Rhizobium Inoculant Knowledge Dissemination and Farm Household Outcomes in Ghana

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Abstract

Although agriculture remains the pillar for livelihood sustenance, especially for poor rural households in sub-Saharan Africa (SSA), productivity in the sector remains low. Key among the factors contributing to low agricultural productivity in the region is poor soil quality. The need to enrich farmlands with the required nutrients to boost crop productivity is therefore high on the region's agricultural transformation agenda. Application of Rhizobium inoculants to boost nodulation of legumes is a modern soil fertility improvement technology aimed at boosting the productivity of legume farmers, especially in regions with generally poor soil quality such as the 3 northern regions of Ghana. Our study provides impact evaluation evidence from a Randomised Control Trial (RCT) conducted for smallholder farmers in the 3 northern regions of Ghana on knowledge dissemination about inoculants through videos and radio listening clubs. The results provide novel empirical evidence on the potential of radio listening clubs and video documentaries as input information dissemination methods in a farming setting. Using panel data for 1,126 households based on 2 rounds of household surveys collected in the study region over the period 2015-2016, and relying on the predictions of the difference-in-differences estimation technique, we find that video documentaries account for increase in inoculant adoption by 13% points, and that adoption was higher for video documentaries than radio listening clubs by 9% points. Our results also show a positive but weak impact of video documentaries and radio listening clubs on crop yields. Overall, video documentaries and radio listening clubs accounted for 98kg/ha and 73kg/ha increase in crop yields respectively. We also find a positive impact of video documentaries on smallholder farmer incomes, accounting for increases in overall average income by GHC714.00. Generally, compared to radio listening clubs, we find a greater impact of video documentaries on outcome indicators. These findings are relevant for agricultural policy formulation and implementation.

Key Words: *Rhizobium Inoculant, Knowledge Dissemination, Smallholders, Radio Listening Clubs, Video Demonstration, Farm Household Outcomes, sub-Saharan Africa, Ghana*

JEL Classification: Q12, Q16

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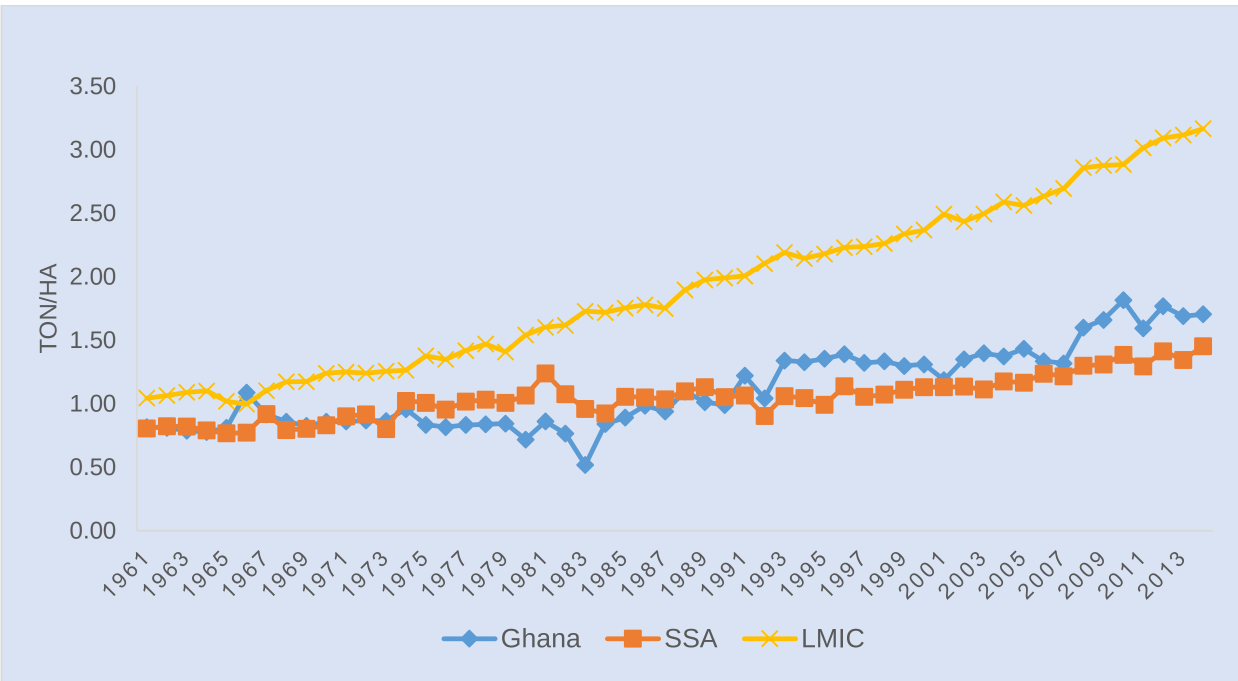
1. Introduction

Agricultural productivity in sub-Saharan Africa (SSA) has been generally low, although the sector remains important for the economic livelihoods of the majority of the region's population as evidenced by low crop yields per hectare. For instance, over the period 1961-2012, cereal yields in SSA falls far below the overall averages reported for Low Middle Income Countries (LMIC), with the gap widening over time (see *Figure 1*). We also observe that cereal yields in Ghana falls below the SSA average between 1973-1991 before rising above the regional average over the period 1991-2012, though cereals reported for the country falls far below the average yields reported for Low Middle Income Countries (LMIC).

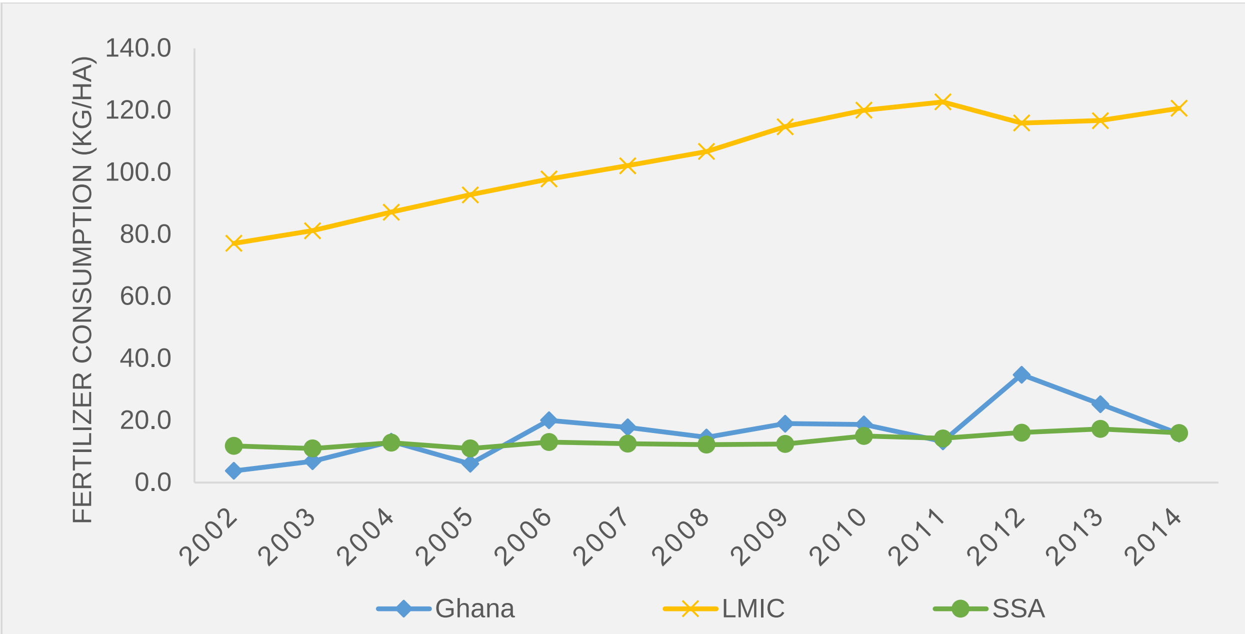
Figure 1: Cereal Yield Trends in Ghana and Selected Regions



Source: World Bank's World Development Indicators (WDI), 2017

Key among the factors contributing to low agricultural productivity in the region is poor soil quality. The need to enrich farmlands with the required nutrients to boost crop productivity is therefore high on the region's agricultural transformation agenda. Poor soils have been identified as a major challenge to increasing agricultural productivity and raising smallholder farmer incomes in Ghana, especially in the three northern regions (Northern, Upper East and Upper West). The need for technologies that improve soil fertility and increase yield and farmer incomes can therefore not be overemphasized. This notwithstanding, available soil amendments, particularly fertilizers, are expensive, with the result that farmers' adoption to improve production remains low. For the period 2002-2014, average fertilizer consumption reported for SSA as a whole and Ghana in particular is very low compared to the average volumes for Low Middle Income Countries (LMIC) (see *Figure 2*).

Figure 2: Average annual fertilizer consumption in Ghana and selected developing regions – 2002-2014



Source: World Bank's World Development Indicators (WDI), 2017

In Ghana, about 60 percent of the population depends on subsistence agriculture as a means of livelihood, with about 27 per cent living under the poverty line (MOFA, 2002). The most affected area in the country is Northern Ghana as it is estimated that up to 80% of the population in this part of the country is poor (Ekekpi and Kombiok, 2008). Some of the major problems that persist in the agricultural sector in Northern Ghana are erratic rainfall and low soil fertility. Further analysis of the agricultural sector in Northern Ghana indicates that poor soil fertility results in poor crop yield, low income of the farmers and hence affects agricultural development negatively in the country (RELC, 2005). Hence, one of the basic needs to be addressed in this part of the country is low soil fertility; the low soil fertility in Northern Ghana is blamed in part on the bush fires, which usually occur annually during the dry season (SARI, 1995). According to the study, this situation renders the soil bare and exposes it to both wind and water erosion in the dry and rainy seasons respectively, thereby depleting the macro-nutrients such as Nitrogen, Phosphorus and Potassium (NPK) and organic matter from the soil (Kombiok, Buah, & Sogbedji, 2012). In response to this, farmers practice shifting cultivation or land rotation to replenish the soil with its nutrients. As a result of increasing population, there is increasing pressure on land and this reduces the effectiveness of this method of replenishing soil fertility for sustainable crop production in Northern Ghana. Farmers further try using nitrogen fertilizers to increase soil fertility. However, the high cost of fertilizers means farmers are unable to buy and use the right quantities for the soil to produce achievable crop yields. This, therefore, calls for appropriate soil fertility management approaches for sustainable crop production in the savannah zone of Ghana. There is therefore the need to increase nitrogen into the soil to increase soil fertility among others.

The Alliance for a Green Revolution in Africa (AGRA), as part of its agricultural transformation agenda for Africa, has started the implementation of the Soil Health Program (SHP) to restore the degraded soils of Africa and subsequently boost productivity. The SHP focuses on rapid dissemination of locally adapted and environmentally sound integrated soil fertility management practices and water management. The program aims at promoting locally appropriate soil management practices that combine the use of organic matter and fertilizers to restore soil health. The overall goal of the intervention is to supplement the efforts of governments aimed at transforming agriculture and increase smallholder earnings and household welfare. In Ghana, the Council for Scientific and Industrial Research's Savannah Agricultural Research Institute (CSIR-SARI), in partnership with AGRA, has proposed Rhizobium inoculant as part of the solution to the soil infertility problem. This technology makes appropriate Rhizobium bacterium available in the soil to help fix atmospheric nitrogen, which could benefit crops grown in rotations or intercropped with them. Studies have shown that the Rhizobium inoculant for soybean is very profitable, with the potential of doubling yields (CSIR-SARI, 2013).

The CSIR-SARI received a grant from AGRA in 2014 to produce and make inoculants available to farmers through collaboration with the private sector. The inoculant technology is expected to address the problem of low soil fertility and subsequently enhance soil health in Ghana by fixing the required atmospheric nitrogen into the soil (Trotman & Weaver, 1986). This is expected to increase crop yield and consequently increases the income of farmers. This method of increasing soil fertility and productivity is considered less costly as compared to the use of Nitrogen fertilizers (Giller, 2001; Mutuma S. P., Okello, Karanja, & Woomer, 2014).

An important step in making the project successful is the dissemination of relevant information about the technology to farmers in a way that would encourage and accelerate uptake. The objective of this evaluation is to analyse the impact of the proposed channels of disseminating the inoculant technology on inoculant adoption, yields, and farmer incomes. This is important because a good technology, even if shown to work on demonstration fields, does not guarantee farmer adoption. Therefore, the need to encourage adoption of the new technology through information packages is a key component of the project.

There are several information dissemination channels that could be used to encourage farmer adoption of the inoculant technology. A key question therefore is which of these information dissemination channels are most effective in terms of the adoption and use of the inoculant technology by farmers? Specifically, the impact evaluation seeks to answer the following research questions:

1. Which method of information dissemination is most effective for the adoption of the inoculant technology?
2. Does the adoption of inoculum by farmers increase crop yields, and does this result in increased farmer incomes?

In order to answer these questions, the study used a difference-in-differences estimation approach to evaluate the impact of the project on selected outcome indicators such as crop yields, crop incomes, input use, farming practices and agriculture investments.

The rest of the paper proceeds as follows. The next section provides a brief discussion of the inoculant knowledge dissemination intervention as well as the theory of change of the programme. We present a brief review of the literature in the following section, followed by the methodology in section 3. The results and discussion followed in section 4, and section 5 concludes with relevant policy recommendations.

2. The Intervention and the Theory of Change

Implementation of the inoculant knowledge dissemination activity involved 108 radio broadcasts on the composition of inoculants, materials needed for inoculation, practical steps in inoculants application (seed inoculation), benefits of using rhizobium inoculants, common types/forms of inoculants and guidelines for storing inoculants and other good agronomic practices (GAPs). Also, 41 radio listening clubs were formed comprising of and overall membership of 1,055. This activity also involved video screening, which reached out to 12,184 farmers. On the fifth activity, 500 copies of a 7-page extension guide and 1,000 flyers on inoculant technology were produced and distributed.

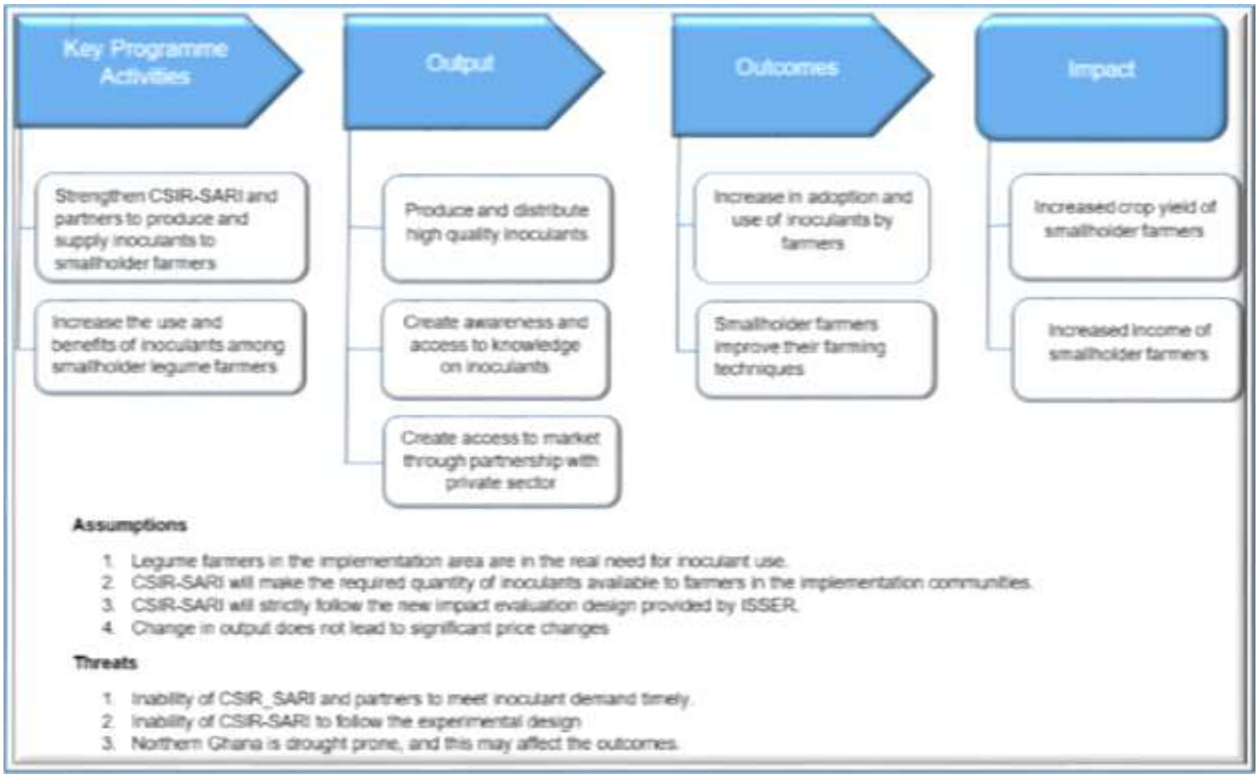
Although farming is the main economic livelihood activity for the majority of households living in northern Ghana, erratic rainfall and low soil fertility remain major problems limiting the profitability of farm enterprises and their potential to reduce poverty, a phenomenon that is more severe in northern Ghana than it is in the south. Poor soils in northern Ghana have been shown to results in poor crop yield, low income and poor agricultural performance in general (RELC, 2005). The low soil fertility in Northern Ghana is blamed in part on the bush fires, which usually occur annually during the dry season. This renders the soils bare and exposes them to both wind and water erosion in the dry and rainy seasons respectively, thereby depleting them of macronutrients such as Nitrogen, Phosphorus and Potassium (NPK) as well as soil organic matter (Kombiok, Buah, & Sogbedji, 2012). Addressing the low soil fertility problem in northern Ghana is seen as a major way of improving the livelihoods of poor farmers.

In order to correct this anomaly, farmers practice shifting cultivation or land rotation. However, as a result of increasing population, there is increasing pressure on land and this reduces the effectiveness of these methods of replenishing soil fertility for sustainable crop production in Northern Ghana. An alternative is the use of mineral fertilizers. However, the most recent nationally representative survey (GLSS 6) shows that only about 48% of farm households use chemical fertilizers. This situation is attributed to the high cost of mineral fertilizers. This situation makes the need for a cheaper technology to improve soil fertility, nodulation and legume yields an important.

Deficiency of nitrogen in the soil has been identified as the major factor limiting legume yield (Bhattacharjee et al. 2008). The introduction of the Rhizobium inoculant technology aims at addressing this. Rhizobium bacterium fixes atmospheric nitrogen into the soil, and when properly used could contribute significantly to soil fertility (CSIR-SARI, 2013; Trotman & Weaver, 1986). Ronner *et al* (2016) notes that soybean inoculation, for instance, enhances yield and is cheaper than inorganic fertilizer. Thus, where poverty is pronounced and farmers are not able to afford mineral fertilizers, legume inoculation becomes a viable option (Thilakarathna and Raizada, 2015). This integrated soil fertility management (ISFM) approach does not only increase legume yields but also increases the yield of other crop that are grown in rotation or intercropped with the legumes, thereby further raising the potential for increased crop incomes.

Given this background, adoption of the inoculant technology is expected to enhance soil fertility and crop yield. The increase in yield is consequently expected to have a positive impact on farmers' income and reduce household food insecurity. The program's theory of change is summarized in Figure 3.

Figure 3: Theory of Change – Rhizobium Inoculant Project in Northern Ghana



Source: Authors' construct

3. Review of Related Literature

Smallholder farmers' adoption of modern agricultural technologies such as inoculants is crucial for improving productivity, raising incomes and subsequently reducing poverty. The literature provides some evidence of the impact of inoculant use on crop yields and income. Evidence from Thailand also indicates increases in yield from 950kg/ha to 1338kg/ha in soybeans after the use of Rhizobium Inoculant (Chanaseni & Kongngoen, 1992). In Kenya, Mutuma *et al* (2014) positive significant impact of inoculants adoption on yields and gross margins of farmers. In south-eastern Nigeria, Bomfield and Ayanba (1980) observed that the use of inoculated soybean resulted in yield increase of over 300%. Campbell (1980) noted that technology adoption by farmers is critical for improving agricultural productivity in Australia.

According to Mutuma et al. (2014), farmers decision-making on the adoption of improved agricultural technologies is a complex process. Earlier studies (Feder, Just, & Zilberman, 1985; Everett, 2003) proposed a theoretical model in which an individual's technology adoption passes through various stages – knowledge, persuasion, decision, adoption and confirmation. This suggests that product knowledge is fundamental to the decision-making process for adoption. In developing countries, however, asymmetry information is well documented, with implications for the adoption of new agricultural technologies. Adoption of emerging farming technologies in developing countries is therefore usually low, due to a wide range of limiting factors. Though these factors depend on the setting and type of technology, the literature identify education, wealth, tastes, risk preferences, complementary inputs, and access to information and learning (Aker, 2011) as factors affecting adoption. Key among these factors is the role asymmetric and costly information particularly associated with smallholder farmers living in remote rural agricultural dominated settings with very high level of illiteracy. Among other determinants, Kebede et al. (1990) identified access to information, education and experience as key drivers of agricultural technology adoption. They also find that the predicted probabilities of technology adoption by the average farmer increases the level of education and exposure to outside information.

Woomer, *et al* (1997) indicate that lack of information concerning inoculants availability and use is a major constraint to adoption. According to Shampine (1998) the problem of agricultural technology adoption is one of asymmetric information and very high search cost. Since adoption of new technologies are crucial for farm productivity, the need to provide adequate and low cost information on emerging productivity enhancing technologies especially in developing countries becomes necessary. This could be achieved through farmer training programmes. According to Anderson and Feder (2007), attempts have been made by governments and international organisations to overcome the asymmetry information related to technology adoption through agricultural extension services aimed at delivering training programmes to provide timely and adequate information to farmers. After several decades of investment in public extension services, limited evidence is available on their impact on new technology adoption. Additionally, public extension service delivery has been criticised for high costs, problems with scale and low levels of accountability (Aker, 2011). According to Rivera *et al* (2001), many agricultural extension systems are not well functioning because of: (i) limited scale and sustainability, (ii) weak linkages between research centres, universities, and agricultural extension systems, (iii) low motivation and accountability on the part of extension field staff, and (iv) little rigorous evidence of the impacts of extension services on farmers' welfare. The effectiveness of traditional extension services at delivering the required results is therefore uncertain, making way for the pursuit of alternative means of farmer training and information delivery.

With the upsurge in information and communication technologies (ICT) in the past few decades, we have available technological systems for a massive outreach and delivery of agricultural knowledge at an incredibly low marginal cost. Radio broadcasts and video shows are part of these technologies available for effective farmer training and information dissemination to enhance the adoption of modern farm technologies. Zossou et al. (2009), comparing the effectiveness of video shows to conventional training workshops and peer learning on innovation transfer to women rice farmers show that video shows were more effective in influencing behaviours and strengthening capacity to innovate than training workshops and learning from peers. Dandedjrohoun et al. (2014) also show educational video outlining the use and benefits of an improved rice-parboiling technology have a positive impact on parboiling adoption.

Wele (1991) show that radio have been effective at diffusion agricultural information in Brazil and Cote d'Ivoire. Mhagama (2015) argue that radio listening clubs can create the platform for famers to acquire, discuss and share relevant information for higher productivity and enhanced food security and incomes. Adesina et al. (2000) observed that farmers who belong to knowledge sharing groups are more likely to adopt the new farm technologies They stressed that farmer groups enhance farmer-to-farmer interactions in technology and thus represents a self-training opportunity.

Our study provides an assessment of the impact evaluation of the impact of video demonstrations and radio listening clubs on farmers' adoption of inoculants, crop yields and crop incomes. The study contributes to the existing literature in various ways. First, to the best of our knowledge, this is the first study comparing the relative effectiveness of video demonstrations and radio listening clubs in promoting the adoption of new agricultural technologies (Rhizobium inoculants in this case). Second, the study provides evidence on the resultant differential impact of video demonstrations and radio listening clubs on legume yields and crop incomes. finally, unlike most previous studies, the current study uses a more rigorous evaluation approach based on Randomised Controlled Trials (RCT) for the impact assessment.

4. Methodology

The study covered the three northern regions of (Northern, Upper East and Upper West regions). These regions are the poorest in the country (Ghana Statistical Service, 2014), with harsh arid conditions, lacking infrastructure and experiencing market exclusion. The study regions are located mainly in the Guinea and Sudan Savannah agro-ecological zones, very close to the Sahara and experience an annual average rainfall of about 1,000mm. The major crops grown are maize, sorghum, millet, rice, cowpea and cotton. Livestock production is generally more popular in the north than in the south and include cattle, sheep, goats and poultry. The main economic activity is agriculture, employing about 71% of the economically active population.

Our impact evaluation is designed around CSIR-SARI's plan for reaching farmers with the inoculant technology. This is to be achieved through awareness and demand creation via farm demonstrations, mass media popularization using radio and video among others. Dissemination through radio listening clubs (Radio) and video documentaries (Video) are core components of our impact evaluation design. Our experimental design assigned 113 villages (or FBOs) to one of three (3) experimental arms:

T(0): Pure control
T(1): Partial Treatment 1 – selected FBOs/communities receive inoculant dissemination information via Video documentaries
T(2): Partial Treatment 2– selected FBOs/ communities receive inoculant dissemination information via Radio Listening Clubs

The randomization essentially followed the stages of the design. At the first stage, we obtained a list of FBOs/communities from CSIR-SARI. We then randomly assigned each of the communities to T(0), T(1) and T(2). Because of the relatively small number of clusters from the Upper East and Western region, the random assignment was not stratified by region but all 113 communities were treated as one strata. The random assignment was done together with the implementer using the Stata software (*Table 1*). At the second stage, we listed households in the 113 selected FBOs in the three regions. Finally, 10 households were randomly drawn from each of the FBOs.

Table 1: Distribution of FBOs (communities) across regions

Arms	Northern	Upper East	Upper West	Total
Control	31	4	4	39
Video	24	2	11	37
Radio	30	2	5	37
Total	85	8	20	113

The sample size used for this study was arrived at by undertaking a power analysis based on ex ante assumptions about key parameters. In particular, we note that different assumptions about these parameters give different power and therefore has implications for the sample size for any study. The key assumptions that informed our power analysis and sample size are as follows.

Level of Significance (α) = 0.05
Intra-Cluster Correlation (ICC) = 0.20
Cases per cluster = 10
Effect size = 0.30

The effect size is based on expected impact on yields and income. These assumptions give us 84% power. This suggests that there is 84% probability that the impact estimates based on the selected sample will find a statistically significant difference when such a difference actually exists. With 10 farm households per community, our total sample size is 1,130. Because we did not achieve 10 households in all the communities our sample reduced by only four households, giving a sample size of 1,126, which still gives us enough statistical power (> 80%).

Our estimations are based on panel data of 1,126 households gathered from 2 rounds of field data collected in the study regions – a baseline and an endline quantitative data. The baseline data collection was undertaken in January and February 2015 whilst that for the endline was in March and April 2017. Data was collected in 113 communities spread across 23 districts in the three (3) northern regions – 14 districts in Northern, 6 in Upper East and 3 in Upper West. The survey instrument used focused on the farming activity of farm households. Although some household nonfarm activity information was included in the instrument, the emphasis was on data relating to agricultural production, harvesting and marketing. Particular attention was paid to getting information on farmer incomes and crop yields—two key impact indicators. The period for the survey was chosen so that it preceded the start of the raining season when farmers are busiest. The actual surveys were led by researchers from the University for Development Studies (UDS) with supervision and guidance from ISSER. Before each of the surveys, enumerators were trained over a number of days. The objective of the training was to ensure that enumerators had a good and common understanding of the questionnaire. As part of the training, the enumerators undertook role-play exercises. Additionally, there was pre-testing of the questionnaire, which involved the administering to selected farmers in a community outside the programme area. Following the pre-tests, the team organised debriefing sessions where concerns and challenges encountered during the pre-tests were discussed. The actual survey started immediately after the training.

Given a largely successful randomization exercise, we can expect the estimates of Average Treatment Effect (ATE) and Average Treatment Effect on the Treated (ATT) to be identical (i.e. ATE = ATT). Therefore, conditional on observed characteristics, *X*, and treatment, we can write the expected value of an outcome variable of interest (e.g., yield) as

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

where D_i is the treatment variable for household i = 1, 2, …, N such that $D_i = 1$ if household i is assigned to a given treatment or indeed received the given treatment and $D_i = 0$ if household i was assigned to the control group or did not received any of the two treatments (i.e., Videos and Radio). 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

$$y_{it} = \alpha + \beta_1 Video_{it} + \beta_2 Radio_{it} + \beta_3 t + \delta_1 (t \cdot Video_i) + \delta_2 (t \cdot Radio_i) + X_{it}\lambda + \varepsilon_{it}, \quad (2)$$

where *t* represents time (i.e., baseline and endline). If the intervention has an impact on a given outcome, then δ_1 and δ_2 would be different from zero at ≤ 0.05 level of significance. We are also interested in the null hypothesis that $\delta_1 = \delta_2$ (i.e., the impact of *Video* and *Radio* are identical). For the outcomes that are roughly continuous, we modify equation (2) as

$$\Delta y_i = \alpha + \beta_1 Video_i + \beta_2 Radio + \Delta X_1 \lambda_1 + X_2 \lambda_2 + \varepsilon_i, \quad (3)$$

where Δ is the change (or difference) operator, X_1 is the vector of time-varying covariates, X_1 is the vector of time-invariant covariates, and β_1 and β_2 measure the impact of the intervention.

Aside the estimate of ATE we also present intention-to-treat (ITT) estimates. The ITT estimates are simply the case where we analyse the impact of the intervention based on the *ex-ante* assignments to treatment and control groups irrespective of compliance. We would expect the ATE and ITT estimates to be similar because noncompliance was not a serious problem.

For each ITT and ATE estimate we present results from three equations labelled Eqn1, Eqn2 and Eqn3, respectively, depending on the variables that enter the vector *X* in equation (2). For the Eqn1 estimates, the vector *X* is null; for Eqn2, the vector *X* contains only region dummies; and finally for Eqn3 the vector *X* contains the full complement of standard controls depending on the particular outcome of interest.

Our estimates involve four types of outcome variables: binary, fractional, semi-continuous and roughly continuous. Each of these types of outcome variables require different types of estimators: probit, fractional probit, Tobit and ordinary least squares (OLS), respectively.

5. Results and Discussion

Our estimates are based on a balanced sample of 1,126 households (pooled sample = 2,252 observations) as shown in *Table 2*.

Table 2: Distribution of sampled households by region

	Communities		Households	
Region	Freq.	Percent	Freq.	Percent
Northern	85	75.2	848	75.3
Upper East	8	7.1	80	7.1
Upper West	20	17.7	198	17.6
Total	113	100	1,126	100

Source: ISSER Inoculant surveys 2015 & 2017

We tested the hypothesis that the treatment and control groups are similar, at least on observed characteristics. The results show that the treatment and control groups are balanced on all observed characteristics, including the main outcome variables of interest. This assures us that we could confidently attribute changes in observed outcomes that we might find at endline to the intervention, *ceteris paribus*.

The key outcomes under study, following the inoculant knowledge dissemination experiment are inoculant adoption, legume yields and crop incomes. One of the specific objectives of the inoculant project is to increase the use and benefits of inoculants among legume farmers. Given a binary adoption variable, we estimated a probit model. The results (*Table 3*) indicate that the video documentaries increased adoption by 3–4 percentage points after controlling for the full set of covariates. Also, the ATE estimates show that the adoption rate among the video arm was approximately 3 percentage points higher than the rate among the radio treatment arm. Here again, the radio listening clubs did not have any impact on inoculant adoption. The results are not surprising because apart from listening, video documentaries offer the opportunity to see footages of what is discussed. This observation corroborates the findings of Dandedjrohoun et al. (2014) who observed that that video documentaries increased the adoption of rice-parboiling technology adoption. It is also consistent with the findings of Zossou et al. (2009) who observed that video documentaries were more effective in influencing behaviours and strengthening capacity to innovate than training workshops and learning from peers.

Table 3: Impact of intervention on inoculant adoption

	ITT			ATE		
VARIABLES	Eqn 1	Eqn 2	Eqn 3	Eqn 1	Eqn 2	Eqn 3
Video	0.054***	0.056***	0.018***	0.065***	0.069***	0.021***
	(0.013)	(0.014)	(0.006)	(0.013)	(0.014)	(0.006)
Radio	0.022	0.020	0.005	0.022	0.020	0.002
	(0.015)	(0.015)	(0.006)	(0.017)	(0.016)	(0.007)
Time	0.066***	0.066***	0.023***	0.069***	0.069***	0.024***
	(0.012)	(0.012)	(0.007)	(0.013)	(0.012)	(0.007)
Impact:						
Video vs. Control	0.117***	0.121***	0.034***	0.137***	0.144***	0.039***
	(0.026)	(0.026)	(0.013)	(0.027)	(0.028)	(0.014)
Radio vs. Control	0.052*	0.051*	0.011	0.051	0.049	0.008
	(0.029)	(0.028)	(0.013)	(0.031)	(0.030)	(0.013)
Radio vs. Video	–0.065	–0.070	–0.024	–0.086**	–0.095**	–0.032**
	(0.034)	(0.034)	(0.015)	(0.037)	(0.036)	(0.016)
Control group mean		0.018			0.018	
Observations	2,252	2,252	2,252	2,072	2,072	2,072

Note: Cluster (village-level) robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 4. Impact of intervention on change in legume yields

	ITT			ATE		
VARIABLES	Eqn 1	Eqn 2	Eqn 3	Eqn 1	Eqn 2	Eqn 3
Impact:						
Video vs. Control	78.835	98.761*	86.846*	97.989*	121.697**	112.128**
	(52.442)	(53.445)	(48.391)	(56.260)	(57.064)	(50.962)
Radio vs. Control	62.897	63.284	58.230	73.231*	73.947*	69.343*
	(41.770)	(42.072)	(37.733)	(43.227)	(44.481)	(40.078)
Radio vs. Video	–15.937	–35.477	–28.615	–24.759	–47.750	–42.784
	(48.417)	(49.093)	(44.419)	(53.676)	(54.302)	(48.410)
Mean for the control group						
Observations	1,126	1,126	1,126	1,036	1,036	1,036

Note: Cluster (village-level) robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The second impact indicator is legume yields. The program's theory of change is that the production and distribution of inoculants to smallholder legume farmers should lead to increased yields in the presence of poor soils and cash constraints to procure productivity-enhancing inputs. The availability of inoculants should help solve the soil deficiency problem and increase yields. Thus, we expect that the yields of farmers who received knowledge on the inoculant technology through the video documentaries and radio listening clubs to be significantly higher than the yields of those who did not receive the information on the technology. The estimates of the impact on yield are presented in *Table 4*.

Although legume yields increased for both the video and radio treatment arms above, that for the control group increased by approximately 87 kg/ha and 58 kg/ha respectively. According to the ITT estimates, the increases were not statistically different from zero at the 5% level. For the ATE estimates, however, once we account for region of residence (Eqn2) and other covariates of yield (Eqn3), we observe that the video documentaries increased yields significantly by about 112–122 kg/ha. The radio listening club impact is only significant at the 10% level, increasing yields by approximately 69–74 kg/ha.

These changes in yields due to the information dissemination channels are indeed large compared with the control group mean. Note also that only 15% and 7% of farm households reached by the video documentaries and radio listening clubs actually used the inoculants. This seemingly low rate of adoption was because the inoculants were not available to farmers at the time when they needed to use them. We can thus conjecture that if the inoculants were available yields would have increased much higher for the treated group than it would be for the untreated. Indeed, even after controlling for other covariates of yield we find that farmers who actually used the inoculants achieved yields of 321 kg/ha, over and above those who did not use the technology (std. err. = 106, *p*-value = 0.003).

The overarching goal of the inoculant project is to raise crop incomes of smallholder farmers. The program's impact on per capita crop income is estimated using a Tobit regression because about 16% of the farm households in our sample did not earn any crop income. We expect that yield increases due to the project would ultimately lead to increased incomes because of the expected increase in marketable surplus. The results (see *Table 5*) show that the video documentary has a significant positive impact on per capita crop income. The videos are estimated to raise per capita incomes by approximately US$26–US$33. This is a large impact given that it represents 30% – 37% of the control group mean per capita crop income. It seems that this impact on crop income is from the impact on households' total crop portfolio rather than income from legume sales alone.

Table 5: Impact of intervention on per capita crop income

	ITT			ATE		
VARIABLES	Eqn1	Eqn2	Eqn3	Eqn1	Eqn2	Eqn3
Video	9.708	5.487	13.038	12.703	9.482	16.323
	(12.836)	(13.289)	(10.974)	(13.853)	(14.487)	(11.694)
Radio	–4.440	–7.739	–4.804	–4.781	–9.494	–4.499
	(11.990)	(11.377)	(9.487)	(12.454)	(11.985)	(10.009)
Time	–10.337**	–10.783**	–16.820**	–10.817**	–11.248**	–17.878**
	(4.759)	(4.778)	(7.201)	(5.095)	(5.116)	(7.829)
Impact:						
Video vs. Control	30.221**	30.811**	26.037**	32.081**	32.675**	27.413**
	(11.905)	(11.914)	(11.413)	(12.955)	(12.987)	(12.493)
Radio vs. Control	–9.280	–8.416	–5.635	–11.095	–9.834	–8.866
	(10.616)	(–8.416)	(10.824)	(11.1641)	(11.188)	(11.334)
Radio vs. Video	–39.501***	–39.227***	–31.673***	–43.177***	–42.509***	–36.279***
	(12.195)	(12.075)	(12.155)	(13.646)	(13.498)	(13.603)
Mean for control group		88.61			86.84	
Observations	2,252	2,252	2,252	2,072	2,072	2,072

Note: Cluster (village-level) robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

As we had noted earlier, the video demonstrations, which also emphasized good agronomic practices, had an impact on farmers' production beyond the legume crops. We also see that whereas the radio listening clubs had no impact on crop income the videos significantly raised mean incomes of participants by about US$32–US$43 over and above the incomes of those who were exposed to the radio.

6. Conclusion

This study has evaluated the impact of two channels of technology information dissemination on key project outcomes. Specifically, this study has tested two (2) broad hypotheses:

1. Video documentaries and radio listening clubs lead to increases in the adoption of the inoculant technology and subsequently increases legume yields.
2. Farm households exposed to the video documentaries and radio listening clubs have higher incomes than those who are not exposed to these channels of information dissemination.

We find evidence in support of these hypotheses, particularly in terms of the impact of video documentaries. Evidence of the impact of radio listening clubs appears weak and insignificant, while video documentaries account for increased likelihood of inoculant adoption, higher legume yields and increased crop incomes.

The north-south divide in Ghana's economic development and welfare in general is well known. In spite of a growing nonfarm sector, agriculture remains the single most important economic activity for the majority of households in these regions. Yet constraints to production and the profitability of farm enterprises remain a major challenge. Any intervention that helps address these constraints and improve the welfare of farm households provide 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 communication boosts adoption. Our results have, however, been tempered by implementation challenges which delayed production and distribution of the inoculants. This challenge in itself is an important lesson for policy and practice, highlighting how project and program impacts could be derailed due to poor implementation.

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 access 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, and indeed the process of scaling up is under way in two other regions from where additional lessons would be learned.

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Appendices

Appendix 1: Balance test and some demographic and indicator summaries

Table A 1: Balance test results for indicators of interest

	Mean				*p*-value		
Indicator	Overall	Control	Video	Radio	Video vs Control	Radio vs Control	Video vs Radio
Outcomes of Interest							
Legume land share	0.34	0.34	0.35	0.35	0.757	0.846	0.904
Improved legume seed (1/0)	0.13	0.14	0.12	0.13	0.653	0.741	0.894
Agrochemicals investment (US$)	54.8	52.9	58.1	53.5	0.634	0.952	0.686
Inoculant use (1/0)	0.01	0.01	0.01	0.01	0.595	0.559	0.995
Legume yield (kg/ha)	950	938	964	951	0.808	0.906	0.905
Crop income per capita (US$)	96.4	97.9	92.8	98.5	0.759	0.970	0.721
Hunger incidence (1/0)	0.34	0.32	0.35	0.34	0.460	0.627	0.870
Food diversity share	0.53	0.55	0.52	0.53	0.262	0.287	0.909
Other observed characteristics							
Female-headed household	0.07	0.07	0.05	0.08	0.542	0.668	0.290
Age of household head	53.8	55.3	59.3	46.7	0.664	0.154	0.072
Household size	7.2	7.0	7.4	7.2	0.266	0.581	0.435
Number of working-age members	3.3	3.2	3.5	3.3	0.069	0.505	0.217
young-age dependency ratio	1.2	1.2	1.1	1.2	0.511	0.553	0.208
Old-age dependency ratio	0.09	0.09	0.09	0.08	0.977	0.615	0.633
Head is literate (1/0)	0.18	0.19	0.20	0.14	0.807	0.091	0.081
Total cultivated area (ha)	3.6	3.3	3.8	3.5	0.421	0.709	0.552
Legume farm size (ha)	1.3	1.1	1.5	1.2	0.352	0.768	0.406
Number of legume crops	1.0	1.0	0.9	1.0	0.389	0.839	0.329
Number of other crops	1.6	1.6	1.6	1.6	0.913	0.694	0.769
Maize producer (1/0)	0.80	0.82	0.79	0.79	0.404	0.438	0.923
Yam producer (1/0)	0.37	0.36	0.36	0.40	0.988	0.622	0.627
Millet producer (1/0)	0.23	0.19	0.25	0.25	0.324	0.375	0.985
Rice producer (1/0)	0.21	0.23	0.21	0.20	0.860	0.705	0.852
Mean distance to plot (km)	2.6	2.6	2.8	2.4	0.477	0.652	0.277
Mean years cultivating plot	11.2	11.6	11.3	10.7	0.722	0.292	0.517
Mineral fertilizer use (1/0)	0.53	0.54	0.58	0.46	0.526	0.206	0.055
Off-farm participation (1/0)	0.52	0.48	0.52	0.56	0.448	0.144	0.454
Livestock commercialization (1/0)	0.50	0.51	0.52	0.48	0.770	0.599	0.397
Asset index	17.99	18.51	19.02	16.39	0.758	0.239	0.155
Owns a financial asset (1/0)	0.27	0.26	0.31	0.25	0.293	0.780	0.203
Received agricultural credit (1/0)	0.21	0.18	0.24	0.23	0.306	0.372	0.877
Visited demonstration plot (1/0)	0.08	0.08	0.08	0.08	0.972	0.794	0.772
Received training on inoculants (1/0)	0.09	0.08	0.08	0.11	0.903	0.473	0.498
Hired labor (1/0)	0.72	0.70	0.76	0.72	0.152	0.620	0.500
Mean staple food price (1/0)	1.40	1.48	1.33	1.37	0.061	0.193	0.689
Community-level variables							
Distance to all-weather road (km)	2.0	2.1	2.0	1.9	0.835	0.791	0.949
Distance to market	6.7	6.9	6.7	6.6	0.915	0.857	0.955
Share of households using inoculant	0.01	0.01	0.01	0.01	0.829	0.559	0.736
Share of households belonging to FBOs	0.30	0.22	0.35	0.33	0.055	0.110	0.795
Lagged legume price (US$/kg)	1.4	1.4	1.3	1.4	0.221	0.803	0.413
Lagged cereal price (US$/kg)	0.9	0.9	0.9	0.9	0.626	0.579	0.260
Lagged yam price (US$/kg)	1.8	1.9	1.8	1.8	0.558	0.809	0.744

Source: Authors' using ISSER Inoculant surveys 2015 & 2017

Appendix 2: Graphical results

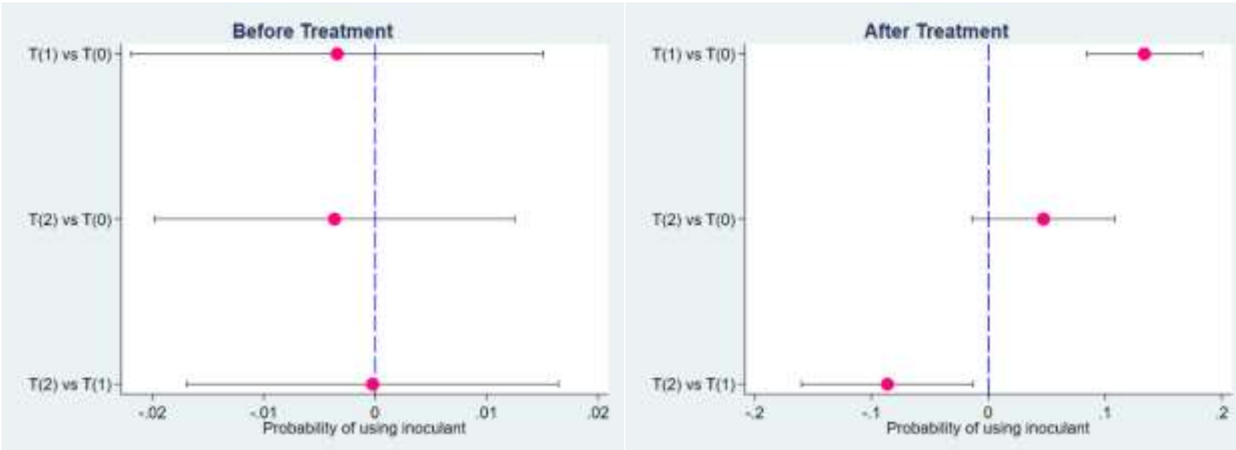

Figure A1. The likelihood of using inoculants is identical for the control and treatment groups before the intervention, but the video documentaries raised adoption significantly, and adoption rate is also higher for the video arm than it is for the radio arm.

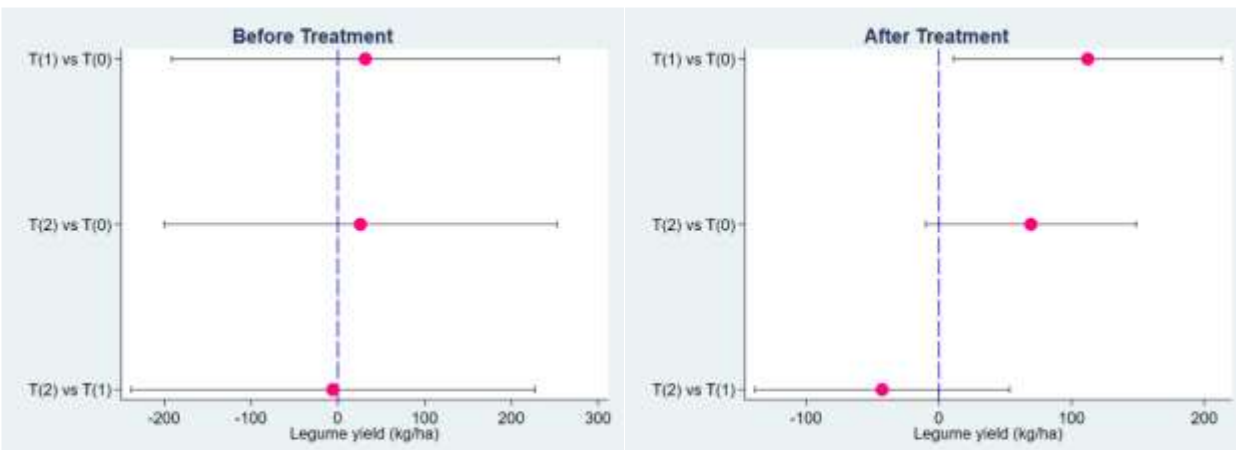

Figure A2. Yields are identical for the control and treatment groups before the intervention, but the video documentary increased yields after treatment; the radio listening clubs did not.

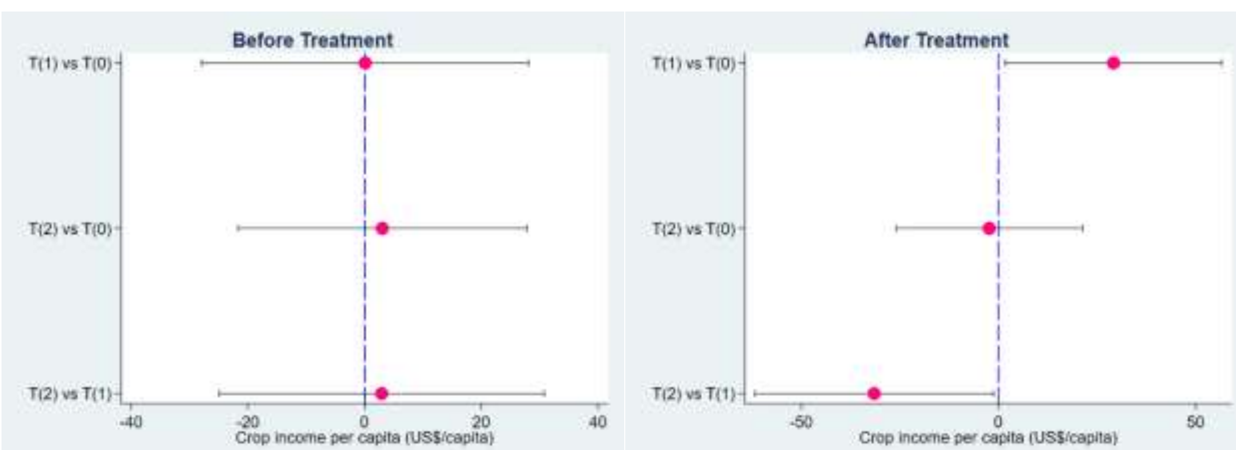

Figure A3. Income is identical for the control and treatment groups before the intervention, but the video documentary increased incomes after treatment; the videos also increased incomes above the radio listening clubs did not.