AN ECONOMIC EVALUATION OF GROUNDNUT RESEARCH IN UGANDA AND GHANA

By

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(Under the direction of Dr. Genti Kostandini)

ABSTRACT

This thesis empirically examines the impact of agricultural groundnut research in Uganda and Ghana performed by the Peanut Collaborative Research Support Program (PCRSP), ICRISAT, NaSARRI, and CSIR-CRI. An ex-post economic surplus model is used to estimate consumer and producer benefits in Uganda from the adoption of improved groundnut varieties. In Ghana, this study evaluates the impact of Farmer Field School (FFS) on improving groundnut production by estimating the average treatment effect through the treatment effects model. Results indicate a positive effect at the national level in Uganda and household level in Ghana.

INDEX WORDS: Agriculture, Evaluation, Impact, Groundnut, Ghana, Uganda, Economic Surplus, Farmer Field School, Treatment Effects, Selection Model

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CHAPTER 1

INTRODUCTION TO PEANUT CRSP RESEARCH IN UGANDA AND GHANA

1.1 Introduction

Increases in agricultural production due to productivity gains didn't occur until the twentieth century. Prior to that time, increases in production rose only from an increase in the area harvested (Ruttan 2002). Over time, continuous farming without development and proper technical practices will decrease yield due to the diminishing level of nutrients from overuse. Although, increases in productivity began 100 years ago, developing countries are just now beginning to take advantage of the new, science-based agricultural development (Ruttan 2002).

Groundnuts (also known as peanuts) are seeds from *Arachis hypogaea* and are a part of the legume family. Groundnuts are grown throughout the world and are a popular crop in tropical and sub-tropical developing countries. Groundnuts are an important crop throughout Sub-Saharan Africa (SSA) which comprises 40% of the world's groundnut harvested area, but only contributes 26% of the world's groundnut production (ICRISAT 2012). Groundnuts are a versatile crop that can be consumed raw or cooked and can be used to make oil. It serves as a nutritious component of diets in developing countries and as a cash crop to provide income for developing country farmers. A variety of pests and diseases have hindered groundnut agriculture worldwide, which has spurred groundnut agricultural research.

Peanut Collaborate Research Support Program (PCRSP) aims to increase groundnut production through biological and mechanical agricultural development, combating constraints of pests, droughts, and diseases through increasing agricultural productivity. Peanut CRSP began in 1982 by the United States Agency of International Development (USAID) in order to advance the goal of helping foreign farmers with groundnut agriculture. The program currently involves 13 universities and 11 nations that aim to promote and enhance groundnut agriculture. The collaboration's work is split into three phases: First, from 1982-1996, projects focused on capacity development through production and processing issues. Second, from 1996 to 2007, the collaboration focused on aflatoxins, production efficiency, socioeconomic factors, and post harvest utilization. Third, from 2007 to the present, the collaboration increased its focus around a value chain approach.

Peanut CRSP also benefits US agriculture, because the research conducted pertains to global constraints. For example, the research on virus resistance has allowed Georgia scientists to prevent viruses from spreading in the US peanut market. As agricultural research and development grows worldwide it is important to assess research benefits in order to better allocate resources. This study estimates the benefits from research and dissemination of improved groundnut varieties in Uganda and Farmer Field Schools (FFS) in Ghana.

1.1.1 Peanut CRSP Uganda History

Peanut CRSP has worked in Uganda since 2001, with several projects each acting to achieve the Peanut CRSP goals in different capacities. Groundnuts are an important part of the Ugandan diet, which provides opportunities for farmers to grow a cash crop and consumers to have a nutritious source of food. Most of the groundnuts produced in Uganda are consumed within the country and their value has increased over the years as their nutrition has become better known (Busolo-Bulafu and Nalyongo 2000). Projects in Uganda have focused on disease resistance and production values to strengthen the groundnut market.

The Groundnut Rosette Disease (GRD) is an endemic that decreases the yield through a loss of crops before harvest. It reduces producer gains through a smaller yield and impacts future decisions for farmers by adding more uncertainty in production. Peanut CRSP works to reduce the impact of GRD by developing and promoting cultivars that are resistant to the disease and training farmers to correctly identify the disease in production.

Ugandan groundnuts have also had problems with high levels of aflatoxin, which are potent mutagenic and carcinogenic materials resulting from fungus in different foods. While many foods contain some level of aflatoxins, groundnuts in Uganda significantly exceed the harmful limit to humans. Peanut CRSP has worked over the past years to reduce the aflatoxin consumption levels from groundnuts by training farmers in identification and cultivation practices to limit the diseases impact. The major effort by Peanut CRSP is increasing adoption of improved varieties to combat production constraints.

1.1.2 Peanut CRSP Ghana History

Initial surveying and documentation by Peanut CRSP in Ghana began in 1997 throughout several groundnut producing regions of the country. At that time, groundnut production was being negatively impacted by several pests and diseases, including millipedes, termites, weeds, Rosette Virus, leaf spot, and aflatoxin. During the initial stage, information on groundnut lines tolerant to diseases and farmer practices in pest management was collected.

In 2002, FFS began in the Ashanti region on integrated pest management techniques. Selected farmers from neighboring districts participated in training of several agricultural practices including site selection, land preparation, seed selection, production practices, plant health and post-harvest handling (Dankyi et al. 2007). Efforts to effect yields and income from the new technologies adopted from the FFS have been reported (Gapasin et al. 2005). Part of the major potential benefits of FFS is the spreading of new information and technology throughout the region by farmer field school participants and extension agents to increase the impact of the FFS.

1.2 Problem Statement

Few quantitative ex-post analyses have been conducted to assess the impact of groundnut research. If the effectiveness and efficiency of the programs can be identified, on both country level and individual household level, along with a suggested focus based on impact, potential future benefits will be significant. The growing trend for accountability of international research programs demands the need for ex-post impact assessments. As a result, this study will provide additional information to policy makers, donors, and researches in developing more effective groundnut development programs in the future.

Agriculture plays a major role in Africa's process of economic growth, achieving high levels of food security and eradicating poverty (McMichael 2009). Agriculture remains a large portion of most African countries' economy as a major source of growth and investment opportunities. The increase in population and food prices, along with the present food insecurity in Africa, necessitate advances in agricultural research.

Groundnuts' contributions to household food levels, nutritional benefits, income generation, and soil fertility make it an important crop to agricultural and economic growth. In the last quarter of the 20th century, diseases and pests lowered groundnut yields, requiring high levels of groundnut research. As the problem persists and a scarcity of research resources exists, it is important to invest and prioritize research that brings the highest level of returns.

1.3 Objective

The objective of this study is to conduct an ex-post impact evaluation of the benefits of improved groundnut varieties and FFS introduced by PCRSP along with The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Council for Scientific and Industrial Research- Crops Research Institute (CSIR-CRI), National Semi Arid Resources Research Institute (NaSARRI), and other institutions that have contributed to Uganda's and Ghana's groundnut sectors. Specifically, this study looks at the benefits to the producers and consumers in Uganda from groundnut research through the introduction of improved drought resistant and rosette resistant groundnut varieties. In Ghana, this study aims to determine the impact of FFSs implementing PCRSP technology on groundnut production at the household level. Finally, it examines the costs associated with these benefits in order to have a better view of what is the return on investments made in groundnut research.

1.4 Hypotheses

There are two main hypotheses in this study:

(i) The adoption of new technologies from groundnut research in Uganda will increase the consumer and producer surplus in Uganda's groundnut sector.

(ii) Farmer Field Schools have a positive impact on groundnut yields for direct participants in the program.

1.5 Methods

To evaluate the impact of groundnut research in Uganda, the economic surplus analysis is used to determine the social gain from adoption of improved varieties. The ex-post analysis evaluates the research induced changes in the groundnut market in Uganda for the last 10 years since Peanut CRSP was present. Since an insignificant amount of groundnuts produced in the country are sold in the export market, the analysis uses a closed economy model. The total impact from farmer adoptions is assessed by the total social gain and broken into benefits to producers and consumers. The national level benefits are then compared to research costs to find the returns on groundnut research investment.

The integrated pest management (IPM) FFS evaluation on groundnut production in Ghana uses data from household surveys collected in 2011. The empirical analysis examines the impact on groundnut yields for farmers who attended FFS programs against a control group of farmers from non-FFS villages and a group of non-FFS participants from FFS villages. The study uses several estimation techniques, focusing on the treatment effects model in order to control for any selection bias or endogeneity that may exist.

1.6 Organization of the Thesis

The thesis is comprised of two separate papers. Each paper includes the literature review, country background, methodology, results, and conclusions. The Uganda national level analysis from groundnut research is presented in Chapter 2. The FFS impact evaluation on groundnut farmers in Ghana is presented in Chapter 3. A final collective discussion of results, final conclusions, and policy/research implications follows in Chapter 4.

CHAPTER 2

AN EX-POST IMPACT ANALYSIS OF IMPROVED GROUNDNUT SEEDS: A CASE STUDY OF UGANDA'S GROUNDNUT SECTOR

2.1 Introduction

Groundnuts play a major role in the economy and livelihoods of smallholder farmers in Uganda. Groundnuts are the second most common legume, behind the common bean, grown in Uganda. Groundnuts are used extensively as an inexpensive source of protein, a substitute to expensive animal meat (Rachier 2005). Groundnut farmers in Uganda are primarily small landowners in rural regions. The most popular region for growing groundnuts is the Eastern Region around Lake Victoria and bordering Kenya.

While groundnut popularity has grown over the past few decades with a constant increase in area harvested; diseases, pests, and droughts have constrained production. The groundnut rosette virus is one of the most destructive diseases to groundnuts in Uganda and throughout the world. The disease consistently lowers the annual yield due to loss of crops and has the potential to eliminate a substantial proportion of a country's groundnut crop, as seen in Zambia in the mid-1990s. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has estimated that the annual economic loss due to the groundnut rosette virus in Sub-Saharan Africa (SSA) is $156 million per year (ICRISAT 2005).

Peanut CRSP and its partners work to develop new technologies that combat against declining yields due to pests and diseases and promote new technology adoption in Uganda. Improved varieties, Serenut 1 and 2, were introduced by the National Semi Arid Resources

Research Institute (NaSARRI) in Uganda during the 1990's prior to Peanut CRSP's presence and at the beginning of the 2000's, Serenut 3 and 4 were released by NaSARRI after the arrival of Peanut CRSP. The development of new technologies is only the beginning of the process of improving Uganda's groundnut market. Availability and adoption constraints must also be analyzed and addressed in order to achieve the potential impact of new technology in agriculture. Even after the creation of improved groundnut varieties, yield rates are still low compared to their potential (Shiferaw et al. 2010).

Existing studies analyzing the adoption impact of agricultural technologies at the national level are normally ex-ante studies that make predictions of future impact (Freeman et al. 2002). While some ex-post studies use alternative methods, to our knowledge, there are no studies on ex-post impacts of improved groundnut varieties in Uganda and few ex-ante studies (e.g. Moyo et al. 2007) using the economic surplus model. A series of ex-post studies on groundnut in Uganda in 2010 and 2011 were released using different empirical methods and focusing mainly on the household level using cross sectional data (Kassie, Shiferaw, and Muricho 2010, 2011). This study provides an ex-post examination of groundnut research in Uganda over the past ten years since the arrival of Peanut CRSP. The economic surplus method is applied using field level data from various sources including recent household level data. The overall market impact is compared to the cost of adoption for farmers as well as the cost of research.

The rest of the paper is organized as follows. The second section provides background information on the use of the economic surplus model in impact assessments. Uganda's groundnut market and groundnut research areas prevalent to Uganda are described in section three. Section four describes the methodology and the data needed to complete the model is in section five. The sixth section presents the analytical results from the study. Finally, the seventh section discusses the key findings and policy implications.

2.2 Ex-Post Impact Study Literature Review

Economic surplus models are used to assess the impact of agricultural research on specific crops, regions, and countries. Alston, Pardey, and Norton (1995) provide an extensive examination on the use of the economic surplus model in assessing agricultural research. It is appropriate for both ex-ante and ex-post studies to use the economic surplus model for impact assessment. An ex-ante approach is used when technologies are not currently adopted and the study predicts the impact of research in the future. Ex-post studies, on the other hand, assess the impact of technologies already adopted. Masters et al. (1996) provide a guide on how to accurately use field data in the economic surplus model to measure aggregate social benefits in an ex-post study.

While ex-ante studies are more common, ex-post impact assessments in which actual data are collected tend to be more reliable (Masters et al. 1996). Zegeye, Tesfahun, and Anandajayasekeram (2007) conducted an ex-post study on hybrid maize varieties in Ethiopia. The study found that hybrid maize varieties have a rate of return of 29% and contribute significantly to improvements in institutional capacity and human capacity building. The study also stated that systematic data collection techniques are critical to future ex-post impact assessments on agricultural growth. Franco-Dixon (2009) used the ex-post evaluation method proposed by Masters et al. (1996) to evaluate hybrix5 sweet corn breeding program in Queensland, Australia. The study found that the period of investment from 1995-2006 on sweet corn research provided producer benefits of six million dollars in present value that were four times greater than the amount of research. While the model calculated benefits through 2006, the study continued to estimate impacts through 2012.

A few ex-post studies were released in 2010 and 2011 presenting the adoption and impact of improved groundnut varieties in Uganda on the household level (Kassie, Shiferaw, and Muricho 2010 and 2011; Shiferaw et al. 2010). These papers used a 2006 household level data survey to provide cross-sectional analysis of adoption at the household level. The studies used both semi-parametric methods in propensity score matching techniques and parametric methods in ordinary least squares to estimate the impact of adoption on household income levels and poverty rates. The studies found that adoption of improved varieties resulted in an increase in crop income for groundnuts from US$169 to US$198 per hectare (Kassie, Shiferaw, and Muricho 2011).

Norton et al. (1987) used the economic surplus model to estimate the impact of agricultural research and extension (ARE) programs in Peru. The study used data on rice, corn, wheat, potatoes, and beans to examine the changes in supply shifts over time. The impact assessment from the study was then used to evaluate the government’s pricing policies on agricultural research. The study concluded that the magnitude of benefits to consumers and producers depended upon the crop’s elasticities of demand. The higher the elasticity, the more beneficial the research was to producers.

Three ex-ante studies used the economic surplus model to predict the impact of groundnut technology in the groundnut sector, one for Uganda and two for Senegal (Moyo et al. 2007; Soufi 2001; Boakye-Yiadom 2003). Moyo et al. (2007) used the economic surplus model to predict impacts of agricultural research on groundnuts in Uganda and its effect on national poverty levels. Moyo et al. (2007) estimated that development from research on the Rosette

Virus resistant varieties of groundnuts in Uganda will result in a 1.5% decline in the poverty rate based on a maximum adoption rate of 50%. Moyo et al. (2007) predict US$36 to US$60 million added to Uganda's groundnut sector in the Eastern region over a 15 year period depending on parameters in the sensitivity analysis. This is an estimate covering only 30% of the country's groundnut sector in the Eastern region. Soufi (2001) used an aggregated and disaggregated market case to compare the impact of a drought tolerant groundnut variety in the market and found the internal rate of return (IRR) to vary between 40 to 60%. Boakye-Yiadom (2003) uses the model to assess the impact of the Centre de Coopération International en Recherché Agronomique pour le Développements (CIRAD) aflatoxin program in Senegal's open confectionery groundnut sector. The latter study found that aflatoxin-reducing programs result in a net gain for the sector between US$0.56 million and US$4.25 million, depending on its assumptions.

2.3 Groundnuts in Uganda

Groundnuts are the second most common legume grown in Uganda. Their history of being grown in Uganda dates back to the mid-1800's when the crop was introduced by the Portuguese to East Africa (Busolo-Fulafu 1990). The crop's popularity among small-scale farmers in Uganda is a result of minimum input requirements and its benefits to soil fertility (Okello, Biruma, and Deom 2010).

Over the last quarter of the 20th century, groundnut yield declined to 60% of peak yield (Laker-Ojok 1994). Uganda experienced a decline in groundnut yields, while at the same time, area harvested for groundnuts continued to grow. Low groundnut yields throughout sub-Saharan Africa are common due to a variety of abiotic, biotic and poor management constraints. Abiotic stresses include climatic issues, soil fertility and soil structure. Biotic factors include diseases, such as Rosette, leaf spot, and aflatoxin, nematodes, and insects. Poor management generally consists of low input use with one the largest impacts from the lack or improper use of fertilizer (Morris et al. 2007). With the increase in popularity and the decrease in yields, there is a great need for research on groundnut production. Peanut CRSP and partner organizations' research focus on these varieties of issues to improve groundnut agriculture and the livelihoods of groundnut farmers.

2.3.1 Groundnut Production in Uganda

Groundnuts remain an important crop to Uganda's agriculture. The World Bank classifies Uganda as an agricultural-based country, signifying the importance of agriculture to the country's economy. Uganda increased their groundnut production from 158,000 metric tons in 1990 to 197,000 metric tons in 2010. However, while overall production increased for groundnuts, the yield decreased significantly over time. The major decrease in yield occurred between 1990 and 1996 before the presence of Peanut CRSP and other research partners in Uganda. As indicated from table 2.1, groundnut yields decreased by 17% from 1990 until 2001. This period of decline was followed by a period of high agricultural research and a resurgence of groundnut yields. Despite the recent growth of yields, the current yield is low compared to the potential (Kassie, Shiferaw, and Muricho 2010).

Groundnuts grown in Uganda are primarily consumed within Uganda's borders. An insignificant amount is exported, with most years having no export market. However, there is an increasing export market for Uganda's groundnut sector. The total exported is still small, but at its growth levels it should be monitored for any significant impacts in later studies. Therefore, a closed market model is implemented in the methodology of this study.

Table 2.1 Uganda's Groundnut Production

Year	Production (MT)	Yield (Hg/Ha)	Year	Production (MT)	Yield (Hg/Ha)
1990	158,000	8494	2001	146,000	7019
1991	144,000	8000	2002	148,000	7014
1992	147,000	7989	2003	130,000	6018
1993	153,000	8181	2004	155,000	7013
1994	142,000	7513	2005	159,000	7066
1995	144,000	7500	2006	154,000	6695
1996	125,000	6410	2007	165,000	7021
1997	134,000	6802	2008	173,000	7090
1998	140,000	7000	2009	185,000	7312
1999	137,000	6989	2010	197,000	7138
2000	139,000	6984			

Source: Food and Agricultural Organization (FAO), 2012.

2.3.2 Research Areas

Abiotic, biotic and management constraints led to the wave of groundnut research on improved varieties in Uganda, with the largest constraint being Groundnut Rosette Disease (GRD). The groundnut rosette disease is the most common disease for groundnuts. There are two forms of the diseases--chlorotic and green rosette (Bock, Murant, and Rajeshwari 1990). Both forms of the disease cause the plants to be stunted, with shortened internodes. The difference between the two is identified by the color of the leaves, a bright yellow for chlorotic and a dark green for the green virus. The disease results in a loss of yields, with the severity depending on the stage of infection (Olorunju et al. 1991). If the plant is infected at the early stages of the life cycle, then 100% yield loss is possible; but, if infection occurs later in the life cycle, only a 5-30% yield loss is likely. Parts of Peanut CRSP's work in Uganda focused on GRD-resistant varieties and educating farmers about proper practices for disease management.

Another major constraint is aflatoxins, carcinogenic mycotoxins produced by a fungus that contaminates groundnuts. The WHO and FAO set regulatory standards for how much aflatoxin can be present in groundnuts before being harmful to humans. In Uganda, excessive amounts of aflatoxin are present in the groundnut market which can lead to serious health effects. High levels of aflatoxin were found in 50-80% of groundnuts samples taken by a Peanut CRSP project. The issue of aflatoxin contamination in groundnuts is connected to production and post harvest handling. By improving storage practices and technology losses, aflatoxin can be reduced by as much as 50% (Gapasin et al. 2005).

A variety of pests threaten groundnut yields in both pre-harvest and post-harvest times. Numerous pests are common to affect groundnuts, including termites, beetles, mealworms, and groundnut leaf miner. Groundnut leaf miner is a common pest in the Kumi and Soroti districts of Uganda (Okello, Biruma, and Deom 2010). The leaf miner population increases in the rainy season during production and typically infects the plant during the pod-filling stage creating problems for immature plants. Pests, typically beetles, also create problems for groundnut production post harvest. There are more than 70 insects known to infect stored groundnuts (Amin and Mohammed 1980). The result is a direct loss in farmer output and an indirect loss by reducing the quality of groundnut produced. The presence of pests created the need for integrated pest management research including insecticides, pest identification, and proper storage management. Implementation of integrated pest management (IPM) technologies as well as non-chemical methods can reduce the effect of pests on groundnut production (Kasenge, Taylor, and Bonabana-Wabbi 2006).

Drought is another problem that threatens groundnut production. Drought varies in timing and intensity which makes it difficult to predict or control against. Drought is a threat to agricultural production for most crops worldwide (Altman 1999). Since the threat of a drought is usually unknown when planting season begins, research is needed to develop groundnut varieties that will produce both when rain is present and when a drought is present (Okello, Biruma, and Deom, 2010).

Fertilizer use for groundnuts in Uganda, as well other parts in Sub-Saharan Africa, is low and when it is used, it is often used in incorrect proportions (Morris et al. 2007). This is caused by both demand and supply side factors in the fertilizer market. There is a low demand due to price and yield variations which reduces the perceived incentives for farmers. The lack of supply of fertilizer exists because of logistical costs and constraints due to poor infrastructure.

2.3.3 Groundnut Varieties in Uganda

Five major improved groundnut varieties are available to Ugandan groundnut farmers at the time of this assessment: Igola, Serenut 1, Serenut 2, Serenut 3, and Serenut 4. Major differences among these varieties are their type, resistance levels, yield potential, coloration, maturation range, taste, and oil content. While each factor contributes to adoption levels, the resistant levels and yield potential are important in assessing the impact from adopting new varieties. Serenut 2 is the most popular of the improved varieties, according to this study's household data and data from ICRISAT (Shiferaw et al. 2010). Serenut 2 has a yield potential up to 3500kg/ha, is moderately tolerant of drought, and is highly resistant to the rosette virus, which is a major improvement from the Serenut 1 variety. While Serenut 3, the next popular improved variety in Uganda, has a lower potential yield than Serenut 2, but it is resistant to rosette and tolerant to drought (Shiferaw et al. 2010).

NaSARRI released Igola, Serenut 1 and 2 were released before the presence of Peanut CRSP during the 1990's and Serenut 3 and 4 were released in 2002. The availability and knowledge of all improved varieties differs throughout the country, but the Banana-Cotton and

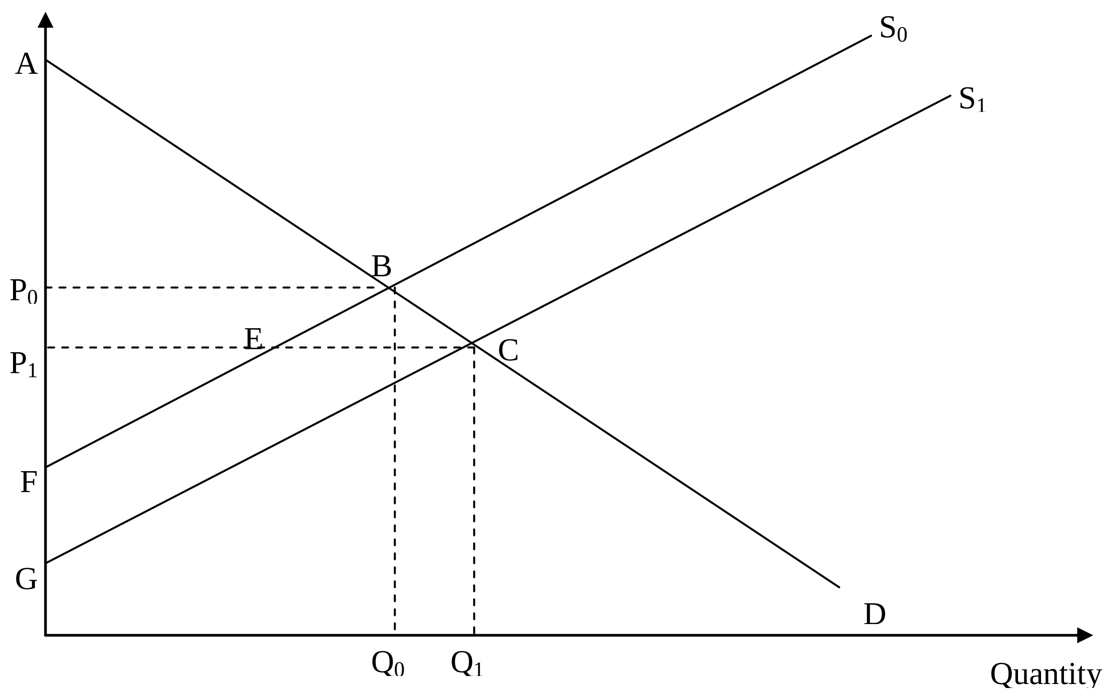
Montane regions have the most districts that are growing improved varieties (Shiferaw et al. 2010). Peanut CRSP adds to the generation of improved varieties through plant breeding and production values. Focus areas include reduction in adoption constraints including availability, farmer knowledge of technology, and farmer capital requirements. With the creation of improved varieties, emphasis needs to be added to these alternative adoption constraints in order to improve adoption levels (Shiferaw et al. 2010).

2.4 Methodology: Basic Economic Surplus Model

This study uses the economic surplus model to assess the economic impact of Peanut CRSP and other groundnut research projects in Uganda. The model estimates the change in consumer and producer surplus that is directly related to the adoption of improved varieties, thus the total benefit to consumers and producers and total social gains. The economic benefits from the technological innovations are analyzed through the economic differences in the two scenarios: one "with" the adoption of new technology and one "without" the adoption of new technology.

A closed economy is appropriate in this economic surplus model, because Uganda has a limited groundnut export market, with some years being non-existent. With almost the entire groundnut production in Uganda sold within the country the world price and supply minimally affects the surplus analysis in Uganda, which is illustrated in figure 2.1. Line D in figure 2.1 represents the demand curve for groundnuts in Uganda, while S_0 and S_1 represent the supply curves "without" and "with" research, respectively. S_0 represents the market supply in the absence of groundnut research and the curve shifts downward and to the right to S_1 when groundnut research is present. The shift in the supply curve comes from the impact on groundnut producers that adopt improved varieties and experience higher yields. With research and technological innovation production costs are expected to decline and/or yields increase for the same cost expenditure. Thus, there is a per unit cost reduction that will change producer surplus by the difference of P_0BEP_1 and FECG. The area of rectangle P_0BEP_1 will be transferred over to consumers in the form of lower market prices but the producers will gain FECG due to a larger quantity produced at a lower cost. The change in producer surplus is ambiguous and is determined by the elasticity of the demand curve. With a more elastic demand curve, the increase in quantity demand for groundnuts exceeds the lower price and producers benefit from adopting new technology. If an inelastic demand curve exists in the market, then producers lose by adopting new technology as the lower price effect outweighs the benefit of a greater quantity at a lower cost.

Figure 2.1: Basic Economic Surplus Model



Consumers always benefit from new research. Since the cost of research is not normally born by farmers, a price increase due to research costs does not occur. In Uganda, USAID and other non-profit research institutions fund a majority of the groundnut research. This cost is born by governments, donations, and grants. The farmer is not paying for research nor is the farmer paying to compensate for the research. Generally, the market price of the new technology does not account for the research expenses. Therefore, farmers don't feel a price squeeze and thus do not raise prices from research. Farmers will only feel the cost of adopting new technologies as a result higher input costs. In this case, consumers gain what the producers lost from lower prices, area $P_0BEP_{1,}$ plus the area of triangle BCE from the new quantity at the new price. The more inelastic the demand curve the greater the benefit to consumers (Alston, Pardey, and Norton 1995). With agricultural research on staple crops, crops that are consumed regularly and make up a significant portion of the local diet, the market usually experiences a relatively inelastic demand curve. Thus, generally in a closed economy, the consumers are expected to gain more than producers from research on staple crops.

The total change in surplus resulting from research is the sum of change in producer surplus and consumer surplus. The total surplus is equal to the entire social gain from the adoption of new technology. Changes in producer, consumer, and total surplus are:

$$\text{Change in consumer surplus } (\Delta CS) = P_0BCP_1$$

$$\text{Change in producer surplus } (\Delta PS) = FECG\text{-}P_0BEP_1$$

$$\text{Change in total surplus } (\Delta TS) = FBCG$$

In an ex-post study the actual change in total surplus comes from two shifts in the supply curve which ends up at S_1. A horizontal shift of S_0 from the increase in groundnut yield due to research shifts S_0 by more than the observed shift of line EC. The horizontal shift is then being partly negated by a vertical shift in the supply curve due to the increased costs to farmers. In order for research to take effect in the market, overall costs normally increase for farmers as requirements of new seed and increased labor arise. Thus, this ex-post study examines the horizontal and vertical shifts in the supply curve to determine the change in total surplus (Masters et al. 1996).

There are several limitations to the economic surplus analysis that must be kept in mind during the analysis. First, the supply and demand elasticities are assumed to be constant. Normally, for linear supply and demand curves, the elasticities would change as the equilibrium moves along the curve. Another criticism is the lack of consideration towards other products and commodities. Alston, Pardey, and Norton (1995) identifies that the lack of income effect from price change in the economic surplus model is a limitation compared to an equivalent variation (EV) method. The paper states that the lack of income effect is likely to have less of an impact than possible incorrect assumptions about the elasticities. A sensitivity analysis is provided at the end of the paper to assist in alternative possible elasticities.

2.4.1 With and Without Research Model

The purpose of the economic surplus model is to assess the impact of research and provide "with research" and "without research" scenarios (Alston, Pardey, and Norton 1995). This is not the same as a "before and after" approach. Over time, crop yields may decline in many settings due to a depletion of nutrients. Also, several exogenous factors will impact price each year possibly forcing the market price in the opposite direction than the research impact. Accounting for this natural effect would not be captured in before/after models. The with/without research model, in this study, aims to evaluate each year's impact of research compared to the same time frame as if research were not present. Therefore, actual data from each year beginning with the initial year is collected. Each year is modeled “with research” and the difference “without research” is calculated using the data on adoption, change in yield, and changes in input costs. This objective is increasingly important while using time series data and non-research changes have not been controlled (Alston, Pardey, and Norton 1995; Masters et al. 1996).

2.4.2 Empirical Model

This study uses several assumptions in this model in order to assess the impact of the new technology. First, Uganda’s groundnut market is considered a closed market and the analysis calculates no impacts from world markets, since there is an insignificant amount of groundnuts exported from Uganda. In the past 15 years, little shelled, unshelled groundnuts and groundnut oil have been sold in the world market. Significant barriers to trade and a lack of market access prevent any significant, if any, impact to producers in the groundnut export market. Therefore, a closed market is assumed, where the prices and quantities are determined within the groundnut market in Uganda.

Second, Uganda’s groundnut market faces a downward sloping demand curve. The assumption of a negative demand curve means that as the price of groundnuts decreases, the quantity demanded increase.

Third, Uganda’s groundnut market faces an upward sloping supply curve. It is assumed that the increase in groundnut prices provides incentives to groundnut farmers to begin to produce more groundnuts. The opposite is also true, as groundnut prices decline farmers have less incentive to produce groundnuts. Farmers will respond by either devoting less land to groundnuts or spend less money on inputs which would decrease yield.

Also, the groundnut demand and supply curves are linear. The assumption of linear demand and supply curves allows for simpler equations when calculating economic surplus. With a linear supply curve the shift that results from research will result in a parallel shift in the supply curve (Alston, Pardey, and Norton 1995).

Finally, it is assumed that the demand curve is unaffected by groundnut research in Uganda. The impact of groundnut research has no effect on the demand for groundnuts within Uganda. In other words, research on groundnut production does not cause consumers to want to buy more or less groundnuts at any given price. It will only affect the supply side and how much farmers will produce at any given price.

2.4.3 Supply and Demand Curves

The equations used for the ex-post economic surplus model here are similar to ex-post impact assessments from agricultural research used by Masters et al. (1996). This study derives its equations and formulations based on Alston, Pardey, and Norton (1995). The economic surplus approach to impact analysis begins with the linear supply and demand curves: Production levels for groundnuts are dependent on the level of inputs supplied by the farmer. These inputs consist of land, labor, seed, fertilizer, manure, and, in some scenarios, pesticides. Each input possesses a cost to the farmer, but impact the level of production. By increasing inputs the level of production goes up, but it comes at a cost to the farmer. As product price increases, farmer input revenue increases, allowing production to increase. Therefore, the supply curve in its linear form can be expressed as:

(2.1) $P_s = a_s + b_s Q_s$

Where P_s is the market price of groundnuts, Q_s is the quantity supplied, a_s is the intercept and b_s is the slope of the supply curve. The demand curve is also linear and downward sloping so that the quantity consumed is inversely related to price. The higher the consumer price, the fewer consumers are willing to consume. Consumers will substitute alternative commodities to offset the change in prices. Therefore, the demand curve is as follows:

(2.2) $P_d = a_d - b_d Q_d$

Where P_d is the demand price and Q_d is the quantity demand and a_d is the intercept of the linear demand curve and b_d is the slope. The supply and demand curves are the basis for the economic surplus model.

2.4.4 K-Shift

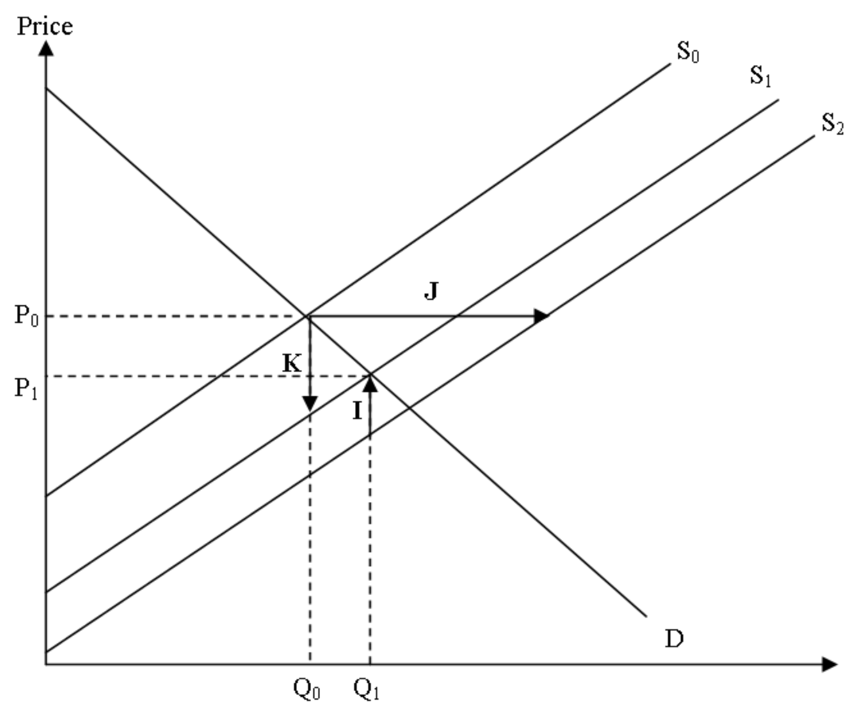
The K-Shift (figure 2.2) in the economic surplus model measures the shift in the supply curve that is a result of research in the form of adoption of new technology or farm practices. It is expected to shift the supply curve down resulting in a higher equilibrium quantity and lower equilibrium price. It is reflective of the changes in yields and costs per unit as a result of the specific groundnut research. It is important to disaggregate the estimates from each form of technology or information in order to prevent a spillover effect from other research areas that could cause an overestimate of the K-Shift (Maredia, Byerlee, and Anderson 2000).

The K-Shift is calculated by first deriving the increased quantities and the increased costs from adopting the new technology. The shift due to quantity is greater than the K-shift used in the model because of the reduction from adoption costs (Masters et al. 1996). In order for farmers to obtain the benefits of improved seed varieties, Serenut 3 and 4, they must purchase the seed on the market. The K-shift is viewed as the most important contribution to calculating the social gain.

2.4.5 Social Gain

In order to calculate the economic surplus and social gain from groundnut research, each year's equilibrium point needs to be derived from actual quantity and price. Each year there is a specific quantity, with supply equal to demand at the equilibrium point, and price. This information, along with information on elasticities, adoption rates, yield changes, and cost changes is used to calculate the shifts of the supply curve and derive the social benefit from the research.

Figure 2.2. Shifts Due to Adoption



In order to conduct an ex-post impact analysis, the counterfactual "without research" scenario needs to be estimated and compared to the observed scenario, since the technology is already present at the time of analysis. In figure 2.2, S_0 represents the supply curve without research, S_1 represents the supply curve with research which is observed, and S_2 represents the supply curve if the new technology could be adopted at no extra cost to the farmer.

To determine the social gain from research, the supply shift (K) must be estimated along with the change in quantity, ΔQ (observed minus estimated), which allows the calculation of the parallelogram that represents social benefit. The change in quantity is not just the observed change from year to year, but the change each year associated with the adoption of the new technology. As in Masters et al. (1996), the social gain formula in an ex-post analysis can be calculated as follows:

(2.3) $SG=KQ-.5K\Delta Q$

The parameters K and ΔQ are not observed directly. The K shift is estimated as:

(2.4) $K= J/(\varepsilon Q/P)-I$

where J is the production increase, ε is the elasticity of supply, and I is the adoption costs.

A proportional k, the net reduction in costs in production of groundnuts as a proportion of output price is represented by dividing the K shift by price:

(2.5) $k=K/P$

The elasticity of supply, ε, joins the other two effects that occur in figure 2.2 in order to determine the K shift: production increases (J) and adoption costs (I). The horizontal shift, J, is the total increase in production from the adoption of the new technology and is represented by:

(2.6) $J= \Delta Y \times A \times AH$

where ΔY is the yield increase from adoption, A is the actual adoption rate of the new technology among farmers, and AH is the total harvested groundnut area. The increase in yield change is calculated by dividing the current yield by the percent change in yield due to adoption per hectare, then subtracting it from the current yield.

The cost of adoption is represented by I, which is the increase in per-unit costs that is required to attain the increase in production. The market price of groundnut seeds for improved varieties in Uganda is greater than local varieties leading to an increase in production costs. The adoption costs can be calculated as:

(2.7) $I = (\Delta C \times A)/Y$

Where ΔC is the cost per-unit of area from adoption and Y is the overall average yield. In order to keep all units consistent to avoid errors, each formula should contain values in kilograms and hectares, depending on the variable.

The change in quantity, ΔQ, is the change in quantity from adopting the new technology. With research, quantity increases each year as a result of increase yields, all else equal. Therefore, there should be a positive change in quantity which is calculated by subtracting the counterfactual estimate of quantity each year from the observed quantity to illustrate the difference from the "without research" curve, S_0. The change in quantity (ΔQ) is represented as follows:

(2.8) $\Delta Q = Q\varepsilon\eta k/(\varepsilon+\eta)$

Both the elasticity of demand, η, and elasticity of supply (ε) are joined with the observed quantity from each year and the proportionate supply shift, k.

Equations (2.1) through (2.8) are used to generate the net economic benefits in terms of the stated currency. The net gain from research can then be calculated by subtracting the research and extension costs from the social benefits.

2.5 Uganda Groundnut Data

The data required to calculate the social gain from the previous section were collected through national household level surveys, macroeconomic databases, and research and evaluation reports. Each of these sources provides market, agronomic and economic data in order to estimate each parameter. The data collection is the most important aspect in producing an adequate impact analysis of agricultural research. The main household survey data was collected by the University of Georgia and Virginia Tech in 2011 providing information on adoption rates and yield changes. Other past household surveys are used to strengthen and increase the quality of ex-post data.

2.5.1 Quantities, Yield, Prices

The quantities of groundnuts grown in Uganda were found from FAOstat database (FAOstat 2012). The production quantity of groundnuts in Uganda increased over time during the last two decades. During the 1990's the yield decreased significantly, due to numerous constraints, but slowly increased during the last decade. Historical nominal price data for the Ugandan groundnut market fluctuates over time with an upward trend. A large spike at the end of the decade is from a global pattern of high food prices. The price data came from FoodNet weekly prices series data which was averaged to get yearly statistics. The real prices collected from FoodNet were adjusted using the Consumer Food Price Index (CPI) for Uganda in order to get real prices (table 2.2). After prices were adjusted for inflation, prices declined during the last few years of the decade during the large inflation period. Therefore, the social benefits are not inflated from the rise in global food prices at the end of the decade.

Table 2.2 Price and Quantity of Groundnuts in Uganda

Year	Real Price ($/tonne)	Total Production (tonnes)
2001	550.85	146000
2002	500.84	148000
2003	524.32	130000
2004	607.68	155000
2005	545.08	159000
2006	529.16	154000
2007	599.53	165000
2008	547.36	173000
2009	437.81	185000
2010	428.79	197000

Source: FAOstat 2012

2.5.2 Demand and Supply Elasticities

The demand and supply elasticities play a large role in calculating the k-shift variable. Several studies looked at different levels of elasticity for a range of crops. In the long run, supply elasticities are normally higher in the range of 0.3 to 1.2 (Rao 1989). A higher supply elasticity is expected in the long run, because more time allows farmers to make decisions about future planting seasons and which crops to plant. This study uses long run elasticity, because of the time gap from the beginning of groundnut research in Uganda to the present time. The theory of groundnuts having a high elasticity is confirmed, because groundnuts comprise a small amount of land and require few specialized factors (Alston, Pardey, and Norton 1995). The supply elasticity of one is therefore used in agreement of economic theory and past studies (Moyo et al. 2007).

The demand elasticities for staple crops with high cultural and diet significance tend to be lower than supply elasticities. The demand elasticity is also low because the Ugandan groundnut market is a closed market. In this study, demand elasticity for the domestic market is 0.50 (Moyo et al. 2007). When applying the economic surplus model, the elasticity of demand influences the outcome less than other parameters (Masters et al. 1996). The consumption of groundnuts by the farmer limits the effect of elasticity of demand. The main importance of elasticity is the distribution of gains to producers and consumers and not the overall contribution to the social gain. As mentioned above, if there is low or highly inelastic demand elasticity, then the adoption might actually harm producers in some situations.

2.5.3 Adoption Rate

The adoption rate has steadily increased since the inception of Peanut CRSP in Uganda. In an ex-ante study, Moyo et al. (2007), projected that adoption rates would increase until around 2012/2013 then begin to level off. Using data from multiple household surveys, the adoption rate was calculated using a linear approximation. Uganda national household surveys in 2002 and 2006 found the adoption of improved groundnut varieties to be 4.1% in 2001 and 11% in 2005. This result is consistent with household surveys by the National Agricultural Advisory Services (NAADS) (UNHS 2001/02 and 2005/06; Benin et al. 2007). Using the 2011 household survey data from this project, we found the adoption rate increase to 50% in 2011, which is consistent with other household survey results (Shiferaw et al. 2010; Kassie, Shiferaw, and Murcho 2011). The large increase in adoption since 2005 may be attributed to the push for improved varieties by PCRSP, NAADS, ICRISAT, and NaSARRI in Uganda.

A linear adoption profile was constructed by using the survey results. This approximation has been widely used in economic surplus and other empirical studies (Alston, Pardey, and Norton 1995). An overestimate of adoption is commonly used with the assumption of one groundnut variety used per household instead of hectares of improved varieties planted.

Oftentimes farmers plant both improved varieties and local for a variety of constraint reasons which can lower overall adoption estimates and is observed in this study (Benin 2007).

In a study by ICRISAT in 2010, many factors were found to affect the adoption levels (Shiferaw et al. 2010). Seed availability, lack of credit, lack of information, and no desire to adopt led to some farmers' non-adoption of new varieties. The biggest constraint on farmers was the availability of new seeds with the second largest being a desire to not want to adopt. Since farmer livelihoods in these small landholder farms depend on yearly yields, skepticism plays a major role in adoption decision. Farmers see change as a risky behavior even if information is presented to show the benefits of adoption. When deciding which seeds to plant, the 2011 household surveys revealed that 64% of farmers consider potential yields as a determent and only 48% say that availability is a factor in deciding what groundnut seeds to plant.

2.5.4 Changes in Cost and Yield

Data on the changes in cost due to adoption of new technology are adapted from data from Moyo et al. (2007) and FAOstat. The primary cost of adoption comes from purchasing new seed. The cost of Serenut 3 and 4 in Uganda are $2.20 per kg more than local varieties which are sold at .80$/kg (Moyo et al. 2007). Serenut 1 and 2 have a lower market cost which is expected because of the longer availability in the market. Over time the seed cost of Serenut 3 and 4 are expected to decrease in the market place. The amount of seed required for each hectare is calculated by dividing total seed for groundnuts in Uganda by the area harvested. The increases in production also increase the need for labor costs for harvesting, drying, and shelling. The increase in labor comes from both hired labor and family labor (Kraybill and Kidoido 2009). Although there is an increase in costs of inputs for farmers to adopt the new technology, the resulting yield increase at the producer prices is expected to far outweigh the costs. Despite a positive return on additional investments, through adopting the new technology, adoption rates continue to be relatively low, partially due to the relatively high initial cost burden placed on the farmers.

Experimental results provide potential yields up to 3500kg/ha for improved groundnuts, but actual yields are only a fraction of their potential (Shiferaw et al. 2010). Weather, lack of rainfall, pests, and poor management techniques, such as the lack of fertilizer use, diminish returns on improved groundnuts. Even after disease or drought varieties are used, fertilizer and pests contribute to a lower yield. Therefore, a focus on crop management on these constraints needs to accompany the spread of improved varieties to reach the full potential of groundnut yields and maximize the social gain to the groundnut sector in Uganda. Also, most farmers do not meet the suggested input use due to financial constraints (Kraybill and Kidoido 2009).

Experimental results indicate that improved varieties, on average, yield 30-40% higher groundnut production than local varieties. The most common local variety, red beauty, yields 1900-2500kg/ha in experimental stations, while the improved varieties yield 2500-3500kg/ha (Okello, Biruma, and Deom 2010; NIDA n.d.). The largest and most comprehensive household data on improved groundnut production was conducted in 2006 by ICRISAT from 900 Ugandan households. The studies find that adopting the new groundnut varieties in Uganda results in a yield increase of 34% (Shiferaw et al. 2010; Kassie, Shiferaw, and Muricho 2011). This result is similar to initial field trial data with variations arising with circumstantial agronomic practices (Chancellor 2002). The highest improved seed yield is Serenut 2 and the lowest is Serenut 4, which provides only a small advantage compared to local varieties which explains its low adoption rate. This increase is an average from the households that adopted the new varieties compared to additional varieties. Since the data collected are from the field and ex-post, it is appropriate to drop the probability of change used by Alston, Pardey, and Norton (1995) as when conducting ex-ante studies.

2.5.5 Research Costs

Peanut CRSP's groundnut research in Uganda was funded in two phases. Prior to 2007, PCRSP spent $174,603 on its research in Uganda and an additional $487,073 since 2007. While this is the actual research funding from PCRSP, it does not capture the entire costs to produce the benefits to the groundnut sector. PCRSP has operated since the 1980's and some of the benefits from other projects and countries will spill over into Uganda's research. Three of the current projects in Uganda began in other countries: Senegal and Bulgaria. There will be a transfer of benefits in terms of background research and employee training. Also, other organizations, ICRISAT and NAADS, have conducted groundnut research in Uganda. Therefore, in order to account for the contribution to research form ICRISAT and to cover any transfer of benefit from other PCRSP activities, the research cost are adjusted by 20% (Moyo et al. 2007).

2.6 Results

This section presents and discusses the results of the impact evaluation. Each parameter is calculated with the data collected throughout the study to give a step by step analysis of the benefit from the groundnut research. The overall benefits achieved from Peanut CRSP and other research programs are weighted against the cost of groundnut research.

The production increase due to the adoption of new technologies accounts for the largest effect on social gain. By adopting new technology, field data show a 34% increase in groundnuts

(Shiferaw et al. 2010). This provides an extra 180 kilograms per hectare in which the technology is adopted. The yield increase due to improved seed is then multiplied by the adoption and total area harvested to calculate the production increase, J. As shown in table 2.3, this production increase rose substantially as both the adoption rate and area harvested increased every year since 2001.

Table 2.3. Calculating Production Increase (J)

Year	Improved Seed Yield (kg/ha) (ΔY)	Adoption Rate (%) (A)	Area Harvested (ha) (AH)	Production Increase (J) ($US)	Proportional Production Increase (j)
2001	178.09	0.041	208,000	1,518,786	0.010402985
2002	177.97	0.06	211,000	2,253,064	0.015223881
2003	152.70	0.08	216,000	2,638,579	0.020298507
2004	177.94	0.1	221,000	3,932,514	0.025373134
2005	179.29	0.11	225,000	4,437,343	0.027910448
2006	169.87	0.174	230,000	6,798,323	0.044149254
2007	178.14	0.238	235,000	9,963,637	0.06038806
2008	179.90	0.302	244,000	13,256,141	0.076626866
2009	185.53	0.366	253,000	17,179,555	0.092865672
2010	181.11	0.43	276,000	21,494,542	0.109104478

The additional costs of adopting new varieties in Uganda are primarily the cost of improved variety seeds. There is also an increase in labor costs, but generally family labor is utilized and hired labor is also inexpensive. The fertilizer use in Uganda is low and should be used with and without improved seed adoption. The new pesticides that are required by some improved varieties also increase the cost. Local seeds costs 80 cents per kg and the highest improved varieties, Serenut 3 and 4, cost $3.00 per kg. The older improved varieties, Serenut 1 and 2, cost around $1.50 (Moyo et al. 2007). The decrease in improved seed price over time is expected as improved seed production increases as they become more common in the market. An average of improved seed price was found by popularity and was compared to the local seed prices. The cost of new inputs when adopting the new technology was multiplied by the adoption rate and divided by the total yield to find the input costs per unit hectare for the entire sector each year. Adoption costs for each year are presented in table 2.4.

Table 2.4. Calculating Adoption Costs (I)

Year	Cost of New Inputs ($/ha) (ΔC)	Adoption Rate (A)	Total Yield (kg/ha) (Y)	Input Costs($/kg) (I)	Proportional Adoption Costs (i)
2001	-143.90	0.041	701.9	-0.0084	-0.000015
2002	-145.13	0.060	701.4	-0.0124	-0.000025
2003	-145.06	0.080	601.8	-0.0193	-0.000037
2004	-144.39	0.100	701.3	-0.0240	-0.000034
2005	-144.93	0.110	706.6	-0.0227	-0.000041
2006	-144.87	0.174	669.5	-0.0357	-0.000071
2007	-147.06	0.238	702.1	-0.0523	-0.000083
2008	-146.87	0.302	709	-0.0632	-0.000114
2009	-154.00	0.366	731.2	-0.0795	-0.000176
2010	-142.00	0.430	713.8	-0.0835	-0.000199

After calculating the production increase and adoption costs, we calculated the supply shift. Since benefits from production increase greatly outweigh the adoption costs, a significant supply shift is expected. The overall production increase is converted into a per-hectare figure and then adoption costs are subtracted to the supply shift, K. The proportional supply shift, k, is found by dividing K by the price, as shown in table 2.5.

Table 2.5. Calculating Supply Shift (K)

Year	Production Increase (J)	Adoption Costs (I)	Price (P) ($/tonne)	Total Production (Q) (tonnes)	Supply Shift (K)	Proportional supply shift (k)
2001	1,518,786	-0.0084	550.86	146,000	5,730	0.01042
2002	2,253,064	-0.0124	500.85	148,000	7,625	0.01525
2003	2,638,579	-0.0193	524.32	130,000	10,642	0.02034
2004	3,932,514	-0.0240	607.69	155,000	15,418	0.02541
2005	4,437,343	-0.0227	545.08	159,000	15,212	0.02795
2006	6,798,323	-0.0357	529.16	154,000	23,360	0.04422
2007	9,963,637	-0.0523	599.54	165,000	36,203	0.06047
2008	13,256,141	-0.0632	547.36	173,000	41,942	0.07674
2009	17,179,555	-0.0795	437.82	185,000	40,657	0.09304
2010	21,494,542	-0.0835	428.79	197,000	46,786	0.10930

The effect of the downward supply shift causes a natural increase in quantity supplied, accounted for in J. Since the demand curve is inelastic, part of this increase in quantity is absorbed by a decrease in price. Therefore, the change in equilibrium quantity that is associated with the adoption of improved technologies is less than the observed quantity. In 2003, the change in equilibrium quantity is positive while the observed change is negative. The total production fell by 18,000 tonnes in 2003, but the counterfactual estimate would be a greater reduction without the presence of technology adoption. Therefore, there is still a positive change in quantity due to technology adoption. This is because the observed quantity change is exposed to other exogenous factors that determine quantity. By calculating the change in quantity in table 2.6, the counterfactual "without" research equilibrium is estimated to compare against the observed ex-post data.

Table 2.6. Calculating Change in Quantity (ΔQ)

Year	ΔQ (tonnes)	Total Production (tonnes)	Elasticity of Supply	Elasticity of Demand	Proportionate Supply Shift (k)
2001	507.02	146,000	1	0.5	0.01042
2002	752.27	148,000	1	0.5	0.01525
2003	881.20	130,000	1	0.5	0.02034
2004	1,312.70	155,000	1	0.5	0.02541
2005	1,481.45	159,000	1	0.5	0.02795
2006	2,269.98	154,000	1	0.5	0.04422
2007	3,325.92	165,000	1	0.5	0.06047
2008	4,425.41	173,000	1	0.5	0.07674
2009	5,737.57	185,000	1	0.5	0.09304
2010	7,177.63	197,000	1	0.5	0.10930

All parameters were calculated in tables 2.3-2.6 and are now used to calculate social gains in table 2.7 using equation (2.3). The cumulative gains since Peanut CRSP began in 2001 are $41,296,360. Since the inputs were adjusted to assess the impact of groundnut research only and prices were converted into real terms, the social gain figure is not inflated. This contribution makes up five percent of the overall value of the groundnut sector since 2001.

Table 2.7. Social Gains

Social Gains ($US)	Year	k-Shift	ΔQ (tones)	Price ($/tonne)	Total Production (Q) (tonnes)
836,434	2001	0.01042	507.02	550.86	146,000
1,127,442	2002	0.01525	752.27	500.85	148,000
1,381,400	2003	0.02034	881.20	524.32	130,000
2,382,989	2004	0.02541	1,312.70	607.69	155,000
2,411,247	2005	0.02795	1,481.45	545.08	159,000
3,577,019	2006	0.04422	2,269.98	529.16	154,000
5,921,738	2007	0.06047	3,325.92	599.54	165,000
7,173,991	2008	0.07674	4,425.41	547.36	173,000
7,419,130	2009	0.09304	5,737.57	437.82	185,000
9,064,972	2010	0.10930	7,177.63	428.79	197,000
41,296,360					

The majority of the funding from Peanut CRSP was split between two time periods 2001-2006 and 2007-2011. Data analysis is therefore split between the two time periods to analyze the net benefits and the returns to investment for groundnut research in Uganda (table 2.8). Over 70% of the social gains appeared in the later period as the adoption rate continued to rise. The research investments also rose in the later period along with the social gain to Uganda's groundnut sector leading to a consistent cost-benefit ratio over time. Overall the costs benefits ratio is in the range of 50 times the costs provided by the agricultural research institutions.

Table 2.8. Net Benefits ($US)

	Social Gain	Research Cost	Net Benefits	Cost-Benefit Ratio	Net Present Value*
2001-2006	10,880,096.18	209,523.6	10,670,572.58	51	29,344,376.59
2007- 2010	29,579,829.88	584,487.6	28,995,342.28	50	

*Calculated at 5% discount rate for entire time period

In table 2.9, a sensitivity analysis depicts the changes of consumer and producers surplus when the elasticity of supply and demand each change by 20%. At the original elasticities, elasticity of demand equal to one half and elasticity of supply equal to one, 66% of the social gain goes to the consumers. This is caused by the inelastic demand of the groundnuts. The more inelastic the demand the higher amount of consumer surplus. The opposite is true for the elasticity of supply, with the producer surplus rising with a decrease in elasticity. As noted earlier in the paper, changing the elasticity of demand has a small impact on the total social gain from adoption. The impact from the demand elasticity only has a significant impact on the distribution of gains. The elasticity of supply has a larger effect, which might influence total surplus. For example, when the elasticity of supply is less than one, the price change due to adoption decreases and the producers gain more from the increased production.

Table 2.9. Sensitivity Analysis

	Change in Consumer Surplus ($US)	Change in Producer Surplus ($US)	Change in Total Surplus/Social Gain ($US)
Ed=.5 and Es=1	27,530,907	13,765,453	41,296,360
Elasticity of Demand			
0.6	25,771,529	15,462,918	41,234,447
0.4	29,547,941	11,819,176	41,367,117
Elasticity of Supply			
1.2	24,334,116	10,139,215	34,473,331
0.8	31,697,603	19,811,002	51,508,605

2.7 Conclusion

This paper provides an impact analysis of Uganda's groundnut sector after the release of improved groundnut varieties to the market through Peanut CRSP and other partner organizations. Since 2001, Peanut CRSP performed groundnut research to improve yields, reduce cost per unit of output, and improve health benefits from groundnuts. The release of Serenut 1-4 and Igola varieties in Uganda allowed farmers to increase production by adopting higher yielding seeds that are resistant to the Rosette Virus and droughts.

Three main conclusions can be drawn from this ex-post report. The main result is that groundnut research in Uganda has generated significant gains for the peanut producers and consuemrs. Over a 10-year period, over US$ 40 million was added to the market through the adoption of improved varieties. This social gain, under the assumed elasticities, distributed $US27.5 million to consumers and $US 13.7 million to producers. The total benefits to the market also far outweigh the costs with a benefit cost ratio of 51 and 50 in each grant period. However, we do not know all of the research costs incurred by other research centers.

Second, the adoption rate is a major contributor to the total impact of adoption and it still has room to grow. The adoption rate grew quickly, up to 50% since 2001, and will likely increase in the upcoming years. With focus on adoption constraints (availability, knowledge, financial credit, etc) the adoption rate can exceed 50%, and continue to increase the production values.

Third, the improved variety impact is low compared to the potential yields for each variety. Further research should focus on how to increase realized farmer yields closer to the potential yields in the experimental plots. This area includes fertilizer use, pest management, and general plot management. One of the greatest opportunities for growth and change in social gains for the future is to increase yields for improved seed varieties in the field.

CHAPTER 3

THE EFFECTS OF INTEGRATED PEST MANAGEMENT TECHNIQUES (IPM) FARMER FIELD SCHOOLS ON GROUNDNUT PRODUCTIVITY: EVIDENCE FROM GHANA

3.1 Introduction

Groundnut is an important crop for both household consumption and cash crop purposes in Ghana (Debrah and Waliyer 1996). Groundnut production for Ghana in 2010 was 2.5 times more than at the beginning of the decade. The sharp rise in production is due to a 75% increase in the area harvested and a 50% increase in yield during the same decade (FAOstat 2012). At the beginning of the decade, several biotic and abiotic stresses, including aflatoxin, Rosette virus, and pests, were prevalent, limiting groundnut output (Attuhen-Amankway, Hossain, and Asibi 1998). The integrated pest management farmer field school (IPM-FFS) program was initiated as a direct response to the need to combat these agricultural stresses.

Farmer Field Schools (FFS) are an adult education program used to disseminate information and technology to farmers (Van den Berg 2004). It is an interactive and participatory model used for IPM methods that is present around the world, but is especially common in many developing countries. FFS began in 1989 in Indonesia with the aim to correct the over usage of insecticides in rice farming. Today the program covers a variety of farming practices and focuses on the major crops of Sub-Saharan Africa, Asia, and Latin America. The model is also used to spread information on non-agricultural topics such as HIV/AIDS, water conservation, food security, and nutrition (Braun et al. 2006).

Sudan was the first country in Sub-Saharan Africa (SSA) to implement FFS in 1993, but the first major FFS program in SSA did not arrive until 1996 in Zimbabwe (Rahman 2003). With the large undeveloped land area in SSA, the FFS model is used as an effective way to spread information and technology to remote villages with little development on social, health, and agricultural topics (Braun et al. 2006). The program's cost effectiveness is a concern, but it does ensure that remote farmers receive the information (Feder, Murgai, and Quizon 2004). With the high costs, important policy and program decisions are made from impact assessments that report on the evaluation of FFS on the intended outcomes.

It is important to determine whether the dissemination of information and technology has generated positive impacts and sustainability. In order for the program to be worthwhile, the FFS program needs to not only spread information, but influence farmer behaviors and decisions that lead to accomplishing the programs goals. One major study concluded that the programs in Indonesia and Philippines are unsustainable with the current structure and costs (Quizon, Feder, and Murgai 2001). Other studies looking at the impact report mixed results, with several concluding the effectiveness diminishes over time with no real long term-effects (Praneetvatakul & Waibel 2006; Feder, Murgai, and Quizon 2004; Feranadez-Cornejo 1996). At the same time, several studies find positive impacts of FFSs (Yorobe, Rejesus, and Hammig 2011; Godtland et al. 2003). The contradicting reports illustrate the difficulty and lack of consensus of a standard form of assessment for IPM-FFS. This may be due to the fact that the program evolved initially to address ecological heterogeneity and combat specific, local pest management issues (Braun et al. 2006).

The purpose of this paper is to evaluate the impact of Ghana's IPM-FFS on groundnut productivity. Specifically, this impact evaluation focuses on the groundnut IPM-FFS in Ghana during the last decade to provide an assessment of the value of Peanut Collaboration Research Support Program (PCRSP), Council for Scientific and Industrial Research-Crops Research Institute (CSIR-CSR), and Savannah Agricultural Research Institute's (SARI) presence in groundnut research and technology dissemination through FFS using household data collected in 2011. FFSs are a primary tool used to spread agricultural research, including Peanut CRSP's, in Ghana. With the growth of Ghana's groundnut production coinciding with the IPM-FFS program, it is important to determine if the program is contributing to enhancing productivity. While most of the impact studies to date evaluated IPM programs on pesticide use and yields, there are no prior studies that focus on groundnut productivity. Most prior evaluations focused on rice, cotton, or vegetables (Braun et al. 2006). This impact evaluation on groundnuts in Ghana will contribute to the literature from an underrepresented region and crop on FFS impact evaluations.

A treatment effect model is used to address self selection issues that arise from the structure of the program to better evaluate the treatment effect of the program. To assess the impact of FFS on groundnut productivity in Ghana, data was collected from Central and Southern Ghana in 2011. To explore the relationship between FFS and productivity, alternative treatment effect modeling approaches dissecting the sample between treatment and control villages are considered each controlling for self-selection and endogeneity issues in the FFS program. As the results indicate, controlling for participation is critical in order to accurately estimate the relationship between FFS participation and groundnut productivity.

The rest of the paper is organized as follows. Section two provides a literature review on FFS impacts including studies focusing on Ghana. The FFS experience in Ghana, along with the data collection method and a description of the data, are presented in section three. The model used is discussed in section four. Results and conclusions are provided in sections five and six, respectively.

3.2 Farmer Field School Evaluation Literature Review

There is an extensive literature on FFSs and a variety of analysis reporting its impact on developing countries. Studies have analyzed the impact on the farmers attending the program against non-FFS farmers to discover any significant differences in knowledge, pesticide use, production, income, or poverty (Davis et al. 2010; Yorobe, Rejesus, and Hammig 2011; Godtland et al. 2003). Several methods have been used in previous studies, including instrumental variable procedures (IV), propensity score matching (PSM), and difference in difference (DiD), with most studies accounting for selection and endogeneity bias. Evidence from these studies found conflicting reports about the significance of FFS impacts in developing countries. The results differ depending on the setting, evaluation methods, and the assumptions used in the evaluation (Godtland et al. 2003). There is currently no agreement on what should be measured, how to measure the data, and how to analyze the data in reference to the impact of FFS (Braun et al. 2006). IPM-FFS programs are designed to effectively disseminate information and technology to a certain region of farmers, usually on a specific crop. Since each crop has different management techniques and each region contains farmers with different cultures and practices, the impact of each study must be analyzed on a case-by-case basis. Given the nature of the program, it is important to identify the setting and specific, relevant variables in order to accurately measure the local impact.

3.2.1 Ghana FFS Evaluations

There are a couple of studies that analyzed the FFSs in Ghana. An early assessment of the groundnut FFSs that implemented PCRSP technology was conducted in 2007. The study focused around one of the early districts to deploy FFS, Ejura-Sekyedumase, and only contained 28 FFS participants in the 120 farmer survey. The study found higher adoption rates of agronomic practices relevant to groundnuts, such as land preparation and pest management, paired with greater social-economic indicators for FFS participants (Dankyi et al. 2007). Since the study used a small sample early in the region's FFS program, the study might not be representative of the population. Also, the study heavily relied on descriptive statistics without controlling for self-selection issues.

Another study examined FFS trainings on cocoa farmers in the Ashanti region of Ghana (Gockowski et al. 2006). The program focused on practices and issues directly related to the management of cocoa crops. A multivariate regression analysis was used to determine the program's impact, which estimated a 14% increase in net production for FFS farmers compared to non-FFS farmers. The study also stressed the impact of FFS training on the decision making ability of farmers. The study indicated that FFSs also develop decision making skills for farmers which would produce results on crops outside of the focus of the FFS and the ability of decisions on agronomic practices not covered in the FFS program (Gockowski et al. 2010).

3.2.2 Other FFS Impact Evaluations

Several impact studies look at the effect FFS programs have on the adoption of certain farming practices. Yorobe, Rejesus, and Hammig (2011) controlling for selection and endogeneity problems via an instrumental variable (IV) model, find that FFS onion farmers in the Philippines have significantly lower insecticide expenditure compared to non-FFS farmers. This finding is important with the conception that using too much insecticide commonly has negative impacts on agricultural output along with environmental and health implications. Godtland et al. (2009) used cross sectional data for PSM and regression analysis to evaluate the impact of FFS in potato production in the Peruvian Andes. They found that FFS participation has a significant impact on IPM knowledge and high levels of IPM knowledge have a significant impact on the production of potatoes. Fernandez-Cornejo (1996) found IPM-FFS to lower insecticide use in the US, causing a small effect on profits, but no effect on yields. This was a result of over-usage of insecticide in the study region, but not enough to affect production levels. Therefore, the change in profit only occurs from lower pesticide costs.

In a study conducted by the International Food Policy Research Institute (IFPRI), FFS data was evaluated for Tanzania, Kenya, and Uganda. The study looked at participant characteristics and used a DiD and PSM approach to analyze overall effectiveness of several FFS in East Africa. The study found an overall significant effect on production and poverty, but found mixed results when broken down by country (Davis et al. 2010). In 2004, Feder, Murgai, and Quizon (2004) employed a difference-in-difference approach to FFSs in Indonesia and found no significant impact. While using the same data, Yamakazi and Resosudarmo (2008) found an increase in short term yields due to a decrease in pesticide use. Yet in the long term, those who attended FFS did not achieve significantly different production results than those who did not attend FFS (Yamazaki and Resosudarmo 2008). Another study found a statistically significant result for a reduction of insecticide use for farmers who attended FFS using a DiD approach similar to Feder, Murgai, and Quizon (2004) (Praneetvatakul and Waibel 2006).

The lack of agreement on the impact of FFS begins with the classification of FFS. From one side of the argument, FFSs are seen as an extension agent tool to disperse information and technology to local farmers. This system relies heavily on one or two agents to spread the information throughout the particular region. The other side of the argument views FFS as an educational activity. Those who are able and willing will participate in the program but will naturally keep most of the information to themselves (Van den Berg 2004; Braun et al. 2006). Each type of program will give differing results about the diffusion of information from FFS participants to non-FFS participants, which will alter results in each region or study. As an educational program, FFS participants will not only gain information and technology but will also gain analytical skills; but these skills are less likely to be transferred from one farmer to the next outside of the FFS (Braun et al. 2006).

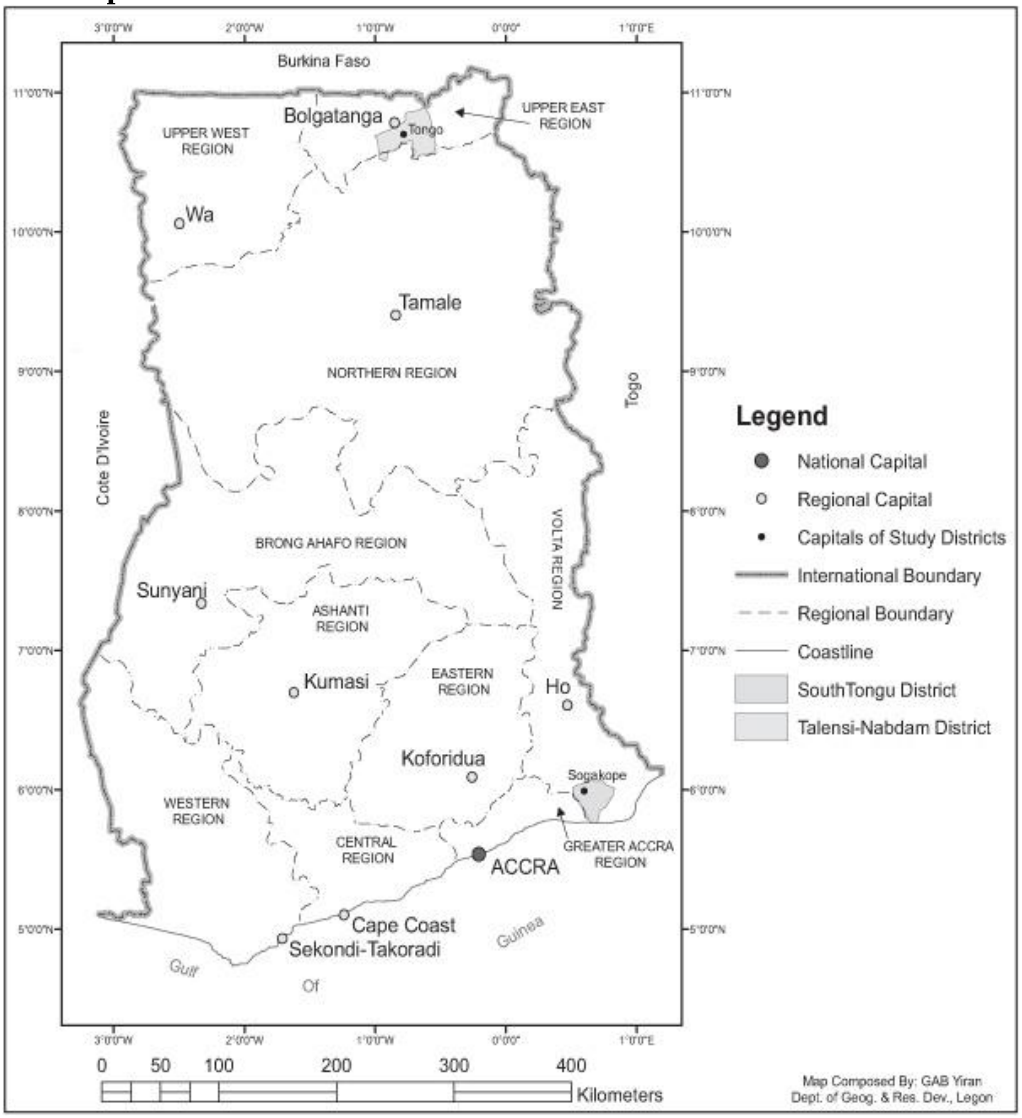
The assumption of the dissemination of knowledge from a participant to a non-participant in FFS will alter the measured impact of the program. Studies in Cambodia and Sri Lanka illustrate a situation where information from the FFS did not disseminate throughout the region. The pesticide expenditure was the same for farmers despite no FFS presence in their village (Van Duuren 2003; Tripp, Wijeratne, and Piyadasa 2005). While no significant differences were found in Cambodia and Sri Lanka, an assortment of Cotton IPM studies showed a 39% reduction in pesticide use for FFS farmers and 26% for neighboring farmers compared to the control group (Braun et al. 2006). FFS participants increased their yield by 10% while simultaneously decreasing their pesticide expenditure. Even though neighboring farmers decreased their pesticide expenditure compared to the control group there was no significant difference in yield, and profitability was only affected by the decrease in pesticide expenditure. Each side of the argument has also produced differing proposed questions to be assessed. Working with different initial research questions about how to assess the impact of FFS leads to differing measures to changes in practice, knowledge, productivity, and profitability.

3.3 Farmer Field Schools in Ghana

In 1997, the initial groundnut research began in the Eastern, Brong Ahafo, Volta, and Ashanti regions of Central and Southern Ghana (see figure 3.1). The initial phase, conducted by the Council of Scientific and Industrial Research- Crops Research Institute (CSIR-CRI), North Carolina State University, and the Peanut Collaborative Research Support Program (PCRSP), began with surveys and documentation of current groundnut pests, cultivars, diseases, and beneficial organisms to groundnuts in the region (Dankyi et al. 2007). Research continued in the initial PCRSP phase in Ghana until 2002 by identifying groundnut production constraints. The information gathered during the initial research period was used as the initial curriculum in the FFS program (Dankyi et al. 2007).

In 2002, FFSs began at Hiawoanu, in the Ejura-Sekyedumasi district of Ghana, involving farmers from Bonyon, Hiawoanwu, Ejura, and Dromankuma. This location was used to initiate the FFS program because of the severity of the damage groundnuts faced from pests and diseases documented from an initial survey (Dankyi et al. 2007). In 2002, a station at Ejura was selected to be the first site for the program for proper supervision with plans to increase to more locations. Each farmer was taken through land preparation, production practices, plant health, seed selection, site selection, and post-harvest handling (Dankyi et al 2007). After a successful first year in Hiawoanwu, the FFS program expanded to the Derma and Atebubu in the Brong Ahafo region as well as the Somanya area of the Eastern region (Figure 3.1). The new sites were selected due to their popular production in groundnuts and groundnut production constraints similar to the initial region (Dankyi et al. 2007).

Figure 3.1. Map of Ghana



During the initial FFS year, in consultation with the Ministry of Food and Agriculture, groundnut farmers were contacted to attend a meeting in order to learn about the purpose of FFS. After the meeting, farmers volunteered to participate in the program. The first year was limited to 40 farmers in order to make the program manageable and effective, proportionately representing both genders (Dankyi et al. 2007). Besides being proportionately representative, no selection criteria were used and any farmers who did not participate were able to participate in FFS in later years. IPM-FFS on groundnut production in Southern Ghana has continuously been operating since 2002 and has trained about 3,000 farmers through 2011 with CSIR-CRI and PCRSP technologies (Dankyi et al. 2007).

3.3.1 Data Collection Methodology

For the purpose of this study, data were collected from the Ashanti, Brong Ahafo, and Eastern regions of Ghana. All three regions are common areas for groundnut production and contain villages that participated in FFS and PCRSP activities. The three regions also spread throughout three ecological zones: Forest, Coastal Savannah, and Transitional. Household surveys were used to collect the data in 2011 in six FFS and six non-FFS villages in each region. The six FFS villages for the study are: Hiawoanwu, Bonyon, Kasei, Atebubu, Derma, and Somanya.

The non-FFS villages were randomly selected by compiling a list of all villages that are within a 10 mile radius of each FFS village. Enumerators collaborated with the agricultural extension officer to compile the lists of non-FFS villages within the designated radius of each FFS village. After the list was compiled, each village was given a number from one to the total number of villages. The village numbers were then randomly chosen to decide which village would participate in the household survey. If the village chosen was too small for our sample, less than 30 households, it was discarded and another village was chosen. The following non-FFS villages participated in the household surveys: Monta, Konkoma, Aberewa Ano, Mensuo, and New Somenya.

Thirty households were randomly chosen from each FFS and non-FFS village. Enumerators and the agricultural extension officer compiled a list of groundnut farmers in each village with each farmer receiving a different number. An enumerator chose a random number between 1 and 10 to decide the initial house in which to conduct the household survey. Every fifth household after the initial house on the list was then chosen for the household survey until a total of 30 households were selected. Within each household, all members who are primary cultivators of groundnuts were interviewed and completed a separate household survey.

Table 3.1. Sample of Households Surveyed

	FFS Village	Non-FFS Village	Total
Villages	6	6	12
FFS Participants	72	16	88
Non-FFS Participants	105	164	269

The distribution of respondents separated into FFS villages and non-FFS villages are included in table 3.1. The classification of an FFS village is where the program took place. It does not mean that FFS is limited to the farmers of that village and producers from neighboring villages cannot travel and participate in a FFS class. In fact, 16 farmers participating in the questionnaire from non-FFS villages have attended FFS. Survey questions ranged from demographics, seed choices, planting decisions, disease and pest control, varieties, and production. The variables used in this study along with their definitions are included in table 3.2. The survey questions were carefully selected to measure qualitative and quantitative indicators. Local partners familiar with the PCRSP and FFS programs were consulted to validate the relevancy of each question. After consulting with the local partners, local enumerators pre-tested the questionnaire by randomly selecting groundnut farmers to assure questionnaire quality.

Table 3.2. Definition of Variables

Variable	Definition
Yield	2010 Groundnut production (50kg bags/acre)
FFS Farmer	=1 if farmer participated in program, =0 otherwise
Age	Farmers age (years)
Education	Highest education level of the head of household
Head of Household	=1 if Head of Household is respondent, =0 otherwise
Experience	Total years growing groundnuts
Distance to Road	Distance of house to nearest paved road
Distance to Extension	Distance of house to extension office
Distance to field	Distance of house to groundnut field
Improved Variety	=1 if farmer uses an improved variety, =0 otherwise
Forest	=1 if farmer is in forest ecological zone, =0 otherwise
Coastal Savannah	=1 if farmer is in coastal savannah ecological zone, =0 otherwise
Transitional	=1 if famer is in transitional ecological zone, =0 otherwise
Trips to Extension Office	Trips the farmer has taken to extension office in last 2 years
Visits from Extension Officer	Visits from extension officer to the farmer in last 2 years

3.3.2 Household Data

Within the survey, data were collected on the source of information that the farmers received about different IPM practices. The survey asked for the primary sources of information, but it allowed farmers to name multiple sources. This information is displayed in table 3.3. Each of the agronomic practices in the table is taught in the groundnut IPM-FFS program. An earlier study compared the differences of quality of practice and found that farmers who claimed FFS as their information source were more likely to perform the agronomic practice properly compared to farmers who learned from experience (Dankyi et al. 2007). The majority of farmers that use the agronomic practice claim to gather the information from experience. The experience variable most likely captures information learned from family or passed down from a parent while growing up, which is consistent with how information is commonly passed in developing countries (Godtland et al. 2003).

FFS farmers comprised about 25% of the survey population. For each of the agronomic practices, 17-20% claim FFS as their primary source of information. This is a significant source, since it is likely that some farmers would have information on a few agronomic practices upon participating in the FFS class. Therefore, around 75% of the FFS farmers who participated in the survey learned something new from the FFS class for each agronomic practice.

Table 3.3. Sources of Information for Various IPM Practices (% of Farmers)

Agronomic Practice	FFS	FFS Farmer	Non-FFS Fellow Farmer	Extension	NGO	Experience	Other	N/A
Site Selection	21	7	15	10	0	57	2	8
Determination of Soil	20	7	14	10	0	58	1	7
Seed Testing	18	6	4	11	0	18	1	50
Re-filling	18	6	10	12	0	36	1	29
Proper Pesticide Use	17	4	0	5	0	1	0	72
Disease Management	20	5	2	8	0	14	0	53

The non-FFSs villages were chosen to be representative and similar to the FFS villages participating in the household survey. The summary statistics for the variables included in the study are presented in table 3.4. There are similarities and differences between the FFS and non-FFS farmers. One difference is that education is greater for FFS participants, but the average for both groups is still within primary school completion. With the education level that low, it is unlikely to see any strong effects, which agree with results from other studies using probit models to determine farmer participation in developing countries' FFS programs (Godtland et al 2003). Second, the visits to and from the extension office are much higher for FFS participants. One possibility is that farmers that interact with the extension office are more likely to know about the FFS school and thus more likely to participate in the program. A second possibility is that farmers have more interaction with the extension office after they participate in the FFS program. The data collected on the interaction between farmers and the extension office is for a two-year period, 2010 and 2011.

Table 3.4. Summary Statistics- Mean (Standard Deviation)

Variable	**Total Sample (n=357)**	**Non- FFS Farmer (n =269)**	**FFS Farmer (n=88)**
Yield	5.98	5.87	6.31
	(3.52)	(3.51)	(3.58)
Age	45.47	45.37	46.36
	(14.91)	(15.33)	(13.44)
Education	4.20	3.47	6.22
	(5.22)	(4.78)	(5.94)
Head of Household	0.65	0.66	0.61
	(0.47)	(0.47)	(0.49)
Experience	12.48	12.30	13.22
	(10.24)	(10.13)	(10.68)
Distance to Road	2.16	2.47	1.16
	(3.76)	(4.09)	(2.13)
Distance to Extension	5.08	5.34	4.31
	(4.06)	(4.19)	(3.44)
Distance to Field	2.04	2.01	2.16
	(1.77)	(1.72)	(1.92)
Improved Variety	0.29	0.30	0.25
	(0.47)	(0.463)	(0.435)
Forest	0.18	0.19	0.14
	(0.39)	(0.40)	(0.36)
Coastal Savannah	0.17	0.16	0.20
	(0.37)	(0.36)	(0.41)
Transitional	0.65	0.65	0.66
	(0.48)	(0.48)	(0.48)
Visits to Extensions Office	2.08	1.21	4.66
	(5.28)	(3.58)	(8.00)
Visits from Extension Officer	6.98	5.12	12.44
	(12.39)	(10.77)	(15.01)

The survey also collected information on improved varieties and we also included agroecology of each village (Fores, Coastal Savannah, and Transistional). Finally there are also two distance variables: distance to road and distance to extension. These two variables are likely to impact FFS participation but not impact yield. These instruments were selected *a priori* and are consistent with previous studies (Yorobe, Rejesus, and Hammig 2011; Feder, Murgai, and

Quizon 2004; Ricker-Gilbert et al. 2008; Rejesus et al. 2009). FFS farmers tend to live closer to the nearest major paved road and closer to the extension office. Previous studies typically find the distance to road to be negative in the selection equation, but there are mixed results reported for the distance to extension (Yorobe, Rejesus, and Hammig 2011; Godtland et al. 2003).

3.4 Methodology

In this paper, a treatment effect model is used to calculate unbiased and consistent estimates of the impact of FFS. This is similar to a sample selection model with missing data, but data are observed for both participants and non-participants in the program (Guo and Fraser 2010). Two different methods, full information maximum likelihood and a two-step estimator, of the treatment effect model are analyzed. This model is used to control for the bias caused by nonrandom assignment to treatment by determining variables which affect participation (Winship and Mare 1992). Two types of bias that might occur in this program are: sample selection bias and endogeneity bias.

Sample selection bias occurs when the dependent variable is observed for a non-random sample. The traditional version of sample selection bias is when the dependent variable is unobserved for the untreated group. This is not the case in this study, since yields are observed for FFS farmers and non-FFS farmers. In this IPM-FFS study, farmers have the choice whether to attend the school, allowing for the potential of a self-selection bias. Without controlling for participation, unobserved variables can affect the decision to participate in FFS by farmers. Without accounting for a common characteristic of farmers, an OLS regression will produce biased results. This bias of using a non-randomly selected sample as an ordinary behavior relationship causes the same error as an omitted variables bias (Heckman 1979). For the specific focus of this paper, potential bias is of concern for two primary reasons: there are unmeasured characteristics that influence farmer yields, and it is unlikely that every variable influencing selection is controlled by the outcome equation.

The endogeneity problem arises when an independent variable in the model is a choice variable, participation in this study, and is correlated with unobservables correlated with the error term. Thus, the error term in the participation regression is correlated with the error term in the outcome equation. This is possible from the non-randomized sample selection process of the FFS program. The treatment effects model accounts for both types of bias, selection and endogeneity, to provide consistent, un-biased results (Green 2003).

3.4.1 Treatment Effect Model

The treatment effect model mimics the Heckman sample selection model, except that the participation variable is directly inserted into the outcome equation since both groups' production is observed (Winship and Mare 1992). The two-part model accounts for the correlation of the error terms of the participation and outcome equation with two stages of regression. The first stage is the participation equation

(3.1) $$P_i^* = \gamma Z_i + \mu_i$$

which determines the value of participation by

(3.2) $$P_i = \begin{cases} 1 \ if \ Pi^* > 0 \\ 0 \ if \ Pi^* \leq 0 \end{cases}$$

where P_i^* is a latent continuous index measuring the net utility associated with program participation for the i_{th} farmer and Z_i are a vector of characteristics which affect participation but are uncorrelated to outcome equation error term. In the participation equation, γ is a vector of parameters to be estimated and μ_i is a random error term.

The second stage of the model is the outcome equation

(3.3) $$Y_i = \beta X_i + \alpha P_i + \varepsilon_i$$

where Y_i is the measure of yields (unshelled groundnut sacks/acre) for each producer, X_i is a vector of observable control covariates (e.g., education, age, experience), P_i represents whether the farmer participated in FFS program and ε_i is a random error term. The treatment effect is derived from the estimation of coefficient α. The selection bias occurs in the model when ε_i and μ_i are correlated.

This model is normally used when selection bias is caused by missing data, but in this case the problem is estimating treatment effect when non-random assignment is present (Winship and Mare 1992). In order to determine the causal treatment effects of FFS participation, equation (3.3) can be generalized into two equations:

(3.4) $$Y_i^0 = \beta X_i + \varepsilon_{1i}$$

(3.5) $$Y_i^1 = \beta X_i + \alpha + \varepsilon_{2i}$$

Where Y_i^0 is the yield for farmers who did not participate in FFS and Y_i^1 is the yield of FFS farmers. The causal difference, α, from the treatment is found by taking the difference: Y_i^1-Y_i^0. Since the dependent variable is observed for both equations (3.4) and (3.5), the regression can be run simultaneously as one equation.

In this model there are three assumptions that are required by the model:

(3.6) $$(\varepsilon, \mu) \sim N(0,0,\sigma_\varepsilon^2, \sigma_\mu^2, \rho_{\varepsilon\mu})$$

(3.7) $$(\varepsilon, \mu) \text{is independent of X and Z}$$

(3.8) $\mathrm{var}(\mu) = \sigma^2_{\mu} = 1$

The first assumption, (3.6) states that both error terms are normally distributed. The mean of each term is zero and the error terms are correlated with $\rho_{\varepsilon\mu}$ the correlation coefficient. The second assumption, (3.7), states the error terms are independent from the explanatory variables. Finally, the third assumption, (3.8), is the standardization of the probit selection equation which normalizes the variance for μ for the probit regression (Heckman 1979). When there is a non-random selection as is the case for FFS participation and the error terms for the two equations are correlated, the estimates for an OLS will be inconsistent.

3.4.2 Empirical Specification

The treatment effects model is essentially running two regressions simultaneously (Guo and Fraser 2010). The first step to quantitatively measure the impact of FFS on groundnut farmers is to estimate a probit model of FFS participation and obtain estimates of γ which can be used to make consistent estimates of the inverse Mills ratio term. The inverse Mills ratio is the probability density function over the cumulative distribution function of a distribution and serves as the function that controls for selection bias (Heckman 1979, Green 2003). In this study, we use several instruments in the first stage probit estimation: distance to the nearest paved road, distance to extension office, age, head of household's education, experience, head of household's status, visits from extension, and trips to extension. These variables are likely to affect participation in the FFS program. The two distance variables and visits from an extension officer are only included in the selection equation. They are not expected to have an impact on yields, but all other selection variables are used in both equations. It helps identify the effect of outcome by treatment by including variables only in the selection equation. These variables have been used in other selection models assessing the impact of FFS programs as valid indicators of participation (Yorobe, Rejesus, and Hammig 2011; Mauceri et al. 2007; Davis et al. 2010; Godtland et al. 2003). The variables included in only the treatment equation act as instruments and could be used in an instrumental variable approach. This study only uses the treatment effects approach because it is less dependent on strong instruments while the IV approach is improper to use with weak instruments.

After the first stage, the outcome equation in the second stage can be estimated by a linear regression. The outcome equation includes the constructed value of the inverse Mills ratio and the vector of observables from the first stage. The covariates chosen to represent farmer characteristics are similar to those used in prior assessments (Feder, Murgai, and Quizon 2004; Mauceri et al. 2007; Yorobe, Rejesus, and Hammig 2011). These are farmer characteristics that might affect IPM technique adoption habits and impact yield which was displayed in table 3.2. The second stage will provide a consistent estimate of α in which conclusions can be drawn about the effectiveness of the FFS program. The standard errors are corrected in the outcome equation in the selection model to correct the heteroskedasticity.

3.5 Results

The results from the FFS participation probit model are presented in table 3.5. They indicate that participation in FFS is not random and that there are characteristics that increase the likelihood of participation in FFS. Thus, there is the possibility that there are unobserved characteristics that also affect participation (Mauceri et al. 2007). More specifically, the probit results show that more educated farmers and those who visit the extension office are both more likely to participate. The distance to road has a negative coefficient and there is no effect from distance to extension office. Thus, the farther away farmers are from a paved road the less access the farmer has to information and programs. This will likely limit farmers' knowledge of the program or ability to travel to the program. The statistically insignificant effect on distance to extension likely results from a balance of farmers not being able to travel the distance to the FFS and the difficulties of the program to reach remote farmers.

Table 3.5. Ghana Farmer Field School Participation Probit

Variable	Coefficient (Std. Error)
Distance to Road	-0.060*
	(0.033)
Distance to Extension Office	0.005
	(0.029)
Age	-0.0003
	(0.007)
Experience	0.010
	(0.011)
Education	0.063**
	(0.016)
Head of Household	-0.013
	(0.184)
Visits from Extension	0.009
	(0.008)
Extension Trips	0.051*
	(0.031)
Constant	-1.127***
	(0.331)
Number of Observations	271

Note: * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

The results from the OLS regression are presented in table 3.6. FFS participation does not produce a significant result in the OLS model selection, which does not control for selection or endogeneity bias. Several variables were found to have a significant impact on groundnut production: age, experience, distance to field, and both ecological zones.

Table 3.6. Ordinary Least Squares

Variable	Ordinary Least Squares
FFS Farmer	0.629
	(0.461)
Forest	-2.635***
	(0.580)
Transitional	1.025*
	(0.616)
Education	0.010
	(0.034)
Improved Variety	-0.712
	(0.452)
Age	0.041***
	(0.015)
Head of Household	0.962
	(0.376)
Experience	-0.064***
	(0.021)
Distance to Field	0.261***
	(0.095)
Trips to Extension	0.013
	(0.033)
Constant	3.456***
	(3.455)
Observations	293
R-Square	0.289

Note: * Significant at 10%; ** Significant at 5%; *** Significant at 1%

The results from the treatment effects model are presented in table 3.7. Two separate techniques, full information maximum likelihood and two step-estimators, are presented to compare results. While both estimates will produce consistent estimates, the full information maximum likelihood techniques will also produce efficient estimates. In both techniques, the treatment effect is found to be a positive, statistically significant variable. Each technique attributes an impact of approximately 4.7 bags of groundnuts per acre to the treatment effect. The results also indicate that the ecological zone, head of household status, experience, and distance to field are statistically significant. The maximum likelihood approach found that the farmer's education, age, and trips to extension were also significant while the two step procedure did not find them significant. Each approach produced a statistically significant chi-square test at the one percent level, verifying the goodness of fit.

In the results, a few of the variables indicated a different direction than might be expected. First, experience has a negative estimate. Experience is measured as the number of years planting groundnuts, but does not account for experience with other crops. Therefore, a farmer's knowledge on agriculture might not be completely captured in their groundnut experience. Second, the distance to field has a positive estimate. Meaning the farther away the field is from the farmer's house, the higher the groundnut production. This could be a result from site selection. Finally, the trips to extension estimate are negative. A farmer is more likely to visit an extension officer when the farmer is in need of help. Therefore, visiting the extension office might be an indicator of problems already in existence which decrease production.

Finally, it is important to look at the rho coefficient for each treatment effect model. The coefficient indicates the level of correlation between the error term in the participation equation and outcome equation. This model is chosen based off the belief that the correlation between the two error terms is nonzero. In each treatment effect model, the rho is statistically significant at that the one percent level, the null hypothesis that the correlation is equal to zero is rejected, strengthening the model assumption.

Table 3.7. Treatment Effects Model

Variable	Maximum Likelihood	Two-Step
FFS Farmer	4.750***	4.694*
	(0.941)	(2.645)
Forest	-1.685**	-1.808**
	(0.707)	(0.726)
Transitional	1.888***	2.072***
	(0.695)	(0.730)
Education	-0.106**	-0.105
	(0.045)	(0.070)
Improved Variety	-0.695	-0.734
	(0.452)	(0.479)
Age	0.032*	0.030
	(0.0180)	(0.018)
Head of Household	1.230***	1.182***
	(0.454)	(0.457)
Experience	-0.072***	-0.069**
	(0.027)	(0.029)
Distance to Field	0.206*	0.194**
	(0.094)	(0.094)
Trips to Extension	-0.072*	-0.072
	(0.039)	(0.062)
Constant	2.874***	2.95***
	(0.969)	(0.978)
Observations	246	246
Rho	-0.706***	-0.695***
Lambda	-2.284	-2.239
Chi-Square	142.97***	154.49***

Note: * Significant at 10%; ** Significant at 5%; *** Significant at 1%

A few variations of the treatment effects model are displayed in table 3.8 to better understand the impact of participating in FFS. The first variation includes only farmers that live in FFS villages. In this regression, there is a statistically insignificant treatment effect. This result is most likely caused by FFS farmers teaching FFS lessons to their neighbors causing an insignificant difference in production. The second variation in table 3.8 included only farmers from villages where FFS participating is not common from the control group. By doing this, there should not be any effect of passing information from FFS classes to neighbors. This variation resulted in a statistically significant treatment effect of 3.4 bags per acre of the FFS program. Therefore, these results suggest that FFSs have a significant positive impact on groundnut production in Ghana.

Table 3.8. Variations in Treatment Effects Model

Variable	**FFS Villages**	**FFS Participants and Non-FFS Villages**
FFS Farmer	0.792	3.413***
	(2.660)	(1.082)
Forest	-1.845*	1.667**
	(1.115)	(0.780)
Transitional	2.080**	3.460***
	(0.906)	(0.802)
Education	-0.005	-0.100*
	(0.075)	(0.059)
Improved Variety	-0.747	-0.701
	(0.664)	(0.570)
Age	0.056**	0.014
	(0.024)	(0.021)
Head of Household	1.008	0.912
	(0.572)	(0.570)
Experience	-0.101***	-0.023
	(0.032)	(0.058)
Distance to Field	0.303**	0.170
	(0.135)	(0.125)
Trips to Extension	-0.103	-0.023
	(0.167)	(0.058)
Constant	2.047	2.602**
	(1.289)	(1.104)
Observations	127	151
Rho	-0.092	-0.792
Lambda	-0.268	-2.401
Chi-Square	79.95	119.98***

Note: * Significant at 10%; ** Significant at 5%; *** Significant at 1%

3.6 Conclusion

The main objective for groundnut IPM-FFSs in Ghana is to improve productivity for groundnut farmers. In this study, we find that farmers who participate in groundnut IPM-FFS implementing PCRSP information and technology have significantly higher production levels than non-FFS farmers. The effect becomes apparent when controlling for sample selection and endogeneity biases. The robustness of the positive result is demonstrated through the agreement in estimations using multiple approaches.

The results of this paper suggest that FFSs are an effective tool to spread information and technologies that increase groundnut productivity in constrained geographic areas. The information and lessons learned in FFS are having a direct effect on the program's goals. Agricultural development and international development institutions may consider using FFSs as a component to spread information and technologies to remote areas of developing countries.

Along with the contributions of this study, there are areas for future work on quantifying the impact of FFS. Several areas of future work include analysis on other outcome variables and the effect on the region's other crops. Research on the effect of groundnut IPM-FFS participants on other crops will provide information on the decision making skills developed in the program. Also, research on the long-term effects of FFS is an important topic for further research. As technology development continues to advance, there is new information to be reported to farmers. This can cause former FFS programs to become outdated which require the continuous dissemination process of new information and technology.

CHAPTER 4

CONCLUSIONS

4.1 Discussion

This chapter discusses the results from the national level study in Uganda and the household level study in Ghana. The purpose is to draw conclusions and takeaways to advance agricultural development in developing countries and to provide additional information on to the research program decisions for Peanut CRSP and other institutions involved in groundnut research in developing countries. Limitations, further research topics, and policy implications are also suggested based from the results from each study. Overall, this study concludes that the research and implementation performed by Peanut CRSP and partnering institutions in Ghana and Uganda for groundnut agriculture has been successful.

The Uganda national level study found a large impact on the groundnut sector from the adoption of improved varieties. Currently the five major improved varieties released in Uganda (Igola, Serenut 1, Serenut 2, Serenut 3, and Serenut4) have led to nearly US$30 million in net benefits to the producers and consumers over a ten-year period. The adoption level of improved varieties in Uganda continues to rise and reached half of all groundnut varieties planted in 2010. The production benefits from planting improved varieties far outweighed the cost of adopting the new technology. Even after the institutional research costs were accounted for, there were still significant net benefits.

There are two main areas of focus that can improve the net benefits: Adoption levels and achieving potential yield changes. Currently, the adoption levels of improved varieties are just over 50%. Along with continuing to release improved varieties, focus should be on the availability and access of released varieties to farmers. Achieving this goal requires increasing farmer knowledge on improved varieties and improving access to capital so that farmers can afford increased costs in agricultural inputs. The former area of focus, potential yield, requires improving farmer agronomic practices and the proper use of agricultural inputs. Currently, farmers are achieving a fraction of improved varieties potential yield due to poor pest management, drought, and low fertilizer use. Also, if farmers are able and willing to use the recommended inputs then groundnut production will increase (Kraybill and Kidoido 2009)

The study in Ghana offers an alternative approach by focusing on the household level instead of the national level. It examines effectiveness of Farmer Field Schools, Peanut CRSP, and partnering institutions to reaching individual farmers and its impact. The evaluation focused on agronomic practices taught in FFSs in Ghana. The study found that FFSs have a statistically positive impact on farmer's groundnut yields. Using FFSs to disseminate information and technology to rural groundnut farmers in Ghana is an effective form, although past studies have shown conflicting results. The positive treatment effect from FFSs was found robust across multiple econometric methods.

Part of the benefit of this study is the contribution to economic literature on the impact of agricultural research. There are a variety of evaluation techniques for agricultural research. The economic surplus model estimating the counterfactual situation is commonly used for national level surveys, but there is no standard for household level evaluations. The treatment effects model proved to be an effective model to control for selection and endogeneity biasness and provide consistent, un-biased results. This method to estimate the average treatment effect of FFS may be utilized in further studies, depending on the specifics of each FFS.

4.2 Limitations and Further Research

The Ghana study used smaller household samples and used primarily cross sectional data. Further research should collect time series data to determine the treatment effect over time. In the Uganda study, adoption level parameters were estimated after collecting three years of data at the beginning, middle, and end of the study period. While it is acceptable to use this strategy, collecting data from each period will ensure smaller errors in the adoption level.

The implications of each study stress the need for further research in both agronomics and economics. As scientists to continue to develop more improved varieties and agronomic practices that better handle the constraints faced by farmers, farmer groundnut yields are still a fraction of the potential yield. While actual field yields may never match potential yields, there is large room for improvement by training farmers to achieve higher yields.

There is also a lot of room for improvement for economic evaluations and agricultural programming. The small adoption levels of improved varieties, agronomic practices, and educational classes, such as FFS, that improve production express the need for futher research on farmer constraints. A high priority should be promoting new varieties in Ghana while limiting capital constraints that lower adoption levels.

4.3 Policy Implications

The benefits and impact found in each study express the need for continued funding and progression in agricultural development. Agriculture is an important component in the developing countries in social and economic aspects. As food insecurity remains an important issue in each country, the increase in production provides more food security for farmers plus an additional source of income.

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APPENDIX A

2011 UGANDA HOUSEHOLD SURVEY

Peanut CRSP IPM Practices of Farmers and their Impacts in Uganda

Questionnaire

Enumerator # [ ]

Interview Date [ ]

Household ID [ ]

Region [ ]

District [ ]

Village [ ]

Latitude of House [ ] **Longitude of House** [ ]

Latitude of Farm [ ] **Longitude of Farm** [ ]

Agro-Ecological System [ ]

(1 =The Banana-coffee System, 2 = The Banana-millet-cotton System, 3 = The Montane System, 4 = The Teso System, 5 = The Northern System, 6 = The West Nile System, 7 = The Pastoral System)

Respondent's Name [ ]

Respondent is Head of Household **YES** ☐ **NO** ☐

Counting yourself, how many people live in your household? ___________________

How far is your house from the nearest market? ________________________ miles

How far is your house from the nearest major road? ____________________ miles

How far is your house from the nearest extension agent? ________________ miles

ROSTER OF ALL HOUSEHOLD MEMBERS

Name of Family Members	**Gender** 1=Male 2=Female	**Age**	**Years of Schooling**	**Relationship to the Head of the Household** 1=Head 2=Spouse 3=Son/Daughter 4=Grandchild 5=Step Child 6=Parent of Head or Spouse 7=Sister/Brother of Head or Spouse 8=Nephew/Niece 9=Other Relatives 10=Servant 11=Non-Relative 99=Other (specify)	**Number of Groundnut Fields for Which You are the Primary Cultivator or Manager**
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					
16.					

PLEASE INTERVIEW **EACH MEMBER** OF THE HOUSEHOLD LISTED IN PAGE 2 THAT CULTIVATES/MANAGES THEIR PERSONAL GROUNDNUT FIELD(S). FOR EACH MEMBER YOU INTERVIEW, PLEASE FILL OUT **A SEPARATE SURVEY**.

Respondent's Name (from page 2) ____
Household ID ____

We are interested in learning about your groundnut production. We would therefore like to ask you a few questions about your groundnut production.

1. Did you grow groundnuts in 2010/2011?
    1. Yes
    2. No

2. How many years have you been cultivating groundnuts? ________________________

3. If you started cultivating groundnuts in **the last five years**, what is the main reason for doing so? Were you convinced by: (CIRCLE ALL THAT APPLY)
    1. Farmer Field School (FFS)
    2. Other Research/Extension Activities
    3. Fellow Farmers
    4. Relatives
    5. Media
    6. Income opportunities
    7. Nutritional values/Food
    8. Employment
    9. Other (Please Specify)____
    10. N/A

4. Please provide the following information on all the crops you grew last year.

Crop	**Number of Acres (if other than acres please specify unit)**	**Number of Seed Bowls Used to Plant the Field**	**Distance of Field From the Your House (miles)**
1. Groundnut field 1			
2 Groundnut field 2			
3			
4			
5			
6			
7			
8			
9			
10			
Total			

*** Please specify units if different than listed**

A. SEED

5. What factors do you consider when choosing which groundnut seeds to plant? (CIRCLE ALL THAT APPLY)
    1. Availability
    2. Drought Resistance (resistant to lack of water or dry conditions)
    3. Duration
    4. Disease Resistance (Please Specify) ______________________________
    5. Quality Characteristic (such as taste, oil content, etc)
    6. Yield
    7. Pest Resistance
    8. Seed Price
    9. Other (Please Specify) ____

6. Have you noticed any spots on the groundnut leaves before harvesting?
    1. Yes
    2. No

7. Please describe how the spots on the leaves look like in terms of color, size, and density (if possible, have farmer show any infected plants).

    ____

8. Have you changed the groundnut seeds in the last 5-10 years?
    1. Yes (Please specify the year(s)) __________________________________
    2. No

9. Have you ever heard of Rosette Resistant groundnuts?
    1. Yes
    2. No

10. Who have you heard from about Rosette Resistant? (CIRCLE ALL THAT APPLY)
    1. Seed retail store/agro-dealer
    2. Fellow Farmers
    3. Open market (from traders)
    4. Extension/Research Station
    5. Other (Please Specify) ____
    6. Cannot Tell
    7. N/A

11. Have you ever used Rosette Resistant groundnuts?
    1. Yes
    2. No

12. Did your yields change after beginning to use the Rosette Resistant groundnut seeds?
    1. Yes (Please Specify Change)
       Increase by ________________________________
       Decrease by________________________________
    2. No
    3. Do not know. Always used Rosette Resistant groundnut seeds
    4. N/A

13. Have you used Drought Resistant groundnuts?
    1. Yes
    2. No

14. Did your yields change after beginning to use the Drought Resistant groundnut seeds?
    1. Yes (Please Specify Change)
       Increase by ________________________________
       Decrease by________________________________
    2. No
    3. Do not know. Always used Drought Resistant groundnut seeds
    4. N/A

15. Are resistant (improved) varieties groundnut seeds available for purchase?
    1. Yes
    2. No

16. What is your main source for resistant varieties groundnut seeds? (CIRCLE ALL THAT APPLY)
    1. Seed retail store/agro-dealer
    2. Seed company stores
    3. Own saved seeds
    4. Fellow Farmers
    5. Open market (from traders)
    6. Extension/research station
    7. Other (Please Specify) ____________________
    8. Cannot Tell
    9. N/A

17. Are regular (local) groundnut seeds available for purchase?
    1. Yes
    2. No

18. What is your main source for regular groundnut seeds? (CIRCLE ALL THAT APPLY)
    1. Seed retail store/agro-dealer
    2. Seed company stores
    3. Own saved seeds
    4. Fellow Farmers
    5. Open market (from traders)
    6. Extension/research station
    7. Other (Please Specify) ____________________

8. Cannot Tell 9. N/A

19. Do you test your seed before planting?
    1. Yes
    2. No

B. DISEASE AND PEST CONTROL

20. How did you manage your primary groundnut pests and diseases last year? (e.g. rosette virus, leaf spots, rust, termites, aphids, thrips, beetles, weeds, etc.)
    1. Fungicide Application
    2. Use of Resistant Varieties
    3. Field Monitoring
    4. Plant Extracts
    5. Hand Weeding
    6. Herbicide Application
    7. Soap Treatment
    8. Use of Treated Seeds
    9. Row Spacing
    10. Plowing
    11. Nothing
    12. Other (Please Specify) ________________

Name/Type of Pest	Control Method (Use Pest Control Code Above)
1.	
2.	
3.	
4.	
5.	

21. What part of the annual production of groundnuts did you lose **because of drought/lack of water**?
    1. In 2010___________________________________
    2. A Decade Ago______________________________

22. What part of the annual production of groundnuts did you lose **because of the Rosette virus**?
    1. In 2010___________________________________
    2. A Decade Ago______________________________

C. VARIETIES

23. Please list your groundnut varieties planted in the **MAJOR SEASON** last year.

Name of Variety Planted in **Major Season**	Variety is: 1 = improved 2 = local	Acres of Variety Planted	Why did you use this variety? See codes below	Who Decided on the Choice of Variety?
1.				
2.				
3.				

1 = High Yield, 2 = Resistant to Disease, 3 = Seed Availability, 4 = Taste, 5 = Easily Marketable, 6 = Oil Content, 7 = Others (Please Specify)

24. Please list your groundnut varieties planted in the **MINOR SEASON** last year.

Name of Variety Planted in **Minor Season**	Variety is: 1 = improved 2 = local	Acres of Variety Planted	Why did you use this variety? See codes below	Who Decided on the Choice of Variety?
1.				
2.				
3.				

1 = High Yield, 2 = Resistant to Disease, 3 = Seed Availability, 4 = Taste, 5 = Easily Marketable, 6 = Oil Content, 7 = Others (Please Specify)

25. Where did you learn about these varieties? (CHECK ALL THAT APPLY)

	Variety 1	**Variety 2**	**Variety 3**
1. Farmer Field School	☐	☐	☐
2. Other Research/Extension Activities	☐	☐	☐

3. Fellow Farmers ☐ ☐ ☐

4. Relatives ☐ ☐ ☐

5. Media ☐ ☐ ☐

6. Other (Please Specify)_____________ ☐ ☐ ☐

D. PRODUCTION

26. What was the production of groundnuts in 2010 from **the fields for which you are the primary cultivator or manager**?

	Field 1	**Field 2**	**Field 3**
***Major season* -** Acreage of groundnut (all varieties)			
***Major season* -** Total production (unshelled, gunny bags)			
Minor season - Acreage of groundnut (all varieties)			
Minor season - Total production (unshelled gunny bags)			

***Please specify units if different than listed**

27. At the time of selling most of your groundnuts, what was the price of a gunny bag?

Price for Unshelled_________________ Price for Shelled ___________________

28. What month did you sell most of your groundnut production?

____

29. Of the cash crops you grew in 2010, which 3 provided you the most income?

1. Most income ________________________________
2. Second most income __________________________
3. Third most income ___________________________

30. Who makes the decisions (e.g. purchasing of inputs, hire of labor, harvesting and marketing) regarding farming activities for **your individual plot**?
    1. Myself
    2. Spouse
    3. Joint decision (myself and spouse)
    4. Other (Please Specify)_____________________________________

E. PRODUCTION CHANGES

31. Please provide the following information on your groundnut production during the last season.

	2010	
	Major Season	**Minor Season**
Total acreage planted with groundnuts (all varieties)		
Total quantity produced (in gunny bags, **unshelled**)		
Total quantity sold (in gunny bags, **unshelled**)		
Total quantity consumed (in basins/bowls, **shelled**)		
Total quantity sold (in gunny bags, **shelled**)		
Total quantity lost due to pests/disease post-harvest		

***Please specify units if different than listed**

F. PRICES

32. What is the current price per gunny bag of groundnuts? Please indicate by variety, if applicable.

Variety	Price for Unshelled	Price for Shelled
1.		
2.		
3.		

33. What was the lowest and highest price per gunny bag of groundnuts in 2010?

Lowest Price (unshelled) ______________ Highest Price (unshelled) ______________
Lowest Price (shelled) ________________ Highest Price (shelled) ________________

G. MARKETING

34. Are you able to sell your produce now more easily than a decade ago?
    1. Yes
    2. No

35. Do you grade/sort your produce/product before selling?
    1. Yes
    2. No

36. Do you now have more easy access to new technology than in the last decade?
    1. Yes
    2. No
    3. Cannot tell

H. USE OF INCOME IN THE HOUSEHOLD

37. How do you spend the money **you** earn from the sale of groundnuts and groundnut-related products from **your individual plot(s)** within the household? (CIRCLE ALL THAT APPLY) Please indicate the portion/percentage of expenditures for each category.
    1. Food items ____
    2. Alcohol and tobacco ________________________________
    3. Health expenses ____________________________________
    4. Children clothes, school fees and books ________________
    5. Personal clothing items ______________________________
    6. Household items____________________________________
    7. Housing issues______________________________________
    8. Hire labor ____
    9. Purchase farming inputs (such as seeds, fertilizer, pesticides or machinery) ____
    10. Other (Please Specify)_______________________________

38. Who initiates the expenditure decision regarding groundnut income from your plot(s)?
    1. Myself
    2. Spouse
    3. Joint decision (myself and spouse)
    4. Other (Please Specify) ____

39. Did you give any harvested groundnut as a gift to others in 2010?
    1. Yes (Please specify the number of groundnut basins)__________________
    2. No

40. Have you seen any changes in your income from groundnuts over the last decade?
    1. Increase in Income
    2. Decrease in Income
    3. No Change in Income
    4. Fluctuations in Income
    5. Cannot tell

41. What was the total household income **from all sources** in 2010?

    TOTAL HOUSEHOLD INCOME (including farming, and non-farming activities)

    ____

I. EXTENSION

42. In the past 12 months, during which months did the local extension agent visit your village?

Aug. 2010	Dec. 2010	Apr. 2011	Aug. 2011
Sept. 2010	Jan. 2011	May 2011	Always
Oct. 2010	Feb. 2011	June 2011	Never
Nov. 2010	Mar. 2011	July 2011	Does Not Know

43. How many times in the last two years has an agricultural extension officer contacted you?

    ____

44. How many times in the last two years have you gone to the offices of the agricultural extension officer for help?

    ____

45. Does your village offer Farmer Field School (FFS) classes or any training programs on groundnuts?
    1. Yes (Please Specify) ____
    2. No

46. What technologies from the FFS have you used with your other crops?

    ____

47. Which crops have you used FFS Techniques/Technology with?

    ____

48. How satisfied have you been with the FFS training?
    1. Very Satisfied
    2. Somewhat Satisfied
    3. Somewhat Unsatisfied
    4. Very Unsatisfied
    5. N/A

49. How many fellow farmers or family members have you shared information with about your new practices and/or FFS technologies? (If you have participated in the FFS)

    ____

50. Of the farmers/persons you shared information with, how many of them do you think are using the new practices?

    ____

51. Do you have a way of acquiring/demanding new peanut related technologies?

1. Yes (Please Specify Source) ________________________________
2. No

Comments

____

APPENDIX B

2011 GHANA HOUSEHOLD SURVEY

Peanut CRSP IPM Practices of Farmers and their Impacts in Ghana

Questionnaire

Enumerator # [ ]

Interview date [ ]

Household ID [ ]

Region [ ]

District [ ]

Village [ ]

Latitude of house [ ] **Longitude of house** [ ]

Latitude of farm [ ] **Longitude of farm** [ ]

Ecological zone [ ]

(1 =Coastal Savannah, 2 = Forest, 3 = Transition, 4 = Guinea Savannah)

Respondent's name [ ]

Respondent is Head of Household **YES** ☐ **NO** ☐

Counting yourself, how many people live in your household? ____________________

How far is your house from the nearest market? _______________________________ miles

How far is your house from the nearest major road? ___________________________ miles

How far is your house from the nearest extension agent? ______________________ miles

ROSTER OF ALL HOUSEHOLD MEMBERS

Name of Family Members	**Gender** 1=Male 2=Female	**Age**	**Years of Schooling**	**Relationship to the Head of the Household** 1=Head 2=Spouse 3=Son/Daughter 4=Grandchild 5=Step Child 6=Parent of Head or Spouse 7=Sister/Brother of Head or Spouse 8=Nephew/Niece 9=Other Relatives 10=Servant 11=Non-Relative 99=Other (specify)	**Number of Groundnut Fields for Which You are the Primary Cultivator or Manager**
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					
16.					

17.					
18.					
19.					
20.					

PLEASE INTERVIEW **EACH MEMBER** OF THE HOUSEHOLD LISTED IN PAGE 2 THAT CULTIVATES/MANAGES THEIR PERSONAL GROUNDNUT FIELD(S). FOR EACH MEMBER YOU INTERVIEW, PLEASE FILL OUT **A SEPARATE SURVEY.**

Respondent's Name (from page 2) ____
Household ID ____

We are interested in learning about your groundnut production. We would therefore like to ask you a few questions about your groundnut production.

1. Did you grow groundnuts in 2010/2011?
    1. Yes
    2. No

2. How many years have you been cultivating groundnuts? __________________________

3. If you started cultivating groundnuts in **the last five years**, what is the main reason for doing so? Were you convinced by: (CIRCLE ALL THAT APPLY)
    1. Farmer Field School (FFS)
    2. Other Research/Extension Activities
    3. Fellow Farmers
    4. Relatives
    5. Media
    6. Income opportunities
    7. Nutritional values/Food
    8. Employment
    9. Other (Please Specify) _______________________
    10. N/A

4. Please provide the following information on all the crops you grew last year.

Crop	Number of Acres (if other than acres please specify unit)	Number of Seed Bowls Used to Plant the Field	Distance of Field From Your House (miles)
1. Groundnut field 1			
2 Groundnut field 2			
3			
4			
5			

6			
7			
8			
9			
10			
Total			

*** Please specify units if different than listed**

5. What do you look for when you are selecting good land (the site) for planting groundnuts?
    1. Weeds with green leafy growths
    2. Other (Please Specify) ____________________

6. Where did you learn the site selection from? (CIRCLE ALL THAT APPLY)
    1. Farmer Field School (FFS)
    2. FFS Farmer
    3. Non-FFS Fellow Farmers
    4. Extension
    5. NGO
    6. Media
    7. Experience
    8. Other (Please Specify) ____________________
    9. Can't tell
    10. N/A

7. How do you determine good soil for groundnut production?
    1. By looking at the texture of the soil
    2. By looking at the existing vegetation
    3. Asking fellow farmers for advice
    4. Other (Please Specify) ____________________

8. Where did you learn the determination of good soil from? (CIRCLE ALL THAT APPLY)
    1. Farmer Field School (FFS)
    2. FFS farmer
    3. Non-FFS Fellow farmers
    4. Extension
    5. NGO
    6. Media
    7. Experience
    8. Other (Please Specify) ____________________
    9. Can't tell
    10. N/A

A. SEED

9. Are regular/local groundnut seeds available for purchase?
    1. Yes
    2. No

10. What is your main source for regular/local groundnut seeds? (CIRCLE ALL THAT APPLY)
    1. Seed retail store/agro-dealer
    2. Seed company stores
    3. Own saved seeds
    4. Fellow farmers

5. Open market (from traders)
6. Extension/research station
7. Other (Please Specify) ________________________
8. Can't tell
9. N/A

11. Do you test your seed before planting?
    1. Yes
    2. No

12. Where did you learn the seed testing from? (CIRCLE ALL THAT APPLY)
    1. Farmer field school (FFS)
    2. FFS farmer
    3. Non-FFS Fellow farmers
    4. Extension
    5. NGO
    6. Media
    7. Experience
    8. Other (Please Specify) ______________________
    9. Cannot tell
    10. N/A

B. PLANTING

13. What do you do if some groundnut seeds do not germinate?
    1. Re-plant new seeds
    2. Nothing
    3. Other (Please Specify) ____

14. Where did you learn the re-filling from? (CIRCLE ALL THAT APPLY)
    1. Farmer field school (FFS)
    2. FFS farmer
    3. Non-FFS Fellow farmers
    4. Extension
    5. NGO
    6. Media
    7. Experience
    8. Other (Please Specify) ______________________
    9. Cannot tell
    10. N/A

C. DISEASE AND PEST CONTROL

15. Do you spray your groundnuts with local soap to control diseases (*alata* or *amonkye*)?
    1. Yes
    2. No

16. Where did you learn the practice of spraying groundnuts with local soap from? (CIRCLE ALL THAT APPLY)
    1. Farmer field school (FFS)
    2. FFS farmer
    3. Non-FFS Fellow farmers
    4. Extension
    5. NGO
    6. Media
    7. Experience
    8. Other (Please Specify) ______________________
    9. Cannot tell
    10. N/A

17. If you find plants that are diseased, what do you do? (CIRCLE ALL THAT APPLY)
1. Nothing
2. Pull the plant
3. Spray with chemicals
4. Spray with local soap
5. Other (Please Specify) ____

18. Where did you learn this from? (CIRCLE ALL THAT APPLY)
1. Farmer field school (FFS)
2. FFS farmer
3. Non-FFS Fellow farmers
4. Extension
5. NGO
6. Media
7. Experience
8. Other (Please Specify) ______________________
9. Cannot tell
10. N/A

19. How did you manage your primary groundnut pests and diseases last year? (e.g. rosette virus, leaf spots, rust, termites, aphids, thrips, beetles, weeds, etc.)
1. Fungicide Application
2. Use of Resistant Varieties
3. Field Monitoring
4. Plant extracts
5. Hand weeding
6. Herbicide application
7. Soap Treatment
8. Use of Treated Seeds
9. Row spacing
10. Plowing
11. Nothing
12. Other (Please Specify) _____________________

Name/Type of Pest	**Control Method (Use Pest Control Code Above)**
1.	
2.	
3.	
4.	
5.	

20. Are you aware that there are beneficial insects that can help manage pests on groundnuts?
1. Yes
2. No

21. How did you hear about the beneficial insects? (CIRCLE ALL THAT APPLY)
1. Farmer field school (FFS)
2. FFS farmer
3. Non-FFS Fellow farmers
4. Extension
5. NGO
6. Media
7. Experience
8. Other (Please Specify) _____________________
9. Cannot tell
10. N/A

D. VARIETIES

22. Please list your groundnut varieties planted in the **MAJOR SEASON** last year.

Name of Variety Planted in **Major Season**	Variety is: 1 = improved 2 = local	Acres of Variety Planted	Why did you use this variety? See codes below	Who Decided on the Choice of Variety?
1.				
2.				
3.				

1 = High Yield, 2 = Resistant to Disease, 3 = Seed Availability, 4 = Taste, 5 = Easily Marketable, 6 = Oil Content, 7 = Others (Please Specify)

23. Please list your groundnut varieties planted in the **MINOR SEASON** of last year

Name of Variety Planted in **Minor Season**	Variety is: 1 = improved 2 = local	Acres of Variety Planted	Why did you use this variety? See codes below	Who Decided on the Choice of Variety?
1.				
2.				
3.				

1 = High Yield, 2 = Resistant to Disease, 3 = Seed Availability, 4 = Taste, 5 = Easily Marketable, 6 = Oil Content, 7 = Others (Please Specify)

24. Where did you learn about these varieties? (CHECK ALL THAT APPLY)

	Variety 1	**Variety 2**	**Variety 3**
1. Farmer Field School	☐	☐	☐
2. Other Research/Extension Activities	☐	☐	☐
3. Fellow Farmers	☐	☐	☐
4. Relatives	☐	☐	☐
5. Media	☐	☐	☐
6. Other (Please Specify)_____________	☐	☐	☐

25. Are resistant (improved) varieties groundnut seeds available for purchase?

1. Yes
2. No

26. How difficult is it to obtain resistant/improved variety groundnut seeds to plant?

1. Very difficult
2. Somewhat difficult
3. Somewhat easy
4. Very easy
5. Cannot tell

27. What is your main source for resistant/improved varieties of groundnut seeds? (CIRCLE ALL THAT APPLY)

10. Seed retail store/agro-dealer
11. Seed company stores
12. Own saved seeds
13. Fellow Farmers
14. Open market (from traders)
15. Extension/research station
16. Other (Please Specify) ____________________
17. Cannot Tell
18. N/A

28. Are you aware of the presence of a Farmer Field School (FFS) in your village?

1. Yes
2. No

29. Have you participated in a Farmer Field School (FFS) for Integrated Pest Management (IPM)?

1. Yes
2. No

30. What year(s) did you attend the FFS? (CIRCLE ALL THAT APPLY)

1. 2001
2. 2002
3. 2003
4. 2004
5. 2005
6. 2006
7. 2007
8. 2008
9. 2009
10. 2010
11. N/A

31. Have you used no-till with herbicides as land preparation method for your groundnut production before?
    1. Yes
    2. No

32. How did you hear about the practice of no-till with herbicide for land preparation? (CIRCLE ALL THAT APPLY)
    1. Farmer Field School (FFS)
    2. Other research/extension activities
    3. Fellow farmers
    4. Relatives
    5. Media
    6. Other (Please Specify) ____
    7. N/A

33. When did you first learn/hear about the practice of no-till with herbicide for land preparation?

    ____

E. PRODUCTION

34. Please provide the following information on your groundnut production during the last season.

	2010	
	Major Season	**Minor Season**
Total acreage planted with groundnuts (all varieties)		
Total quantity produced (in maxi bags, **unshelled**)		
Total quantity sold (in maxi bags, **unshelled**)		
Total quantity consumed (in bowls, **shelled**)		
Total quantity sold (in maxi bags, **shelled**)		
Total quantity lost due to pests/disease post-harvest		

***Please specify units if different than listed**

35. Who makes the decisions (e.g. purchasing of inputs, hire of labor, harvesting and marketing) regarding farming activities for **your individual plot**?
    5. Myself
    6. Spouse
    7. Joint decision (myself and spouse)
    8. Other (Please Specify)___________________________________

F. PRICES

36. At the time of selling most of your groundnuts, what was the price of a gunny bag?

    Price for Unshelled________________ Price for Shelled __________________

37. What month did you sell most of your groundnut production?

    ____

38. What is the current price per maxi bag of groundnuts? Please indicate by variety, if applicable.

Variety	Price for Unshelled	Price for Shelled
1.		
2.		
3.		

39. What was the lowest and highest price per maxi bag of groundnuts of 2010?

    Lowest Price (unshelled) _______________ Highest Price (unshelled) _______________

    Lowest Price (shelled) _________________ Highest Price (shelled) _________________

G. MARKETING

40. Are you able to sell your produce now more easily than a decade ago?
    1. Yes
    2. No

41. Do you grade/sort your produce/product before selling?
    1. Yes
    2. No

42. Do you now have more easy access to new technology than in the last decade?
    1. Yes
    2. No
    3. Cannot tell

H. USE OF INCOME IN THE HOUSEHOLD

43. How do you spend the money **you** earn from the sale of groundnuts and groundnut-related products from **your individual plot(s)** within the household? (CIRCLE ALL THAT APPLY) Please indicate the portion/percentage of expenditures for each category.
    1. Food items ____
    2. Alcohol and tobacco ___________________________________
    3. Health expenses _______________________________________
    4. Children clothes, school fees and books ___________________
    5. Personal clothing items _________________________________
    6. Household items ______________________________________
    7. Housing issues _______________________________________
    8. Hire labor ____
    9. Purchase farming inputs (such as seeds, fertilizer, pesticides or machinery) ____
    10. Other (Please Specify)__________________________________

44. Who initiates the expenditure decision regarding groundnut income from your plot(s)?
    1. Myself
    2. Spouse
    3. Joint decision (myself and spouse)
    4. Other (Please Specify) ____

45. Did you give any harvested groundnut as a gift to others in 2010?
    1. Yes (Please specify the number of groundnut bowls) ___________________
    2. No

46. Have you seen any changes in your income from groundnuts over the last decade?
    1. Increase in Income
    2. Decrease in Income
    3. No Change in Income
    4. Fluctuations in Income
    5. Cannot tell

47. What was the total household income **from all sources** in 2010?

    TOTAL HOUSEHOLD INCOME (including farming, and non-farming activities)

    ____

I. EXTENSION

48. In the past 12 months, during which months did the local extension agent visit your village?

Aug. 2010	Dec. 2010	Apr. 2011	Aug. 2011
Sept. 2010	Jan. 2011	May 2011	Always
Oct. 2010	Feb. 2011	June 2011	Never
Nov. 2010	Mar. 2011	July 2011	Does Not Know

49. How many times in the last two years has an agricultural extension officer contacted you?

____

50. How many times in the last two years have you gone to the offices of the agricultural extension officer for help?

____

51. What technologies from the FFS have you used with your other crops?

____

52. Which crops have you used FFS Techniques/Technology with?

____

53. How satisfied have you been with the FFS training?
    1. Very Satisfied
    2. Somewhat Satisfied
    3. Somewhat Unsatisfied
    4. Very Unsatisfied
    5. N/A

54. How many fellow farmers or family members have you shared information with about your new practices and/or FFS technologies? (If you have participated in the FFS)

____

55. Of the farmers/persons you shared information with, how many of them do you think are using the new practices?

____

56. Do you have a way of acquiring/demanding new peanut related technologies?
    1. Yes (Please Specify Source) ________________________

2. No

Comments