of each 500m² plot was harvested, weighed and data recorded	Follow-up 1 survey_Household data: Total maize production by the household
		YEAR 1						
Period of time	***June 2017***		***June 2017***	***June 2017***	***June to December 2017***	***June to December 2017***	***December 2017***	***January 2017***
Treatment group	YES	NO	YES	YES	NO	NO	YES	YES
Comparison group	YES	NO	YES	NO	YES	NO	YES	YES
		YEAR 2						
Period of time	***Not applicable but treatment and control groups from the randomization in Year 1 were kept the same.***	***Not applicable***	***Not applicable***	***Not applicable***	***Not applicable***	***June to December 2018***	***Not applicable***	***January 2019***
Treatment group			NO	NO	NO	YES	NO	YES
Comparison group			NO	NO	NO	YES	NO	YES

5.1 Theory of Change

The intervention was designed to help farmers increase maize production and improve food security in their households. When poor farmers were well targeted and exposed to new production technology in a farmer-field-school approach, they acquired new knowledge and skills and were influenced by their peers. It was necessary that they be trained on their own farmland, however. If an agricultural-extension-service agent installed the $500m^2$ plot on a farmer's land and visited regularly to apply the advice and support, then the management of that plot would help convince the farmer to change methods and ensure a positive perception because yields would increase significantly on the experimental plot compared with the rest of the farmland.

Whatever learning took place during the FFS process, then, it would be strengthened by practical experience in the farmer's own plot and that would positively affect perceptions and beliefs about new agricultural technologies. That, in turn, would cause farmers to adopt the technology and apply it at scale on all their farmland, leading to an increase not only in productivity but in total household production.

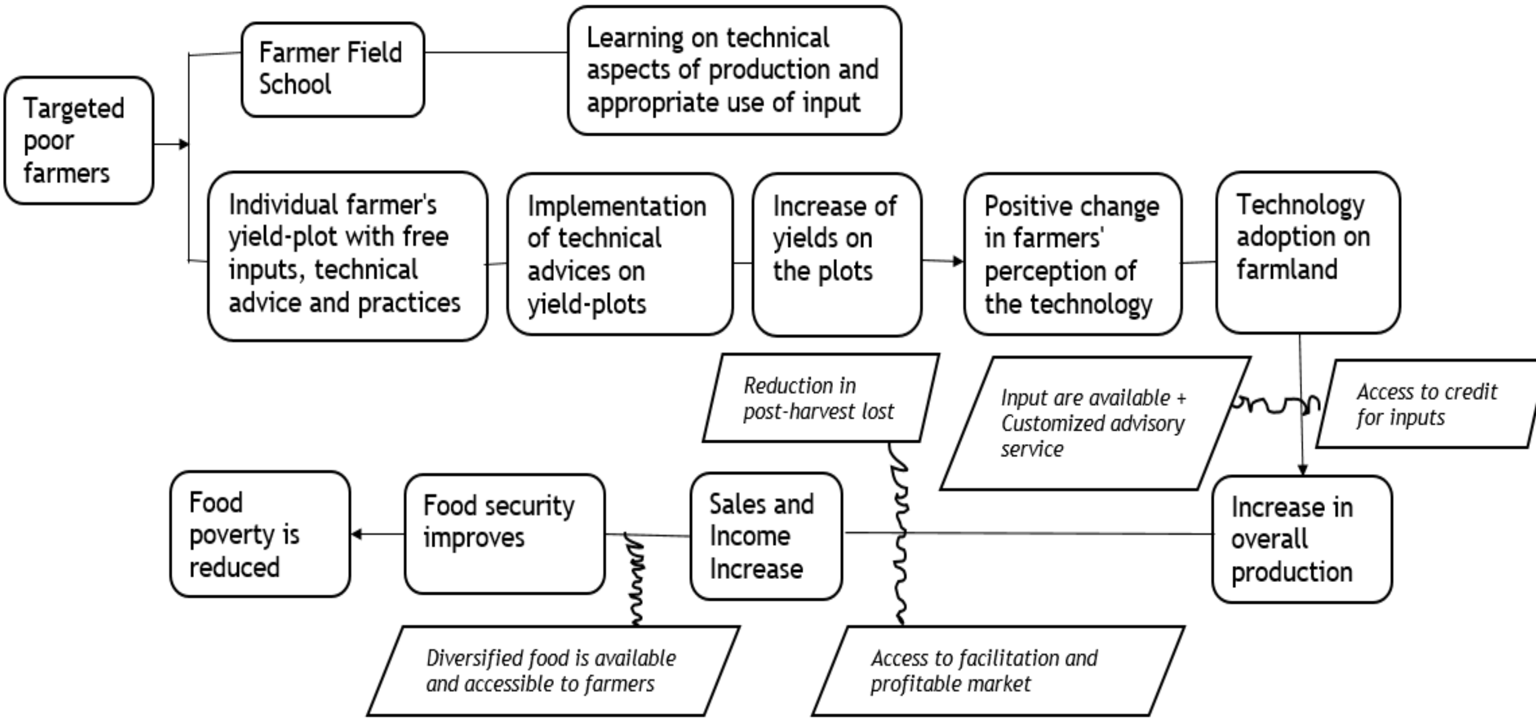
In operational terms, a farmer would adopt the intervention if the resource-intensive extension model was provided on the small experimental plot and if the farmer was a member of a group that received training through the FFS approach. As far as the mechanism for this change, it was important for farmers to receive agricultural-extension support during sowing and for the application of fertilizers and pesticides/herbicides because those critical stages determined a good harvest.

If this happened, overall production would increase in subsequent up seasons, assuming inputs were available and affordable to farmers and that they also had access to customized agricultural advisory services. In the context of this research, all the activities described above to increase production at the plot level and, thereafter, at the household level, were combined into what we referred to as the resource-intensive agricultural-extension-services-delivery model.

If an increase in production took place, that would lead to an increase in sales, assuming good market conditions, and farmers' income would therefore also improve as long as farmers had less post-harvest loss and received appropriate help to reach profitable markets.

With a substantial increase in household income, farmers would improve food security in their households because they would have access to diversified and accessible food in their communities. Ultimately, if a farmer was exposed to a resource-intensive extension model, his household was expected to experience a reduction in food poverty and an improvement in life conditions. Figure 2 illustrates the process described above.

Figure 2: Theory of change of the intervention



VI. Experimental Design and Data

6.1 Clustered Randomized Control Design

Using a cluster randomized control trial, we compared the effectiveness of two different agricultural-extension-service models on production of maize among farmers in Benin. Farmers are organized by communes that represent quite homogenous administrative units influenced by the same agro-ecological conditions and governed by the same administrative authority. We reflected this in our sampling strategy, which was why we stratified the experiment at the commune level. This approach also had a statistical advantage because it increased the precision of our estimates.

We also assigned treatments at the village level to ensure that only one group of farmers in a village was assigned to either of the treatment arms. This was meant to minimize chances of information spillover across groups and potential compromise of the design. Spillover was further minimized in reference to treatment components: because farmers received inputs for plots of only 500m^2, it was unlikely they would share these limited inputs with comparable farmers in another village.

Randomization was conducted using a computer-based approach before the intervention and during a joint meeting in each of the nine communes. The list of eligible villages, farmers' groups, and farmers was shared by the project management unit and all eligible villages (seventy-eight in total) were included in the assignment. A village was eligible and included in the evaluation sample if it was in any of the nine communes covered by the project, if it produced maize, and if farmers in that village had organized voluntarily into groups, ensuring that only one member of a household could be in each group. Table 2 shows the distribution of the evaluation sample.

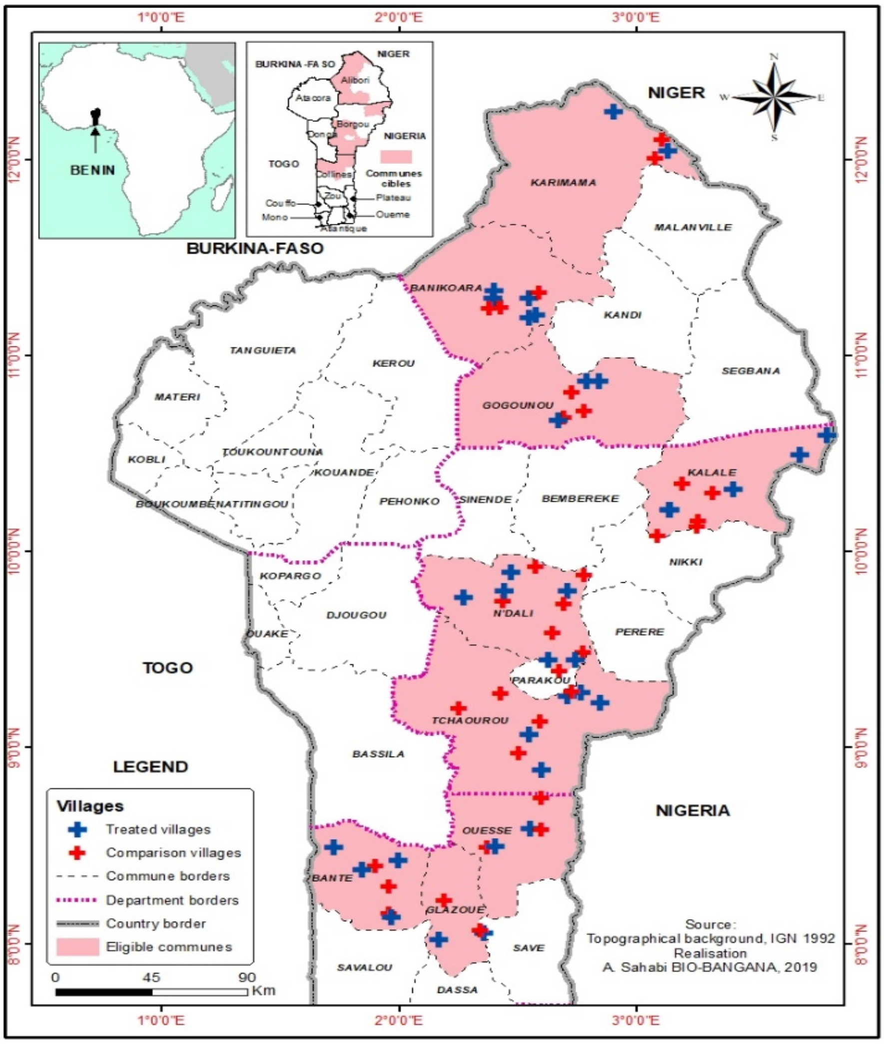
Table 2: Distribution of the Evaluation Sample across All Nine Communes

Communes	Treatment		Control	
	Initial number of villages	Initial number of farmers	Initial number of villages	Initial number of farmers
KARIMAMA	2	30	2	30
BANIKOARA	5	77	5	78
GOGOUNOU	3	46	3	45
TCHAOUROU	6	93	6	86
N'DALI	7	111	8	125
KALALE	4	63	6	91
OUESSE	2	30	3	47
BANTE	4	64	4	65
GLAZOUE	2	30	6	90
Total	**35**	**544**	**43**	**657**

To determine who was assigned to which treatment arm, we received a list of eligible villages for each commune. We then randomly assigned them into treatment and comparison groups. Because there were nine communes, we ran the randomization nine times. Knowing that it was possible to have more than one farmers' group in some villages, the rule applied was to randomly select one of the groups in that village and include them in the research sample. All the farmers who were members of a group would receive the treatment assigned to their group. The size of the groups varied from twelve to seventeen farmers. Figure 3 maps the results of the randomization in the study area.

As a result of the random assignment, the treatment group included 544 farmers and the comparison group included 657 in the initial evaluation sample (a total of 1,201 farmers). They were distributed across thirty-five treatment villages and forty-three comparison villages (a total of seventy-eight).

Figure 3: Illustration of Randomization and Sample Distribution Results in the Intervention Areas



6.2 Data

We used quantitative data from two different sources. First, we collected data on the production of each of the experimental plots. At the end of the first agricultural season in

December 2017 (Year 1), we went to each 500m^2 plot, harvested and weighed the production, and recorded the data.

The second source of data was total household maize production as reported by farmers surveyed conducted at the end of the first season (Year 1) and the second (Year 2). Note that household total production data were reported by each farmer and not measured, while plot-level data were measured by a team assembled for this purpose.

During the last round of household surveys in February 2019, qualitative data were collected from both treatment and comparison groups using direct observation, key-informant interviews, and focus-group discussions with farmers who were members of the evaluation sample.

Figure 1 shows the timeline and data of the first and second years. As indicated, one of the limitations of the study was that we were not able to collect baseline data. By the time we completed the design and agreed on the two treatment arms, farmers had already started soil preparation. Nevertheless, we added a few variables to the first follow-up questionnaire survey to test whether the distribution along those variables was similar. The balance check with these post treatment data confirmed a successful randomization as shown in Tables A2 and A3.

Our analyses were based on two types of data collected on 800 farmers: plot-level data collected at one point in time (end of the first season) and household panel data collected at two points in time (end of the first season and end of the second season). In the process of constructing the panel data, 800 households overlapped in both household surveys and were included in the final panel sample for analysis.

Considering that 1,201 farmers were initially randomized, the final sample size of 800 was the result of several factors, including mismatching of the initial list with ground realities and attrition. Figure 4 presents sample size dynamics over time.

During the first-year field work, we noted some discrepancies between the size of the groups as communicated by the project management unit and the reality on the ground. Some groups had added more names than actually existed, some farmers had moved from the sampled villages, and others no longer produced maize. This led to a reduction of the initial sample size from 1,201 to 876 farmers in the first year.

During field work in the second year, the results of the randomization were again used to contact farmers. We noted missing farmers, farmers who no longer produced maize, and those who had migrated. The sample size at the end of the second year was 915 farmers instead of the 1,201 initially planned.

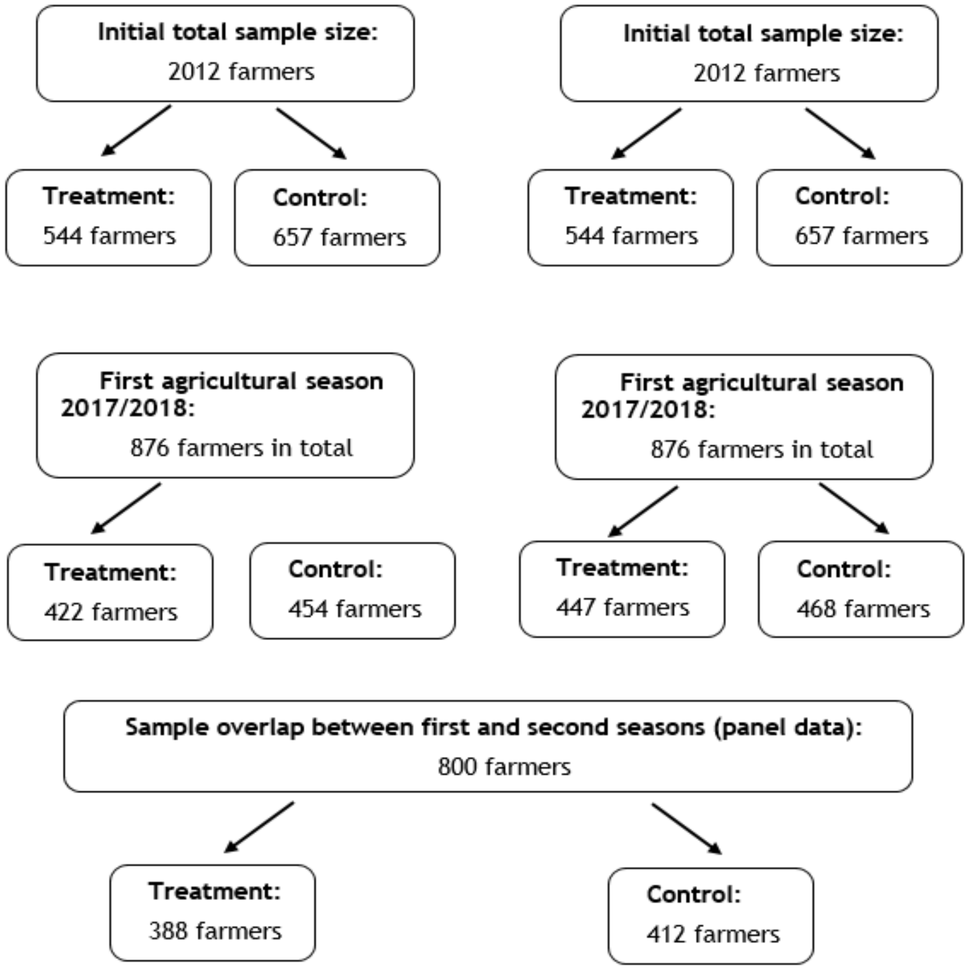
The attrition rate was 9.5%, and analysis of the attrition pattern produced the results presented in Appendix A1. For both household-level and individual-farmer-level variables, the characteristics of those who opted out were not systematically different between the treated and the control group. The randomization properties were therefore not compromised, and the results were still valid.

The main outcome of interest was maize yield measured in two different ways. On one hand, we harvested and weighed the yield of the small plots, and we also ask each farmer to estimate his total household production on all the farmland planted with maize during the first and second seasons. With regard to measurement error, we applied a correction factor to the total production self-reported by farmers. The correction factor was the ratio between the yield observed on the 500m^2 plots set-up in Year 1 and the yield declared by farmers.

From the data collected, the study population was characterized by married farmers who were largely male (87%) with an average age of 40 years. The farmers had less than four years of formal education, and around 17% of them had a primary education. On average, they had been in maize production for more than seventeen years and were largely natives (93%), which suggested good experience in maize production including access to arable land. They had, on average, around eight dependents. The farmers' households included, on average, three children under 15, with 2.08 active men and 1.79 active women who contributed to their income. The total land size owned or used by the households was twelve hectares on average.

The results of the balance-check analysis are presented in Tables 8 and 9 in the Appendices. They show that randomization was successful because the distributions of most variables were similar in the treatment and control groups. The only variable that challenged the balance test was years of education of the producer, which showed an average of 3.2 years in the control group and around 2.3 years in the treatment group. In absolute terms, this difference of less than a year was statistically significant which translates as precision and not necessarily a difference that jeopardized randomization. A similar trend was observed in literacy which was another way of capturing farmers' education.

Figure 4: Sample Size Dynamics Over Time



VII. Empirical Strategy and Findings

7.1 Empirical Strategy

We used two models to evaluate the impact of the intervention. The first estimated the intention-to-treat (ITT) effect of the intervention on maize yield at the plot level. The data used came only from the fist agricultural season of 2017-2018 and were collected at the level of the maize plot set-on in each farmer's land. The following regression equation was estimated:

$$Y_{ivb} = \propto + \gamma 1 * [T_v] + \gamma 2 * [X_i'] + \rho_b + \varepsilon_{ivb} \quad \text{(Eq 1)}$$

where γ represented the treatment effect on Y_{ivb}.; Y_{ivb} represented the yield harvested at the plot level by farmer "i" in village "v" and commune "b"; "T_v" was treatment status. It was a binary variable set to 1 for farmers who were assigned to the resource-intensive extension model; and 0 for farmers who were assigned to the hybrid extension model. X_i' was a matrix of individual characteristics that were highly correlated with the outcome y_{ivb}. ρ_b referred to strata (commune) fixed effect; the error term ε_{ivb}, was clustered at the village level.

The second model estimated the intention-to-treat (ITT) effect of the resource-intensive extension model treatment compared with the hybrid extension model on household total maize production. We used longitudinal data constructed from questionnaire surveys given at the end of the first agricultural season and thereafter at the end of the second season. We pooled these data and used an OLS regression equation to estimate the differential impact at the end of the first and the second production season. As mentioned, there were no baseline data in the specification. The equation was written as followed:

$$Y_{ivb} = \beta 0 + \beta 1 * [time] + \beta 2 * [T_v] + \beta 3 * [time * T_v] + \beta 4 * [X_i'] + \rho_b + \varepsilon_{ivb} \quad \text{(Eq 2)}$$

where Y_{ivb} represented household total maize production as declared by farmer "i" in village "v" and commune "b" during the surveys. The time variable was set to 1 for the second-year data and 0 for the first data. "T_v" was treatment status. It was a binary variable that was set to 1 for farmers who were assigned to the resource-intensive extension model; and 0 for farmers who were assigned to the hybrid extension model. X_i' was a matrix of individual characteristics that were highly correlated with the outcome y_{ivb}. ρ_b referred to strata (commune) fixed effects; the error term ε_{ivb}, was clustered at the village level.

The parameter $\hat{\beta}1$ represented the time trend effect in the group of farmers who were assigned to the hybrid extension model. They were the comparison group; $\hat{\beta}2$ represented the mean difference between farmers who were assigned to the resource-intensive extension model (treatment group) and those who were assigned to the hybrid extension model (comparison group). $\hat{\beta}3$ depicted the marginal effect in the second year. Hence the $\hat{\beta}2$ + $\hat{\beta}3$ in the second year provided the actual differential impact between farmers who were assigned to the resource-intensive extension model (treatment group) and those who were assigned to the hybrid extension model (comparison group).

7.2 Empirical Findings

7.2.1 Impact on Plot Yield

The results in Table 2 show the impact of the intervention on maize yield at the plot level. As expected in the theory of change, when farmers were assigned to the resource-intensive extension model (treatment group) their yields at the plot level were significantly higher than the yields of farmers who were assigned to the hybrid extension model (comparison group). Being exposed to the resource-intensive extension model was likely to increase productivity by 412 kg/hectare on average, which represented a gain of 24% in comparison to farmers in the comparison group who were exposed to the hybrid-extension model. In absolute terms, whereas comparison-group farmers harvested on average 1,700 kg of maize per hectare, those in the treatment group were likely to harvest around 2,112 kg.

Considering that these results were based on observed yield data at the plot level, we assessed farmers' perceptions of the intervention using their declaration of yields at the plot level. The analysis of those data showed that farmers who were treated with the resource-intensive extension model declared a significantly higher yield (2,710 kg/hectare) compared with those who were in the hybrid-extension model group (2,011 kg/hectare), a 34% increase in yield. This suggests that farmers had a good perception of the effectiveness of the treatment (the resource-intensive extension model) in comparison to the hybrid-extension model, which aligned well with the causal path depicted in the theory of change.

In comparing observed and declared yield data, farmers apparently tended to overestimate their production. This could be interpreted as an indication of the positive effect of the intervention on farmers' beliefs, perceptions, and subjective assessment of the extension delivery. We generated a correction factor determined as the ratio between observed and declared yields. The correction factor was applied to the production data collected during household surveys.

Returning to what was predicted from the theory of change in the subsequent year, the positive impact observed during the first year was expected to affect farmers' behavior in the second year, causing them to purchase the inputs they needed and request extension advisory services during critical production phases. In other words, farmers who were exposed to the resource-intensive extension model would replicate what they learned, practiced, and saw on their plot during the first year to all their household's maize farmland. In such a way, their production would increase significantly compared with the group of farmers who were exposed to the hybrid-extension model in the first year.

Table 3: Intention-to-Treat (ITT) Effect on Yield at the Plot Level (Estimates are from Equation 1)

VARIABLES	(1) Maize yield at the plot level (kg/500m²) measured agricultural-extension agents	(2) Maize yield at the plot level (kg/500m²) declared by farmers	(3) Productivity (kg/ha) measured agricultural-extension agents	(4) Productivity (kg/ha) declared by farmers
Treatment	20***	34**	412***	699**
	(5)	(14)	(113)	(287)
Mean in control group	85***	100***	1,700***	2,011***
	(2)	(12)	(50)	(240)
Observations	800	800	800	800
Mean in treated group	105	135	2112	2711

Robust standard errors clustered at the village level, in parentheses *** p<0.01, ** p<0.05, * p<0.1

7.2.2 Impact on Maize Production and Food Security

We examined how the differential impact of the resource-intensive extension model vs. the hybrid-extension model during the first agricultural season affected total production during the following season when farmers in both groups were exposed to a standard extension delivery model (described in the section on "Description of the Treatment"). The main outcome of interest was total household maize production, but a household food consumption score was also reported to test any effect on food security.

Table 3 reports ITT estimates using a pseudo double-difference approach. The results should not be interpreted as a regular difference-in-differences because we did not use baseline data in the analysis. At the end of the first year, the total declared production of the group that received a resource-intensive extension model was 880 kg (specification with no control variables) and 1,001 kg (specification with control variables)—larger than what was declared on average in the group assigned to hybrid-extension model. These estimates were not statistically significant in either of the specifications, however. Considering the possibility of measurement errors, a correction factor was applied to declared production. The estimates changed in absolute terms but were not statistically significant. These results of the differential effect on total production at the end of the first year suggested that the effectiveness of the resource-intensive extension model didoes not make farmers change their behavior and adopt the technology on all their maize farmlands during the season when they were treated.

Similar to the first year, analyses of Year 2 data on household total productions (and the total production corrected for measurement errors) showed that farmers in the resource-intensive group increased their total production by 1,335 kg (specification with control variables) compared with the group that received a hybrid-extension model in Year 1. After correcting for measurement error, the difference in total production in the group that received the resource-intensive extension model in Year 1 was larger by 1,645 kg compared to the other group. In both scenarios, however, the effects observed in Year 2 were not statistically significant and showed quite large standard errors. Considering the second-year results, the causal chain broke down because the plot-level impact during the first year of the experiment did not lead to the effect expected for total household production.

In reference to Table 3, an evaluation of the effect of time on household maize production showed that farmers who received a hybrid-extension delivery model during the first agricultural season (comparison group farmers) saw their production increase significantly by 1,485 kg (declared production) and 1,386 kg (corrected production) only if they received the standard extension model during the second year. These results suggest that the standard extension model was effective to some extent and that other factors might have been at work during the second agricultural season that contributed to increased production in the control group. NGOs or other government projects may have become involved, for instance.

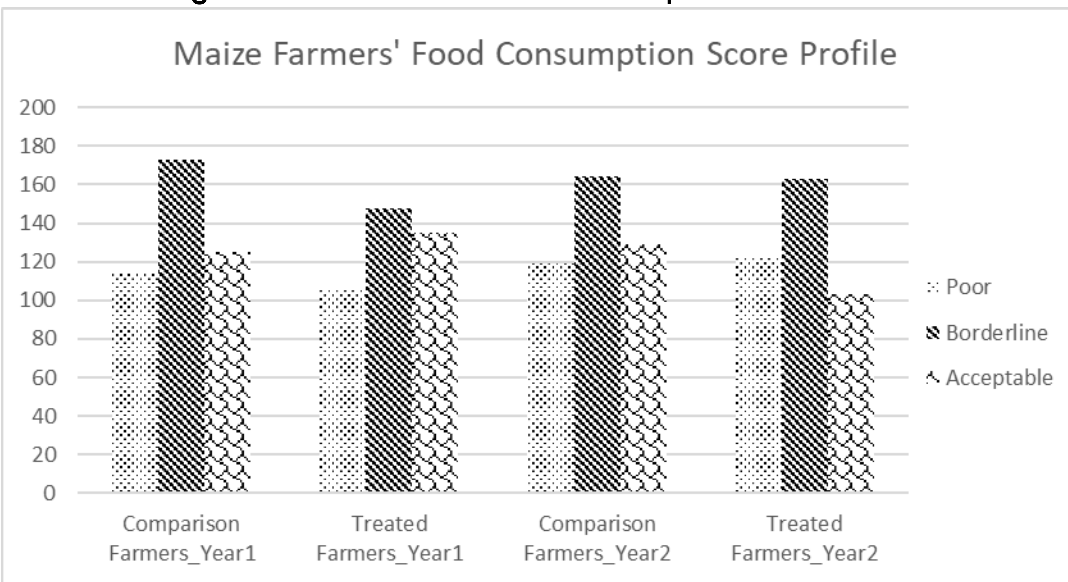
As far as food consumption security was concerned, an impact on household production in Year 2 would have affected food security in line with the theory of change. Hence, it was not surprising that the results in Table 3 show no impact on household food consumption. Further analysis of farmers' food consumption score profile is presented in Figure 5. In both groups, whether in Year 1 or Year 2, a large share of farmers were apparently on the borderline, suggesting that any negative shock could have pushed them into the food-poor category. Figure 5 shows that the number of households characterized by a poor food-consumption profile increased from Year 1 to Year 2 in both treatment and comparison groups. This suggests that more efforts need to be made in terms of production and consumption of diversified food to ensure that all households improve their food-consumption profile.

Table 4: Intention to Treat (ITT) Effect on Total Production in First and Second Seasons, and Food Consumption Score (Estimates from Equation 1)

VARIABLES	(1) Total production (kg) declared	(2) Total production (kg) declared	(3) Total production (kg) corrected	(4) Total production (kg) corrected	(5) Household Food Consumption Score (FCS)	(6) Household Food Consumption Score (FCS)
ITT effect during the first season 2017-2018	880 (1,127)	1,001 (1,133)	540 (1,161)	692 (1,155)	1.3 (1.4)	1.5 (1.4)
Time trend in control group from season 2017-2018 to 2018-2019	1,478** (633)	1,485 ** (635)	1,377** (632)	1,386** (636)	-0.3 (1.3)	-0.3 (1.3)
Marginal impact of resource-intensive extension model vs. a hybrid-extension model in Year 2	343 (1,340)	334 (1,335)	968 (1,259)	953 (1,255)	-3.082* (1.7)	-3.121* (1.7)
Maize farmer's number of years of study without repetition	-	183 (171)	-	182 (173)	-	-0.02 (0.1)
Maize farmer's literacy in any language	-	-436 (1,063)	-	-76 (1,051)	-	2.7*** (0.9)
Mean in control group	3,744 *** (957)	3,383*** (1,096)	3,632*** (949)	3,087*** (1,084)	30.8*** (0.9)	29.5*** (1.0)
Observations	1,600	1,600	1,600	1,600	1,600	1,600

Robust standard errors clustered at the village level, in parentheses *** p<0.01, ** p<0.05, * p<0.1

Figure 5: Maize Farmers' Food Consumption Score Profile



7.2.3 Solving The Puzzle: Where Did The Causal Chain Break?

a. Take-Up Analysis in the Context of the Theory of Change

Two types of take-up results are presented in Table 4. The first concerns the use of agricultural inputs; the second is about providing regular agricultural-advisory services to farmers.

We found that the likelihood that farmers would use inputs such as improved seeds, chemical fertilizers, and pesticides was similar in both treatment and comparison groups, and any statistical difference between the groups was merely due to chance. Most farmers (98.7%) also used the improved seeds they were given on their yield plots. Even when they were not provided free, chemical fertilizers and pesticides were used by 71% and 79% of control group farmers, respectively.

However, the results on the use of herbicides show that farmers in the comparison group were 7% more likely to use herbicides than their peers in the treated group (statistically significant at 1% level). This suggests that, in the absence of the close oversight of the agricultural-extension agent, farmers were more likely to use herbicides even when it was not appropriate to do so. We may infer that, in the absence of the intervention, namely without a resource-intensive extension model, farmers would overuse herbicides on their farm, which would naturally involve consequences for production, production costs, and the quality of their products.

It was possible that the misuse of herbicides had a negative effect on production in the yield plot in the group of farmers who were exposed to the hybrid-extension model. In contrast, because farmers in the resource-intensive model group did not misuse herbicides, it was likely that their behavior positively contributed to an increase in average yields among that group. We did not, however, have data on the quantity of input used to further explore those analyses.

Considering the agricultural advisory service and support provided to farmers, the results show that farmers in the treatment group were 26% more likely to be visited on their yield plot and to receive support from an agricultural-extension agent than were those in the hybrid-extension delivery group. In exploring whether such a difference existed during key production phases, we found that farmers exposed to the resource-intensive extension model were more likely to receive significantly more visits and support during production phases when they used fertilizers and applied pesticides and herbicides. In comparison to farmers in the hybrid-extension model, who received sporadic visits, the probability that treatment-group farmers would receive support from agricultural-extension agents increased by 43% during the period appropriate for the use of fertilizers and by 62.2% during the period appropriate for the application of pesticides and herbicides.

These results suggest that the phases of fertilizer application and the use of pesticides/herbicides were critical times when extension agents should have given farmers more attention. To a great extent, this intensive visit and support drove the impact observed on the production of maize at the plot level in both groups. In that context, a policy that allows farmers to receive systematic and intensive support during those key phases is advisable. It is worth mentioning that, in addition to making extension agents available to farmers during key phases, another critical point was to make sure that farmers possessed the fertilizers, herbicides, and pesticides that were necessary to apply the agents' advice. In reference to one of the main features of the resource-intensive extension model, extension agents were informed beforehand that farmers had all the inputs required to implement the technical advice they were given. That factor may also have driven the results and is worth considering in terms of policy recommendations and action.

The results in Table 4 also show that farmers in both treatment and comparison groups had a similar likelihood of being visited and receiving support from extension agents during soil preparation, sowing, and harvesting. These findings suggest that farmers have a good understanding of what to do during those phases and that extension agents no longer consider those phases critical.

Farmers' learning at the level of their yield plots during the first year was crucial in the theory of change and was key for adoption. While little additional learning would have taken place during soil preparation, sowing, and harvesting, in reference to the technical skills required and the intensity of visits and support during the use of fertilizers, herbicides and pesticides, farmers may have learned something. It was unlikely, however, that they had mastered sensitive, soft skills related to fertilizers, pesticides, and herbicides over one or two seasons of training over one season. Rather, learning required the presence of and hand-holding by agricultural-extension agents throughout the production season and especially during critical phases. Otherwise, farmers would essentially execute the advice verbatim without necessarily understanding why they were doing what they had been advised to do. This implies that, in the absence of agricultural-extension agents, farmers would likely do what they had learned on their own without support from the advisory service and not necessarily what they had learned on their yield plot.

Table 5: Take-Up of the Intervention at the Plot Level (Estimates from Equation 1)

(1) VARIABLES	(2) Treated - Comparison	(3) Comparison	(4) Observations
USE OF INPUTS IN THE FIRST YEAR AT THE PLOT LEVEL			
Use of chemical fertilizers -Urea + NPK- (%)	-1.9 (4.5)	71.3*** (3.4)	800
Use of pesticides (%)	1.8 (2.5)	79.4*** (2.1)	800
Use of herbicides (%)	-7*** (2.6)	87.9*** (1.6)	800
VISITS AND SUPPORT OF AGRICULTURAL-EXTENSION AGENTS			
Number of extension agent visits	26.9** (11.8)	2.085*** (8.1)	800
Received visit and support of an agricultural-extension agent during soil preparation	-1.5 (2.7)	20.6*** (02.0)	800
Received visit of an agricultural-extension agent during sowing	2.8 (2.9)	18.3*** (1.8)	800
Received visit and support of an agricultural-extension agent during the application of chemical fertilizers	43.3*** (2.7)	21.4*** (1.6)	800
Received visit and support of an agricultural-extension agent during the application of pesticides and herbicides	62.2*** (2.6)	15.2*** (21)	800
Received visit and support of an agricultural-extension agent during harvesting	-1.8 (1.9)	9.3*** (1.4)	800

Standard errors clustered at the village level, in parentheses *** p<0.01, ** p<0.05, * p<0.1

b. Behavior change to adopt new technology: Learning at plot-level and adopting at all farm plots level

Adoption of maize-production technology was measured through sowing of improved seeds; the use of fertilizers, herbicides, pesticides in appropriate quantities; and requests for agricultural advisory services during key production phases. It was essential to ensure that the resource-intensive extension model, as it was implemented, affected maize production and food security throughout the intervention causal chain. Though the impact occurred at an early stage of the chain, however, the future expected effect (in Year Two) did not take place. This made it necessary to further explore the causal path to identify where the transmission flow stopped, even though, in the second year, a standard extension advisory service was provided to farmers.

Table 5 shows the effect on adoption of a resource-intensive extension model vs. a hybrid-extension model in Years 1 and Year 2. Overall, in testing whether farmers used improved seeds, local seeds, pesticides, herbicides, or organic and chemical fertilizers in all their maize farmlands as the result of resource-intensive-extension delivery, we found no difference between the average farmer in the resource-intensive group and the average farmer in the hybrid-extension model.

Also, the results also show that, when farmers were exposed to the hybrid-extension model in Year 1 before they receiving the standard extension model in Year 2, they were likely to use more local seeds (12% increase) and fewer improved seeds (21% reduction) . Some farmers explained this by noting that they often combined first-generation improved seeds with part of the production from those seeds and used them for the subsequent year's planting. In doing so, they minimize their seed cost but were more likely to use chemical fertilizers to enhance production.

We additionally found that farmers in the comparison group were less likely to use pesticides (a reduction of 12%), herbicides (a reduction of 9%), or organic fertilizers (a reduction of 1%) from the first season to the second season because they tried to take advantage of lasting effects of the inputs they had used during the first season.

The results also indicated similarity in the likelihood that farmers in both the resource-intensive extension model and the hybrid-extension model would receive agricultural advisory services on all their maize plots during the first and second seasons. This means no impact was observed on those variables. Because both groups received similar agricultural-extension support, it was not surprising that the same behavior was noticed across the groups. These results were supported by the qualitative data in which farmers in both groups complained at length about the lack of cash to purchase inputs at the village level or from shops in nearest cities. Because farmers in general did not purchase the inputs required during the second year, the agricultural-extension agents could not necessarily provide the best advisory service, not even to the resource-intensive extension-model farmers who had made better use of the intervention during the first year.

Table 6: Use of Input and Technologies on Maize Farms (Estimates from Equation 2)

VARIABLES	(1) Time trend impact in the hybrid-extension model group	(2) Impact of resource-intensive extension model vs. a hybrid-extension model in Year 1	(3) Marginal impact of resource-intensive extension model vs. a hybrid-extension model in Year 2	(4) Constant	(5) Observations
Use of local seeds for maize production. (%)	12.9*** (4.7)	0.3 (4.6)	1.1 (6.1)	72.0*** (3.1)	1,600
Use of improved seeds for maize production. (%)	-21.1*** (4.0)	-2.4 (5.0)	1.8 (6.0)	38.9*** (2.9)	1,600
Use of pesticides for maize production. (%)	-12.1*** (3.7)	6.5 (3.9)	-5.9 (5.3)	23.8*** (2.8)	1,600
Use of herbicides for maize production. (%)	-9.7*** (3.5)	-4.7 (2.8)	5.6 (4.8)	89.3*** (2.0)	1,600
Use of organic fertilizers for maize production. (%)	-1.0 (2.5)	2.2 (2.7)	-2.4 (3.3)	8.2*** (1.5)	1,600
Use of chemical fertilizers for maize production. (%)	13.6*** (4.1)	-5.8 (4.7)	-0.2 (7.0)	46.3*** (2.8)	1,600
Received advisory services (%).	-49.0*** (4.5)	-1.8 (3.4)	-4.1 (6.3)	85.6*** (2.7)	1,600
Applied new technologies taught by the extension agent, in maize farms. (%)	9.5 (7.0)	1.7 (7.5)	-12.3 (9.4)	43.9*** (05.0)	1,600

Standard errors clustered at the village level, in parentheses: *** p<0.01, ** p<0.05, * p<0.1

c. Heterogeneity Analysis: Quantile Treatment Effect Analysis

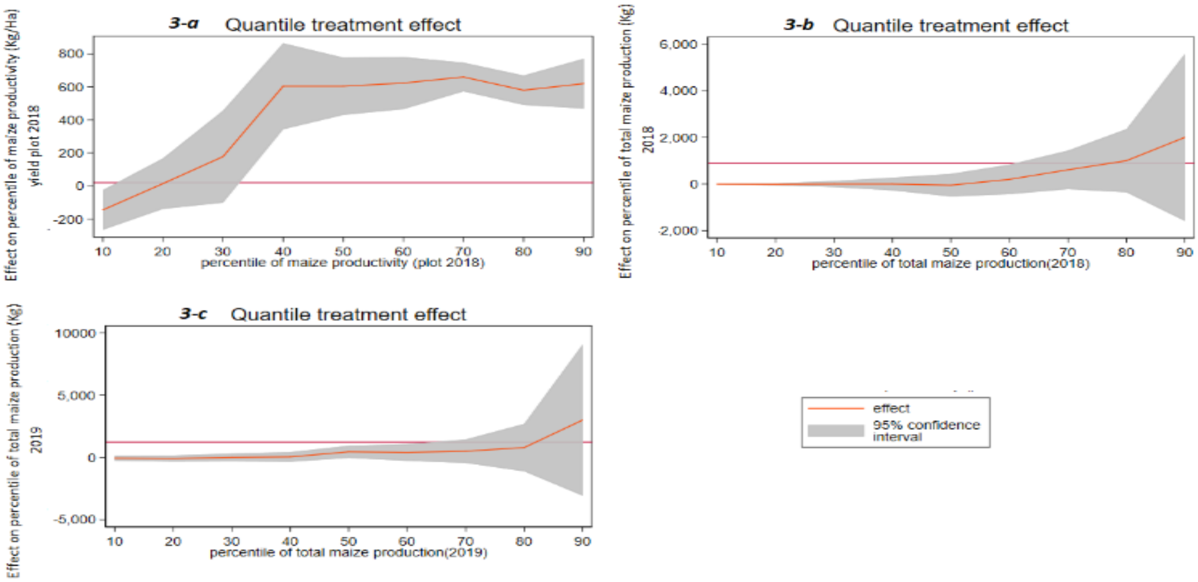
In reference to the intervention theory of change, one would expect better-off farmers to purchase the fertilizers, pesticides, and herbicides they needed to produce maize and to offer incentives to extension agents to visit their farmlands during critical production phases. In doing so, those farmers would more effectively manage production constraints. Considering that if such well-off farmers existed in the sample, moreover, they would have shown different effects of the treatments on production.

Considering the lack of any significant effect of the intervention on production in the first and second agricultural seasons, despite a significant increase in maize yield and farmers' good impressions, we further explored the findings by undertaking a quantile regression analysis to explore how the effect of a resource-intensive extension model vs. a hybrid-extension model varied across sub-groups of farmers.

The results of the quantile regression analyses are presented in Figure 6. They show that, under the rank-preservation assumption, farmers with large productivity on their plots, meaning those in the 40 to 100 percentile of the distribution, benefited greatly and equally from the intervention. This result is illustrated on Figure 6, 3a: Very poor farmers who were below 20% of the distribution were barely affected by the intervention. In this context, it is fair to note that, in general, poor and small-scale farmers targeted by the project were affected by the intervention and had a positive perception of it. The impact of the intervention on maize productivity was smaller for those between percentile 20% and 40%, though the effect was smaller than that observed for farmers in the 40th to 100th percentile.

The results in Figure 6, 3b and Figure 6, 3c were less conclusive though they show that, in terms of 2018 and 2019 production, farmers received a similar small effect no matter what percentile they were in. The right tail of the distribution, beyond 80%, was quite noisy and did not allow any conclusions to be drawn. Overall, these results suggest that the resource-intensive agricultural-extension delivery model was progressive, though it did not necessarily reduce inequality of productivity between farmers with high potential at the top of the distribution and those with very low potential at the bottom of the distribution. In the discussion section, we explore hypotheses that could explain these findings.

Figure 6: Quantile Treatment Effect



VIII. Discussion

The PAPVIRE-ABC project was designed and implemented in Benin to address a wider challenge about the best way to support farmers to increase cereal production (specifically, maize) and address food security issues. Considering the central role of agricultural-extension services in increasing crop production, reducing post-harvest loss, expanding access to markets and to agricultural income, and reducing food insecurity, the project tried out an innovative resource-intensive-extension delivery model. In the context of the project, an alternative extension model was designed that drew from the standard model of extension in the study area. The alternative model was a hybrid-extension model that combined features of both the resource-intensive model and the standard model.

To evaluate the impact of the resource-intensive model vs. the hybrid-extension model, a randomized control trial was designed and implemented during the first year of the study. In the second year, the treatment and comparison group were kept the same, but only a standard extension delivery model was offered to farmers in each of the groups.

The main difference between the two extension models in the first year was the offer of free fertilizers, pesticides, and herbicides as well as the financial incentive given to extension agents to provide close monitoring, support, and advisory services to the farmers during all critical phases of production. The intervention took place on a 500m^2 maize plot set-up in individual farms.

The paper combined data collected on maize plots during the first agricultural season and household panel data collected during the first and second years of the study. We used an OLS estimation to estimate the Intention-to-Treat (ITT) Effect. The results show that the resource-intensive extension model had a greater and statistically significant effect on maize production at the plot level compared to the hybrid-model. Similar results were found concerning farmers' perceptions and their adoption of the technology on the maize plots during the first agricultural season when the intervention was implemented.

However, the positive effect of the resource-intensive extension model over the hybrid extension model did not make farmers adopt the technology and increase their production in the following year when only standard extension services were available to them.

Hence, the model worked well at the plot level during the first season when all inputs were provided to farmers and the extension agents were incentivized to provide technical advice and support in using the inputs appropriately. While such an approach was effective at the plot level even when it was compared with an alternative approach (at small scale), the expected adoption pattern and the impact on production did not happen at scale on the rest of the farmland planted with maize during the first and second seasons.

This second-year outcome could be an implementation failure rather than design failure because the standard extension model assumed there were enough extension agents, which was not necessarily the case. Even when there were enough agents, they were not in general well equipped and motivated to conduct regular visits to all the farmers during key production phases. In addition, the same model expected farmers to access the inputs they needed in their villages. In practice, however, farmers use inputs to cultivate cotton, though some could not afford them. These points were based on qualitative data we collected during informal discussions and direct observations during field visits.

In search of improving extension delivery models, it would important to think of more effective measures to assist farmers to absorb credit constraints. Though the project document suggested a facilitation system that linked farmers with microcredit institutions, this did not happen in a steady way in the course of the study. Several farmers reported cash constraints and could not afford the package of inputs they need on their farm.

Also, it may be the case that one agricultural season was not enough for farmers to learn and master what happened on their yield plots. We also noted that the number of advisory service agents in the project area was always less than demand. Because there was no incentive to agents that favored treatment-group farmers during the second year, farmers in both groups competed equally for advisory services. Because treated farmers received intensive attention the year before and because, in general, the agricultural-extension agents were the same, a preference may have been given to those who were in the control group the year before. It could also be the case that those in the treatment group reduced their requests for advisory services because they had mastered the procedures, which allowed comparison-group farmers to receive more advisory support.

These possible explanations of the findings were echoed by Udry (2010) who indicated that if farmers did not adopt technologies that were proven to increase productivity, it was because those technologies were not profitable. Unfortunately, we did not have enough data to support a proper cost-benefit analysis. In a second class of explanations for low yields, Udry focused on market failures in rural Africa. We noted, however, that land tenure was not per se a constraint in the intervention setting.

Considering those findings, we recommend enforcement of the intervention theory of change with rigorous monitoring of implementation. This would require a increased supply of agricultural-extension agents, especially critical production phases, and a more successful implementation of the facilitation component to ensure that farmers have access to profitable market and are confident enough to dive into the risks of adopting the proposed technology.

For future research on this topic, it would be worth exploring the impact of a resource-intensive extension model over more than one year; testing the change in outcomes when farmers' cash constraints were mitigated through reliable credit services. We would also recommend further exploring the hypothesis of incomplete learning with farmers exposed to agricultural-extension services in standard more improved models.

References

Agwu, A. E., Dimelu, M. U., and Madukwe, M. C. (2008). Innovation System Approach to Agricultural Development: Policy Implications for Agricultural Extension Delivery in Nigeria. African Journal of Biotechnology, 7(11), 1604-1611.

Arshad, F., Muhammad, I., Shah, N. A., and Robina, K. (2010). Agricultural Extension Agents and Challenges for Sustainable Development (A Case Study of Peshawar Valley). Sarhad Journal of Agriculture, 26(3), 419-426.

Asiabaka, C. (2002). Promoting Sustainable Extension Approaches: Farmer Field School (FFS) and Its Role In Sustainable Agricultural Development In Africa. International Journal of Agriculture and Rural Development, 3(1), 46-53. http://www.givewell.org/files/dwda%202009/interventions/agriculture/the%20rise%20and%20fall%20of%20training%20and%20visit%20extension.pdf.

Bandiera, O. and Rasul, I. (2006). Social Networks and Technology Adoption In Northern Mozambique. The Economic Journal, 116(514), 869-902.

Conant, Jeff and Fadem, Pam (2008). A Community Guide to Environmental Health. Berkeley, CA: Hesperian Foundation.

Conley, T.G. and Udry, C.R. (2010). Learning About A New Technology: Pineapple In Ghana. American Economic Review, 100(1), 35-69.

Davis, K., Nkonya, E., Kato, E., Mekonnen, D. A., Odendo, M., Miiro, R., and Nkuba, J. (2012). Impact of Farmer Field Schools On Agricultural Productivity and Poverty In East Africa. World Development, 40(2), 402-413.

Diab, A. M. (2015). Learning Impact of Farmer Field Schools of Integrated Crop-Livestock Systems In Sinai Peninsula, Egypt. Annals of Agricultural Sciences, 60(2), 289-296.

Haile, Mekbib and Abebaw, Degnet. (2012). What Factors Determine the Time Allocation of Agricultural Extension Agents on Farmers' Agricultural Fields? Evidence from Rural Ethiopia. Journal of Agricultural Extension and Rural Development, 4(10), 318-329. Available at https://ssrn.com/abstract=2057597.

Hodonou, A. (2014). Productivité dans le Secteur Agricole: Etat des Lieux, Contraintes et Pistes d'Amélioration. Porto-Novo: Commission Nationale PIB-TOFE du Bénin.

Kondylis, F., Mueller, V., and Zhu, S. (2017). Seeing Is Believing? Evidence From An Extension Network Experiment. Journal of Development Economics, 125, 1-20. Available at https://doi.org/10.1016/j.jdeveco.2016.10.004.

Laajaj, R. and Macours, K(2017). Learning-By-Doing and Learning-from-Others: Evidence from Agronomical Trials in Kenya. In A. de Janvry, E. Sadoulet, and T. Suri, Eds., Learning for Adopting: Technology Adoption in Developing Country Agriculture, 97-102.

Larsen, A. F. and Lilleør, H. B. (2014). Beyond the Field: the Impact of Farmer Field Schools on Food Security and Poverty Alleviation. World Development, 64, 843-859.

Ministry of Agriculture, Livestock Farming and Fishery (MAEP) (2014). Rapport de Performance du Secteur Agricole, Gestion 2014. Cotonou: Gouvernement du Bénin.

Ministry of Agriculture, Livestock Farming and Fishery (MAEP) (2015). Rapport de Performance du Secteur Agricole, Gestion 2015. Cotonou: Gouvernement du Bénin.

Moumouni, I., Nouatin, G.S.,and Baco, M.N. (2011). Du Système Formation et Visites au Conseil a l'Exploitation Agricole Familiale au Bénin: Rupture ou Continuité? Cahiers Agricultures, 20, 376-381. DOI: 10.1684/agr.2011.0514.

Munshi, K. (2004). Social Learning in a Heterogeneous Population: Technology Diffusion in the Indian Green Revolution. Journal of Development Economics, 73(1):185-213. Niu, C. and Ragasa, C. (2018). Selective Attention and Information Loss In the Lab-To-Farm Knowledge Chain: the Case of Malawian Agricultural Extension Programs. Agricultural Systems, 165, 147-163.

Ragasa, C. and Mazunda, J. (2018). The Impact of Agricultural Extension Services in the Context of a Heavily Subsidized Input System: The Case of Malawi. World Development, 105, 25-47.

Udry, Christopher (2010, September). The Economics of Agriculture in Africa: Notes toward a Research Program. African Journal of Agricultural and Resource Economics, 5(1), 1-16.

Annex

Table A1: Attrition Analysis (Estimates from Equation 1)

	(1) Attrition indicator
Treated - Controls	-0.015 (0.019)
Controls	0.094*** (0.013)
Observations	876

Standard errors clustered at the village level, in parentheses: *** p<0.01, ** p<0.05, * p<0.1.

Table A2: Balance Check at Household Level (estimates from Equation 1)

(1) Household-Level Variables	(2) Treated - Controls	(3) Std Dev	(4) Controls	(5) Std Dev	(6) Observations
Household size	-0.107	(0.359)	7.896***	(0.212)	800
Number of children (below 5 years old)	-0.050	(0.099)	1.162***	(0.074)	800
Number of children (5-10 years old)	-0.148	(0.107)	1.359***	(0.072)	800
Number of children (10-15 years old)	-0.067	(0.094)	1.285***	(0.064)	800
Number of children (15-21 years old)	0.114	(0.117)	1.117***	(0.060)	800
Number of men (older than 21 years)	0.012	(0.073)	1.445***	(0.050)	800
Number of men contributing to household income	0.134	(0.141)	2.084***	(0.080)	800
Number of women (older than 21 years)	0.030	(0.096)	1.486***	(0.066)	800
Number of women contributing to household income	0.148	(0.171)	1.792***	(0.081)	800
Number of out-migrants	0.011	(0.031)	0.095***	(0.021)	800
Land owned or used (hectare)	0.652	(1.616)	12.333***	(1.085)	800
Livestock	0.166	(0.589)	3.611***	(0.373)	800

Standard errors clustered at the village level, in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table A3: Balance Check at Individual Level (Estimates from Equation 1)

Individual (producers) level variables	Treated - Controls	Std Dev	Controls	Std Dev	Observations
Leader of contact group (%)	0.015	(0.010)	0.074***	(0.007)	800
Male producers (%)	0.020	(0.029)	0.875***	(0.021)	800
Age	1.202	(0.813)	39.967***	(0.650)	800
Household head (%)	0.012	(0.028)	0.871***	(0.022)	800
Married (%)	0.012	(0.016)	0.948***	(0.012)	800
Number of spouse	-0.024	(0.067)	1.362***	(0.051)	800
Number of dependents per producers	0.172	(0.412)	7.962***	(0.238)	800
Households active members working permanently with you	0.033	(0.209)	3.229***	(0.126)	800
Experience in maize production (years)	0.633	(0.924)	17.984***	(0.708)	800
Literacy in any language (%)	-0.088*	(0.045)	0.520***	(0.030)	800
Number of formal education years	-0.863**	(0.356)	3.209***	(0.261)	800
Primary education level (%)	0.012	(0.027)	0.177***	(0.020)	800
Native producers in the village (%)	-0.034	(0.027)	0.933***	(0.019)	800

Standard errors clustered at the village level, in parentheses: *** p<0.01, ** p<0.05, * p<0.1