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IMPACTS OF FERTILIZER SUBSIDY ON FARM-LEVEL PRODUCTIVITY AND FOOD SECURITY: A CASE STUDY OF RICE-PRODUCING HOUSEHOLDS IN NORTHERN GHANA

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Executive summary

Subsidies are policy tools that support specific sectors of an economy with the intention of revamping performance or protecting a sector. They are often criticized as ineffective policy tools since they can lead to dependency or even crowd out the private sector. Depending on the implementation strategy and the situation, policies can be beneficial, destructive, or have no apparent impact.

Despite the debate about their appropriateness as policy tools, input subsidies have been re-introduced in sub-Saharan Africa with the initial intention of mitigating the effect of global food price hikes, which peaked in 2008. The new generation of subsidy programs are expected to improve access and use of fertilizers, increase agricultural production and productivity, and ultimately improve the well-being of arable crop farmers. So far, evidence only available for countries in eastern Africa, suggests that the programs have largely succeeded in increasing productivity, production, incomes, and food security. Between 2008 and 2013, the Government of Ghana spent over United States Dollar (USD) 215 million on 724,005 metric tons (MT) of subsidized fertilizers. Justification of these expenditures is therefore necessary.

This research is motivated by the quest to provide evidence on the impacts the new subsidy programs in Western Africa. The research identifies and assesses the impacts of the *Fertilizer Subsidy Program of Ghana* on farm-level performance and food security of rice-producing households in the northern part of the country. Rice-producing households are the focus since rice is a commodity of strategic economic importance in Ghana, as well as in Africa as a whole. This is because domestic demand for rice in Ghana is far higher than domestic supply, causing a gap which is filled by imports. The cost of importing rice is paid for with scarce foreign currency. This situation may threaten national food security. The fertilizer subsidy is an imperative component of the national rice development strategy as it seeks to improve access to fertilizers with the aim to enhance productivity and production. Northern Ghana contributes about 30% of the

nation's rice production and has the potential to increase this share. Meanwhile, agriculture in northern Ghana is rain-fed and farmers struggle with declining soil fertility, which negatively impacts productivity and food security. Increasing fertilizer use through the subsidy could greatly improve the livelihoods of rice-producing households in northern Ghana.

This research begins with an exploratory study on determinants of fertilizer adoption among 330 smallholder farmers. This exploratory study is, however, less robust since the sampled households were likely to be beneficiaries of a soil health project from the Alliance for a Green Revolution in Africa (AGRA) and, selectivity bias associated with participation in the subsidy program was not accounted for. The study however shows that fertilizer adoption decisions are in two stages. It recommends the need for regular training of members of farmer based organizations as a way of improving farm-level performance through the adoption of fertilizer. This recommendation is more general as it does not analyze any specific agricultural production system. The study provides useful insights on the design of activities and on analytic procedures which address the core questions of this research.

Chapter 3 contains a more in-depth study of fertilizer use in rice-growing households. It examines the role of the fertilizer subsidy program in fertilizer adoption decisions based on data from a cross-section of 820 systematically selected rice-producing households. The analyses show that these rice-producing households use different combinations of fertilizers. Overall, nearly 67% use at least one type of fertilizer and 44% use a combination of nitrogen-phosphorus-potassium (NPK) and ammonium (NH4) fertilizers. Using Cragg's two-step regression models, the fertilizer subsidy program is shown to increase the probability and intensity of fertilizer adoption. The study shows that effective adoption of the recommended combination of NPK and NH4 fertilizers can be achieved by linking farmers to training programs on good agricultural practices. Moreover, enhancing access to information and complementary technologies can improve adoption of the recommended fertilizer combination.

Chapter 4 assesses the impact of the program on farm-level productivity and computes partial factor productivity of land and labor using the same database as the previous chapter. The average land productivity of rice, 1,309 kg/ha, is still below the national and global average of 2,539 kg/ha and 4,548 kg/ha, respectively. Correcting for endogeneity of participation in the fertilizer subsidy program, the estimated local average treatment effect (LATE) impact parameters show that the fertilizer subsidy increases land productivity modestly and decreases labor productivity. Increased access to fertilizers requires the use of additional labor for fertilizer application. The negative impact of the subsidy program on productivity may be because yield increases are not enough to compensate for the extra labor employed. Including the provision of labor saving technologies and intensive training in productivity enhancing techniques as part of fertilizer subsidy programs may help unleash the full benefits of the program.

Chapter 5 examines the impact of the program on food security. More specifically, a sample of 740 rice-producing households is used to compute the amount of calories, proteins, and fats consumed in the abundant, normal, and lean periods of the year. The results show that at any point in time, some households are food insecure. The incidence of food insecurity is highest during lean periods and lowest during periods of abundance, implying instability in household food security throughout the year. Most households have adequate access to calories and proteins, although the majority does not have access to an adequate amount of fats. Improving the crop mix to include crops that can provide adequate access to these nutrients is recommended to improve food security. This part of the research also used the LATE procedure to estimate the impact of the subsidy program on food security. The results show a positive impact of the subsidy program on the nutritional value consumed food and the effect is highest during the lean period.

In conclusion, this thesis shows that the fertilizer subsidy program is effective at increasing the adoption of fertilizers. The program increases the land productivity of rice, but decreases labor productivity. The subsidy leads to significant improvements in the food security of rice-producing households. Linking fertilizer subsidy programs to productivity enhancing interventions and the availability of complementary technologies is necessary to maximize its impact. Technology adoption studies should endeavor to consider technologies as a package, instead of individual components. Going forward, it is recommended that the Government should compare the cost effectiveness of the subsidy program to alternative policy options, such as rice importation, to guide the allocation of scarce financial resources.

The focus of this study on lowland rice-ecologies in northern Ghana limits the ability to extend the recommendations to other rice ecologies and to the country as a whole. Nevertheless, the recommendations may be useful for neighboring countries which have similar ecologies, such as Ivory Coast, Burkina Faso, Togo, Benin, and Nigeria.

Zusammenfassung

Subventionen sind wirtschaftspolitische Maßnahmen, die eingesetzt werden um spezifische Sektoren eines Wirtschaftssystems zu unterstützen; entweder mit der Absicht, die wirtschaftliche Leistung des Sektors umzugestalten oder um den Sektor zu schützen. Allerdings werden häufig Subventionen als ineffiziente Maßnahmen kritisiert, da sie in die Abhängigkeit führen oder gar den Privatsektor verdrängen könnenoften. Tatsächlich können sich Subventionsmaßnahmen, abhängig von ihrer Implemetierungsstrategie, sehr förderlich oder sehr destruktiv auswirken.

Trotz der bestehenden Auseinandersetzungen über die Zweckmäßigkeit von Betriebsmittelsubventionen wurden diese in Subsahara-Afrika mit der ursprünglichen Absicht wiedereingeführt, die Auswirkungen der weltweiten Lebensmittel Preissteigerungen abzumildern, die im Jahr 2008 den Höchststand erreichten. Es wird erwartet, dass die neue Generation von Subventionsprogrammen, auch „intelligente Subventionen“ genannt, den Zugriff auf und die Nutzung von Düngemitteln verbessern wird, womit eine Steigerung der landwirtschaftlichen Produktion und Produktivität erreicht würde. Letztendlich würde dies in einer Steigerung des Wohlbefindens der Begünstigten resultieren.

Bislang zeigen die vorliegenden Daten, dass die Programme im östlichen und südlichen Afrika größtenteils erfolgreich waren, was die Steigerung der Produktion und Produktivität, sowie Einkommen und Nahrungssicherheit betrifft. Seit dem Inkrafttreten der Programme im Jahr 2008 bis ins Jahr 2013 hat der ghanaische Staat 215 millionen USD für insgesamt 714.005 Mt subventionierter Düngemittel ausgegeben. Es besteht daher die Notwendigkeit, diese hohen Ausgaben zu rechtfertigen.

Die vorliegende Forschungsarbeit möchte Nachweise für die Auswirkungen der neuen Subventionsprogramme in Westafrika erbringen. Im Wesentlichen werden die Auswirkungen des Düngemittel-Subventionsprogrammes in Ghana auf Betriebsebene sowie die Nahrungssicherheit von Reisproduzenten im Norden des Landes untersucht. Dieser Schwerpunkt ergibt sich aus der Tatsache, dass Reis ein Rohstoff von hoher wirtschaftsstrategischer Relevanz in Ghana und in ganz Afrika ist. Die heimische Nachfrage nach Reis ist bedeutend höher als das heimische Angebot, und um die Angebotslücke zu schließen, ist es notwendig, knappe Devisen darauf zu verwenden um Reis zu importieren. Diese Situation kann die nationale Nahrungssicherheit gefährden.

Düngemittelsubventionen sind in der nationalen Entwicklungsstrategie entscheidend, da sie den Zugang zu Düngemitteln vereinfachen und damit die Produktion und Produktivität steigern sollen. Nord-Ghana trägt mit ca. 30% zur heimischen Reisproduktion bei und hat das Potenzial, diesen Anteil noch zu erhöhen. Unterdessen ist die Landwirtschaft in diesem Teil des Landes regenbewässert, und die Landwirte haben mit abnehmender Bodenfruchtbarkeit zu kämpfen, was sich negativ auf die Produktivität und Nahrungssicherheit auswirkt. Zunehmende Einsatz von Düngemitteln durch Subvention könnte das Leben der Reisproduzenten in Nord-Ghana erheblich verbessern.

Der vorliegenden Arbeit beginnt eine explorative Studie über die Determinanten des Subventionsprogramms bei 330 Kleinbauern voran. Diese Studie ist jedoch nur bedingt aussagekräftig, da die befragten Haushalte höchstwahrscheinlich Nutznießer eines Bodengesundheitsprojekts der „Alliance for a Green Revolution in Africa“ (AGRA) sind. Zudem wird die potentielle Verzerrung, die durch die Teilnahme am Subventionsprogramm zustandekommt, nicht berücksichtigt. Die Studie zeigt, dass bei Entscheidungen zur Aufnahme der Düngemittelverwendung zwei Phasen durchläuft werden.

Auf den Forschungsergebnissen basierend empfielt die Studie regelmäßige Schulungen für Mitglieder von landwirtschaftlichen Organisationen als Möglichkeit, die Leistungsfähigkeit auf Betriebsebene hinsichtlich der Düngemittelanwendung zu erhöhen. Diese Empfehlung ist eher allgemein gehalten und zielt nicht auf ein bestimmes landwirtschaftliches Produktionssystem ab. Allerdings liefert die Studie hilfreiche Einblicke, die als Orientierungshilfe für den Aufbau der Forschungsaktivitäten und die analytischen Verfahren im Hinblick auf die Kernfragen der vorliegenden Dissertationsforschung dienten.

In einer präzisierten Studie wird die Rolle der Düngemittel-Subventionsprogramme bei Entscheidungen zur Düngemittelübernahme untersucht in Kapitel 3. Hierfür wird ein Querschnittsdatensatz von 820 systematisch ausgewählten Reisproduzenten verwendet. Die Datenanalyse zeigt, dass die Reisproduzenten verschiedene Düngemittelkombinationen verwenden. Insgesamt fast 67% der Haushalte verwendet mindestens eine Art von Düngemittel, während 44% eine Kombination aus NPK und NH4 Dünger. Unter Anwendung des Heckman-Zweistufen-Verfahrens zeigt sich, dass das Düngemittelförderprogramm die Wahrscheinlichkeit der Düngemittelübernahme, sowie die Intensität der Anwendung erhöht. Eine tatsächliche Übernahme der Anwendung von NPK und NH4 Düngemitteln, der empfohlenen Kombination, kann durch Verknüpfung mit Schulungsprogrammen zu guten landwirtschaftlichen Praktiken erreicht werden. Darüber hinaus kann die Verbesserung des Zugangs zu Informationen und zu ergänzendem Technologieeeinsatz die Übernahme der empfohlenen Düngemittelkombination verbessern.

Der nächste Schritt in der vorliegenden Forschungsarbeit ist eine Bewertung zum Einfluss des Subventionsprogramms auf die Produktivität auf Betriebsebene. Unter Verwendung desselben Datensatzes berechnet dieser Bestandteil der vorliegenden Dissertationsforschung die partielle Faktorproduktivität von Fläche und Arbeitskraft. Die durchschnittliche Flächenproduktivität von 1.309,44 kg/ha liegt unter der nationalen

Flächenproduktivität von 2.538,58kg/ha und der globalen Faktorproduktivität von 4.547,80 kg/ha. Berücksichtigt und korrigiert man die Endogenität der Teilnahme am Düngemittel-Subventionsprogramm, zeigen die geschätzten Einflussparameter des lokalen durchschnittlichen Behandlungseffekts (LATE), dass die Düngemittelsubventionen die Flächenproduktivität mäßig steigern, jedoch die Arbeitsproduktivität senken.

Düngemittelsubventionen reichen offensichtlich nicht aus, um die Produktivität auf Betriebsebene in Nord-Ghana zu erhöhen. Es wird eher eine überproportionale Nutzung an Arbeitskraft gefördert. Die Bereitstellung arbeitssparender Technologien und intensive Schulungen zu produktivitätssteigernden Techniken als Bestandteil der Subventionsprogramme könnte dabei helfen, den vollen Nutzen des Programms zu entfalten.

Zu guter Letzt werden in der vorliegenden Arbeit die Auswirkungen des Programms auf die Nahrungssicherheit untersucht. Hierfür wird ein Datensatz von 740 Reisproduzenten verwendet, um die Mengen an Kalorien, Proteinen und Fetten zu berechnen, die jeweils in Zeiten der Fülle, in normalen Zeiten und in weniger ergiebigen Zeiten konsumiert werden. Die Ergebnisse zeigen, dass manche Haushalte zu einem beliebigen Zeitpunkt an Nahrungsunsicherheit leiden. Natürlich ist die Häufigkeit während der weniger ergiebigen Zeiten höher und in Zeiten der Fülle niedriger, was impliziert, dass die Ernährungssicherheit der Haushalte instabil ist. In Bezug auf die drei betrachteten Nährstoffe war zu sehen, dass die meisten der Haushalte ausreichenden Zugang zu Kalorien und Proteinen haben. Jedoch hatte die Mehrheit der Haushalte keinen Zugang zu ausreichenden Fettmengen. Eine ideale Möglichkeit um die Ernährungssicherheit zu erhöhen, wäre, das Anbauspektrum dahingehend zu verbessern, dass Feldfrüchte, welche diese essentiellen Nährstoffe enthalten, mit eingeschlossen werden. Für diesen Teil der Arbeit wurde wieder das LATE Verfahren angewendet, um die Auswirkungen des Subventionsprogrammes auf die Nahrungssicherheit zu bewerten. Es wurden positive

Auswirkungen festgestellt. In der Tat zeigt sich, dass der Einfluss in den weniger ergiebigen Perioden größer ist.

Abschließend zeigt die vorliegende Arbeit, dass das Düngemittelsubventionsprogramm bezüglich der steigenden Übernahme zur Anwendung von Düngemitteln generell wirkungsvoll ist. Das Programm steigert die Flächenproduktivität marginal, aber verursacht eine überproportionale Nutzung an Arbeitskräften. Das Subventionsprogramm führt zu eine signifikante Verbesserung der Nahrungssicherheitssituation der Reisproduzenten. Eine Verknüpfung der Subventionsprogramme mit Interventionen zur Erhöhung der Produktivität, sowie die Zugänglichkeit zu ergänzenden Technologien ist notwendig, um den Einfluss der Programme zu maximieren. Studien zur Technologieübernahme sollten bestrebt sein, Technologien als Paket zu untersuchen statt nur einzelne Komponenten aufzugreifen. Hinzunfügend wird empfollen, dass die Regierung die Kosten des Subventionsprogram mit alternative Programme, wie beispielsweise der Import von Reis, vergleicht um die Verteilung knapper finanzieller Resourcen zu lenken.

Da der Schwerpunkt der vorliegenden Arbeit auf Raisanbaustrukturen im Flachland Nord-Ghanas liegt, sind die Handlungsempfehlungen nur begrenzt auf andere Reisanbauregionen bzw. das gesamte Land erweiterbar. Auf jeden Fall sind die Empfehlungen relevant für Nachbarstaaten mit ähnlichen Anbaustrukturen, wie zum Beispiel die Elfenbein küste Togo, Benin, Burkinafaso und Nigeria.

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Appendix

Abbreviations

AfricaRice	Africa Rice Center
AGRA	Alliance for a Green Revolution in Africa
ATE	Average treatment effect
AU	African Union
DiD	Difference-in-differences
CAADP	Comprehensive Africa Agriculture Development Program
CFS	Committee on World Food Security
CSIR	Council for Scientific and Industrial Research
FAO	Food and Agricultural Organization
IV	Instrumental variable
JEL	Journal of Economic Literature
LARF	Local average response function
LATE	Local Average Treatment Effect
MOF	Ministry of Finance
MOFA	Ministry of Food and Agriculture
MT	Metric tons
NH4	Ammonium
NPK	Nitrogen-Phosphorus-Potassium
PFP	Partial Factor Productivity

PSM	Propensity score matching
SARI	Savanna Agricultural Research Institute
SRID	Statistics, Information and Research Directorate
TFP	Total Factor Productivity
USD	United States Dollar
WFP	World Food Program

Chapter 1: Introduction

1.1 Background

Subsidies are policy tools used to support specific sectors or socio-economic groups of an economy. They can be in the form of direct or indirect cash transfers (Holden and Lunduka, 2012; Baird et al., 2009), or tax reduction (Gruber and Levitt, 2000) and can be targeted at institutions, businesses, or individuals. They are generally introduced to promote growth in specific industries (Bergström, 2000), improve the competitiveness of indigenous industries, revive failing industries, and to encourage firms or industries to be environmentally conscious (Schrank, 2003). These objectives have implications on the welfare of beneficiaries (individuals or group), industries, government expenditures, and the overall economy.

Regardless of their potential benefits, subsidies are criticized as inefficient means of allocating scarce public resources and can result in negative effects on social and environmental resources (Minot and Benson, 2009). This assertion is espoused by Clark et al. (2005) who examine the buyback fisheries policy of the United States of America, showing that buyback subsidies are over-rated resource management tools that reduce economic performance and resource conservation, particularly if fishermen can anticipate the benefits.

Empirical evidence finds varying outcomes of subsidies. Most studies find little or no effect and some find negative effect on intended outcomes. A simulation analysis of the impact of a fertilizer subsidy in the Philippines by Rosegrant and Herdt (1981) show that the subsidy increases rice yields, particularly for irrigated farms. Busom (2000), on the other hand, shows that a research and development subsidy does not necessarily increase firm size in Spain, but may instead crowd-out firms. Ricker-Gilbert et al. (2010) further show that crowding-out effect of fertilizer subsidies on commercial fertilizer is higher among non-poor farmers, suggesting the need to target subsidies to poor farmers. On the contrary, Bergström (2000) finds a positive relationship between capital subsidies and firm growth, but find no effect on productivity. Microfinance subsidies are shown to improve the efficiency of institutions, but negative effects are observed beyond a certain threshold (Hudon and Traca, 2011).

The contrasting effects of subsidies have partly been attributed to implementation strategies (Druilhe and Barreiro-Hurlé, 2012). A rigorous and independent evaluation of the impacts of such programs on the welfare of beneficiaries is recommended (Chirwa, 2010). Indeed, the validity of the empirical methodologies applied in the evaluation of subsidy programs in terms of their ability to address the problem of selection bias cannot be ignored. Structural models that account for the assignment of treatment have thus been recommended (Klette et al., 2000).

Despite criticism and uncertain outcomes, subsidies on agricultural inputs, including seeds and chemical fertilizers (Rashid et al., 2013), have been re-introduced in sub-Sahara Africa. The subsidies were initially intended to mitigate the effect of global price hikes on vulnerable households. This new generation of input subsidies (Druilhe and Barreiro-Hurlé, 2012) is intended to facilitate access and use of the inputs, increase farm productivity and food production, and enhance food security among beneficiary farmers (Banful, 2008). Similar to other subsidy programs, available evidence provides contrasting results on outcomes of the input subsidy programs, particularly in eastern Africa.

In general, available evidence suggests that fertilizer subsidies for instance have increased fertilizer use, yields, and agricultural production. However, the success of the subsidy programs depends on implementation strategies (Druilhe and Barreiro-Hurlé, 2012). For example, Jayne and Rashid (2013) show that the costs of subsidy programs in sub-Sahara Africa outweigh the benefits. They suggest a revision of implementation strategies to include complementary investment in agricultural intensification. The negative effect of fertilizer subsidy on maize prices in Malawi and Zambia (Ricker-Gilbert et al., 2013) may have accounted for this observation by Jayne and Rashid (2013). In a synthesis of the effect of subsidies on fertilizer use in Kenya, Malawi, and Zambia, Jayne et al. (2013) find that some subsidy recipients re-sell subsidized fertilizers. The study indicated that the impact of the program can be overestimated if this diversion is not accounted for in the analysis. Another review by Lunduka et al. (2013) shows that the fertilizer subsidy program of Malawi causes dramatic increases in maize production at the national-level, but productivity increases at the farm-level are modest.

In Zambia, subsidy for hybrid maize seeds is shown to have high private and social benefit-cost ratios at the household-level (Mason and Smale, 2013). Denning et al. (2009) attributed an increase in national maize productivity in Malawi to the county's input subsidy program. The impact of the subsidy program is shown to be higher among poorer households. In a simulation analysis, Housou and Zeller (2011) shows that targeting the poor and smallholder farmers may improve cost efficiency. Further simulation analyses show that the program has a greater indirect beneficial effect in areas with high incidence of poverty (Dorwad and Chirwa, 2013).

With the exception of Nigeria, where subsidy on seeds is shown to increase household income (Awotide et al., 2013), most studies on the new generation of subsidy programs have focused on countries in eastern Africa. In the case of the *Fertilizer Subsidy Program of Ghana*, existing evidence of impacts is not yet available. Two studies have evaluated the effectiveness of the implementation process without estimating impacts on program indicators (Yawson et al., 2010; Banful, 2008). The interest in the program can be sustained if there is information on its outcome. This thesis aims at contributing to filling this knowledge gap by examining the impacts of the program on farm-level performance and household well-being.

1.2 The Fertilizer Subsidy Program of Ghana

Fertilizer subsidy programs are part of a set of strategies adopted by African governments to mitigate the effect of global food and input price hikes on farmers (AU, 2006). In July of 2008, the Government of Ghana instituted a nationwide subsidy on four types of inorganic fertilizers (NPK 15:15:15, NPK 23:10:05, urea, and sulphate of ammonia) (MOFA, 2013). The subsidy was implemented through region-specific vouchers with face values that represented approximately 50% of the retail price of fertilizers. In the first year, arable crop farmers received vouchers from the agricultural extension agents of the Ministry of Food and Agriculture (MOFA), which enabled them to buy specific quantities of fertilizers. A voucher could be used to purchase the specific fertilizer from any retailer in the region where the voucher was issued. The retailers then passed on the redeemed vouchers to an importer or dealer who transmitted an invoice to MOFA for payment (Banful, 2008).

A year after its implementation, there were calls by stakeholders in the agricultural sector to reform the implementation process. This was mainly due to challenges with the distribution of vouchers. It was observed that the officials of MOFA kept the vouchers to themselves and in some cases sold the vouchers at much higher prices. In some instances, extension agents distributed the vouchers to their favorite farmers. Moreover, regardless of their needs, every farmer was entitled to only one voucher which could only purchase 50kg of a specific fertilizer. These factors combined with fertilizers shortages compelled farmers to buy fertilizers at rather high prices (Yawson et al., 2010).

To address these challenges, in 2009 the Government withdrew the fertilizer vouchers and replaced them with subsidized fertilizer price announcements in June of every year through written communication to the regional and district directorates of MOFA. Subsidized prices are effective until the end of the major cropping season in September. Under the current program, farmers are not limited by the quantity they can purchase (MOFA, 2010).

Unlike eastern Africa where subsidies sought to target poor smallholder farmers (Jayne and Rashid, 2013), the program was universal in Ghana: all arable farmers were eligible to participate in the program. Between 2008 and 2013, the Government of Ghana spent USD 215,147,581 on a total of 724,005 MT of subsidized fertilizers. Albeit without an in-depth analysis, observed growth in the agricultural gross domestic product of about 4.7%

over the same period as well as increases in yields and the production of arable crops (MOFA, 2013) can be attributed in part to subsidy program.

1.3 Problem statement

Among the arable crops supported by subsidy programs in Ghana and across Africa, rice stands out as a crop of strategic economic importance. Records show continuous growth in the share of Africa in global rice imports due to deficits in domestic supply (FAO, 2012). In Ghana, rice demand is projected to grow at an annual rate of 11.8% between 2010 and 2015 (ISSER, 2011). This has been attributed to rapid population growth, urbanization, and changing food preferences (Bam et al., 1998). Apart from food, the rice industry is also a source of employment and income for actors in the value chain (Asuming-Brempong and Osei-Asare, 2007). The availability of rice throughout the year has significant implications on food security in Ghana.

Rice cultivation in Ghana is organized under three ecologies, namely, rain-fed upland, rain-fed lowland, and irrigated (Marfo et. al., 2008). The first two ecologies contribute nearly 90% of total rice production and occupy more than 75% of the total rice area. Cultivation in the lowland ecology is characterized by small land holdings (field sizes are between 1.5 and 5 ha), inadequate use of yield enhancing technologies, and low yields (between 0.5 and 1.5 tons/ha) (Bonman et. al., 1992). Improving access to fertilizers, through the subsidy program, should contribute significantly to increasing yields.

Nearly 30% of Ghana's rice production is obtained from the three regions in northern Ghana namely, Upper East Region, Upper West Region, and Northern Region (MOFA, 2013). The soils in these regions are, however, poor and cannot sustain crop production without soil amendments through the use of fertilizers (Langyintuo and Dogbe, 2005). The regions also have a high incidence of poverty and food insecurity (WFP, 2013). The fertilizer subsidy program should have significant impact on farm-level performance and the well-being of farm households in the three regions.

The subsidy program is intended to contribute to efforts to boost domestic rice production by the Government of Ghana. In addition to mitigating the effect of global food and input price hikes on farmers, the program is expected to bridge the widening gap between domestic rice demand and supply through increases in rice productivity and production. The subsidy program should therefore contribute to the fight against poverty and food insecurity among beneficiary farm households in the country.

The fertilizer subsidy program absorbs 50% of the cost of fertilizer, reducing the total cost of arable crop production. To justify continuous investments in the program, the Government of Ghana and development partners must be convinced about the contribution of the program to fertilizer adoption decisions, and impacts on farm-level performance and welfare of arable crop producers. As mentioned hitherto, this study provides the first quantitative evidence of impacts of the *Fertilizer Subsidy Program of Ghana*.

1.4 Research questions, hypotheses, and objectives

During a cropping season, farmers make decisions on the types and quantities of inputs to use. For improved technologies, such as fertilizers, farmers face two levels of decisions; the first level is the decision of whether to adopt or not to adopt; and the second level of the decision is the amount of application. While some studies argue that these decisions are separate, others argue that the decisions are joint (Tambo and Abdoulaye, 2011; Fufa and Hassan, 2006). This study explores the separability of the two levels of fertilizer adoption decisions.

As mentioned above, the *Fertilizer Subsidy Program of Ghana* is expected to increase access and use of fertilizers, productivity and production, farm and household incomes, and food security. The motivation of this thesis is that these expectations have thus far not been investigated. The lack of evidence is particularly apparent for rice-producing households in northern Ghana. To reduce this knowledge gap, this thesis provides answers to four critical questions:

1. Are fertilizer adoption decisions in two steps?
2. What influences the decision of rice-producing households to adopt fertilizers while the *Fertilizer Subsidy Program of Ghana* was in place?
3. How has the fertilizer subsidy impacted farm-level productivity among rice-producing households in northern Ghana?
4. How has the fertilizer subsidy impacted food security among rice-producing households in northern Ghana?

Based on these questions the thesis tests the following hypotheses.

1. Ho: Fertilizer adoption decisions are made in a single step; Ha: Fertilizer adoption decisions are made in two separate steps.
2. Ho: The fertilizer subsidy has no effect on fertilizers adoption decisions of rice-producing households; Ha: The fertilizer subsidy increases fertilizer adoption among rice-producing households.
3. Ho: Farm-level productivity of rice-producing households is the same for participants and non-participants of the subsidy program; Ha: Farm-level productivity of participants is higher than that of non-participants.
4. Ho: Household food security for rice-producing households is the same for participants and non-participants of the subsidy program; Ha: Household food security of participants is higher than non-participants.

To address the four research questions above, this thesis primarily evaluates impacts of the fertilizer subsidy program on farm-level productivity and food security among a cross-section of randomly selected rice-producing households in northern Ghana. More specifically, the thesis:

1. Explores the separability of fertilizer adoption decisions among farm households in northern Ghana;
2. Examines determinants of the probability and intensity of fertilizer adoption among rice-producing households in northern Ghana, under the subsidy program;
3. Estimates the impact of the subsidy program on farm-level productivity among the rice-producers in northern Ghana; and

4. Estimates the impact of the subsidy program on household food security among rice-producers in northern Ghana.

1.5 Overview of key concepts

This thesis relies on four main concepts, namely, adoption, productivity, food security, and impact. These concepts are briefly discussed in this section.

1.5.1 Adoption of improved technologies

When a new agricultural technology is introduced, farmers decide whether to adopt or not to adopt it. Most studies represent the adoption decision with a binary variable (i.e., 1 for adoption and 0 for non-adoption) to examine the incidence or probability of adoption among potential beneficiaries (Akinola et al., 2012; Arora and Bansal, 2012; Dibba et al., 2012; Mzoughi, 2011; Rezvanfar et al., 2009). The intensity of adoption has also been represented by the amount of resources (e.g. time, land or capital) allocated to technologies (Tambo and Abdoulaye, 2011; Mussei et al., 2001; Kristjanson et al, 2005).

The adoption decision process has been shown to be affected by characteristics of farm households, such as gender, age, experience, skills, household size, education, farm size, capital, and income. In rural households, male farmers have relatively better access to productive resources that can easily be invested into new technologies. The resources of a household in terms of its size, farm size, capital, skills, and incomes also present opportunity to invest in improved technologies. Experience, sometimes represented by age, informs the need for improved technologies and can increase the probability and intensity of adoption. Education can enable better understanding of the benefits and application of technologies (Wandji et al, 2012; Mzoughi, 2011; Tambo and Abdoulaye, 2011; Wetengere, 2010).

Accessing information on the availability and rubrics of technologies through institutions such as farmer associations, extension services, and markets can influence adoption decisions. Experience and knowledge also shape perceptions, which have been found to affect adoption decisions. For example if a farmer has experienced the benefits of fertilizers in general, that farmer will easily develop a positive perception and expectation about recommended rates of application (Wandji et al, 2012; Mzoughi, 2011; Tambo and Abdoulaye, 2011; Wetengere, 2010; Salasya et al, 2007; Kaliba et al, 2000; Adesina, 1993).

For a cross section of respondents, regression procedures such as logit and probit regression models have been used to estimate the probability of adoption. On the other hand, Tobit regression models have been used to estimate the decision on the intensity of adoption (Mzoughi, 2011; Kristjanson et al., 2005; Adesina, 1993). In an attempt to correct for sample selection bias, Tambo and Abdoulaye (2011) applied Heckman's sample selection model to estimate the probability and intensity of adopting drought tolerant maize varieties in Nigeria. Sample selection bias in this case is due to the assumption that the intensity of adoption of the technology depends on the probability of adoption. Because the intensity of adoption is not random in the sample, Heckman's sample selection model is required to correct for the associated bias. In the absence of selectivity bias, Cragg's two-step model presents a less restrictive estimation of the determinants of the probability and intensity of adoption (Cragg, 1971).

In this thesis, it is assumed that the probability and intensity of fertilizer adoption are separate decisions. The sets of factors that influence the two decisions are therefore expected to differ. Determinants of adoption decisions are therefore examined with two-step regression models.

1.5.2 Agricultural productivity

Productivity is generally defined as output per unit of aggregated input, i.e., Total Factor Productivity (TFP), and output per unit of a single input, i.e., Partial Factor Productivity (PFP) (Key and McBridge, 2003). Regardless of flaws in imperfect market prices, TFP accounts for the overall effect of inputs in a production process and can also be decomposed into technical and allocative efficiency indices (O'Donell, 2011). Different

PFP measures can produce conflicting policy recommendations; however, if they are carefully constructed, they can be legitimate measures of variation in output (Nin et al., 2003).

Productivity has been used to measure and compare performance across countries, industries, firms, and farming systems (Brambilla and Porto, 2006; Escribano and Guasch, 2005; Restuccia et al., 2008). Regression procedures with cross sectional, panel, and time series data have also been used to identify socioeconomic, institutional, and technical factors as determinants of productivity (Van den Ban and Hawkins, 1996; Kimhi, 2003; Restuccia et. al., 2008).

A typical rice-producing household in northern Ghana cultivates rice, other cereals, and sometimes vegetables on different plots of land. The same equipment, i.e., hoes, cutlasses, knapsack sprayers, etc., are used on all these plots. Farmers are usually unable to report the percentage of inputs used on different plots (Akramov and Malek, 2012). As such, computing TFP for rice will be erroneous. Instead, PFP is a more feasible measure of productivity.

1.5.3 Household food security

Food security exists when all people, at all times, have access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 2008). This definition contains four main aspects of food security: availability, access, utilization, and stability (FAO, 2008). Codjoe and Owusu (2011) describe: food availability as the existence of food stocks for consumption; food access as the ability to acquire sufficient quality and quantities of food; and food utilization as the capacity to make use of food for a productive life. Food stability refers to the continuous availability of food under all conditions (FAO, 2008).

These aspects of food security have been examined with measures of income, food expenditure (Feleke et al., 2005), dietary diversity scores (Moursi et al., 2008), calorie intake (van der Veen and Tagel, 2011; Babatunde et al., 2010), and perception (Rahim et al., 2011) at national-, community-, household-, and individual-levels. Regression procedures have also been used to identify determinants of food security (Amaza et al., 2009). Dietary diversity scores provide information on the nutritional value of food consumed (Moursi et al., 2008) without indicating adequacy of the amount consumed.

Measures of adequate food consumption can be provided by food and non-food expenditures, calorie intake, and perception, yet these measures are limited in terms of information on nutritional value. This thesis explores a food security measure that capture both nutritional value and the amount consumed, namely, quantities of calories, proteins, and fats consumed. It is also argued that the quantity of food consumed as a measure of access, better represents reality than food availability. Moreover, the thesis provides a description of stability of the food consumption.

1.5.4 Estimating the impact of interventions

Studies have shown that development interventions can cause significant changes in behavior, performance (Davis, 2010), food security (Amaza et al., 2009), and poverty (Awan et al., 2011). Some of these studies have applied regression procedures to evaluate the mean difference in observed outcomes for beneficiaries and non-beneficiaries. The results from such analyses have been shown to be characterized by selection bias and are therefore inefficient estimates of the causal effects of the interventions (Imbens, and Wooldridge, 2009). Selection bias in this case is due to the fact that participation in the program is not randomly assigned.

In an attempt to deal with the problem of selection bias, methodologies based on the counterfactual outcome framework have been used to estimate the average treatment effect (ATE) impact of interventions on expected outcomes. Among the methods, randomized evaluation is highly recommended because of its potential to minimize selection and unobserved biases (Duflo et al., 2006). In the absence of randomization, quasi-experimental methodologies, such as propensity score matching (PSM) (Abadie and Imbens, 2006), difference-in-differences (DiD) (Athey and Imbens, 2006), and instrumental variable (IV) regression (Brooks and Chrischilles, 2007) are common methods to produce consistent estimates of impacts from interventions.

The *Fertilizer Subsidy Program of Ghana* is universally assigned, such that all farmers have the opportunity to decide whether to participate or not. This presents an endogenous selection problem. To account for this bias, an instrumental variable regression based approach is used to estimate the impact of the program on farm-level productivity and household food security among rice-producing households in northern Ghana.

1.6 Organization of the thesis

This thesis is organized in six chapters. The following chapter is an exploratory study which examines fertilizer adoption decisions among smallholder farmers. It applies Cragg's double hurdle regression model to examine the probability and intensity of fertilizer adoption. The study provides an important basis for a detailed assessment of fertilizer adoption. This is because it is not restricted to a specific production system, thereby providing a more general view of the fertilizer adoption process. This chapter is based on a paper which is published in *Sustainable Agricultural Research* (Martey et al., 2014).

Chapter 3 focuses on rice-producing households in northern Ghana and presents improvements in the methodology by identifying the most common fertilizer combination adopted by rice-producing households. It also uses Cragg's model to estimate the determinants of fertilizer adoption in general as well as adoption of the combination of NPK and NH4 fertilizers. It controls for the effect of participation in the *Fertilizer Subsidy Program of Ghana* on adoption. This is absent from the analyses in Chapter 2. A paper from this chapter has been accepted for publication in *Quarterly Journal of International Agriculture*.

Chapter 4 presents empirical evidence of the impact of the *Fertilizer Subsidy Program of Ghana* on farm productivity. Due to price distortions, partial factor productivity indices for land and labor are examined. Participation in the subsidy program presents an endogeneity problem. To account for this bias, instrumental variable based regression is applied. The nature of the program and the characteristics of the rural farm communities that are studied suggest a natural experiment. As such, the local average treatment effect (LATE) estimator, which estimates the impact of the program on households who are unintentionally targeted by the program, is applied. A manuscript based on this chapter has been submitted for consideration as an article in *Agroecology and Sustainable Food Systems*.

Chapter 5 also applies the LATE procedure to estimate the impact of the subsidy program on food security. In this chapter, food security is computed in terms of quantities of calories, proteins, and fats consumed by rice-producing household. Moreover, these measures are calculated for three periods, namely, abundant, normal, and lean periods to examine the stability of food security among rice-producing households throughout the year. A paper from this chapter has been accepted for review in *Food Security*.

The thesis concludes in Chapter 6, which contains a summary of the entire research and a discussion of the main results. This includes critical policy implications and highlights the limitations of the research.

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Chapter 2: Fertilizer adoption and use intensity among smallholder farmers in northern Ghana-A case study of the AGRA Soil Health Project[1]

Edward Martey, Alexander Nimo Wiredu, Prince Maxwell Etwire, Mathias Fosu, Samuel S. J. Buah, John Bidzakin, Benjamin D. K. Ahiabor, and Francis Kusi

Abstract

Northern Ghana is characterized by food insecurity largely due to the over reliance on rain-fed agriculture under low farm input conditions. This chapter investigates the effect of factors influencing mineral fertilizer adoption and use intensity among a cross section of 330 systematically selected smallholder farmers in northern Ghana. Using Cragg's model, the probability of fertilizer adoption is shown to be determined by age, nativity, farm size, access to credit, and distance to an agricultural office. The results show that the intensity of adoption is influenced by income of the household head, membership of farmer association, distance to an agricultural office, access to an input shop, non-participation in an agricultural development project by an income earning household, and an income earning male household head. Distance to an agricultural office is a positive determinant of fertilizer adoption and use intensity. The study recommends improving road infrastructure and technical training of agricultural extension agents. Members of farmer based organizations must be trained on a regular basis to enhance their productive skills and technology uptake.

Key words: Fertilizer; adoption; soil health project; probit; truncated

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2.1 Background and problem statement

Agriculture in Ghana is organized predominantly on a smallholder basis. About 90% of farm holdings are less than 2 ha, although there are some large farms and plantations, particularly for rubber, oil palm, coconut, and cocoa, and to a lesser extent for rice, maize, and pineapples (Chamberlin, 2007). Smallholder farmers are dispersed making the provision of support services expensive and largely ineffective. Production is also mainly rain-fed with limited mechanization and inadequate use of improved technologies, such as high and stable yielding crop varieties, good agricultural practices, fertilizers, and other agro-inputs. These and other factors contributed to low levels of productivity in the agricultural sector (Chamberlin, 2007). Effective strategies that can improve farm-level performance are crucial for the overall development of the agricultural sector and well-being of farm households.

Cereals are critical for the agricultural sector in Ghana. Northern Ghana, which comprises the Northern, Upper East and Upper West regions, accounts for over 40 percent of agricultural land (MOFA, 2010) and is considered the breadbasket of the country. The area is, however, inundated with high levels of food insecurity and poverty. Nearly one million people or about half of the population of the area face annual food deficit (GSS, 2008) which is a major concern to the Government and its development partners. About 80% of the population depend on subsistence agriculture with very low productivity, and low farm income (MoFA, 2010). Annual per capita income in the area is about USD 200, which is one-third of that of Ghana (GSS, 2008). The main reason for the extreme poverty and the high incidence of food insecurity in northern Ghana stems from the over reliance on rain-fed agriculture under low farm input conditions.

Low soil fertility has also been identified as a major contributor to low yields recorded by the agricultural sector (MoFA, 2010). The soils of northern Ghana are particularly low in organic carbon (<1.5%), total nitrogen (<0.2%), exchangeable potassium (<100 ppm), and available phosphorus (< 10 ppm, Bray 1) (Adu, 1995, Benneh et al. 1990). A large proportion of the soils are shallow with iron and magnesium concretions (Adu, 1969). Soil fertility management is also sub-optimal, which also affects yields considerably. Estimates show negative nutrient balance for all crops in Ghana (FAO, 2005), suggesting escalating rates of soil nutrient mining which threatens the sustainability of agriculture and poverty reduction strategies. There are also inefficiencies and bottlenecks in fertilizer distribution networks, which limit access, and eventually increase the cost of fertilizers (FAO, 2005). These are likely to affect decisions about the use of fertilizers and other agro-inputs.

Most studies on soil fertility management have quantified the socio-economic, institutional, and production factors that influence the probability and intensity of adoption among smallholder farmers (Akpani et al., 2012; Ariga et al., 2009; Waithaka et al., 2007). Regression analyses ranging from binary to multinomial models have been proposed to study adoption behaviors of farmers. Normally, the econometric specification largely depends on the objective of the study and the type of data available (Shiferaw et al., 2008). More specifically, the studies have applied logit and probit models where the dependent variable is dichotomous, whereas the Tobit model measures the intensity of the use of a technology (Adesina and Zinnah, 1993; Kristjanson et al., 2005; Maddala, 1983; Shiyani et al., 2002; Tobin, 1958) given the restrictive assumption that the probability of adoption and use intensity are jointly determined.

This study relaxes the restrictive assumption and applies Cragg's double hurdle model (Cragg, 1971) to empirically determine fertilizer adoption and use intensity in northern Ghana. The model employed in this study is appropriate since fertilizer adoption and intensity use are two distinctive choices. It is a parametric generalization of the Tobit model in which two separate stochastic processes determine the decision to adopt fertilizer and fertilizer use intensity. The model assumes that farm households make two consecutive decisions with respect to adoption and intensity of use of fertilizer. The first hurdle involves the fertilizer adoption equation estimated by the probit model, while the second hurdle involves an outcome equation which uses a truncated model to determine the extent of the optimum use of fertilizer. According to Coady (1995) and Croppenstedt et al., (2003), the model accounts for the existence of a significant number of farmers who have positive desired demand for modern inputs, but who are too constrained to adopt them.

2.2 Method

2.2.1 Data and sampling technique

Basic information for the analysis was obtained from primary data collected in 2012, with the aid of a structured questionnaire (Appendix 1A). In addition to the survey, key informants interviews and focus group discussions were conducted to augment the household survey.

The survey was conducted within the intervention zone of a soil health project from Alliance for a Green Revolution in Africa (AGRA) in northern Ghana. The project disseminates information on improved soil management practices through field demonstrations. A total of 330 smallholder farmers were systematically selected, and interviewed. The sampling process combined purposive, stratified, and random procedures in three stages. In the first stage, 11 districts (five from the Northern region; three from the Upper East region; and three from the Upper West region) were purposively selected to include major cereal growing districts. Within each district, six communities were randomly selected. At the community level five households were randomly selected from a list of farm household obtained from community leaders. In all, 330 farmers from 66 communities were interviewed for this study.

2.2.2 Estimation of probability and intensity of fertilizer adoption

Given the assumption that the probability and intensity of fertilizer adoption are independently determined the double hurdle model is used for the analysis. In the first hurdle, an individual's decision to adopt fertilizer is dichotomous, involving two mutually exclusive decisions of whether to adopt or not to adopt. A probit regression model is used to quantify the factors influencing the probability that a sampled smallholder farmer adopts fertilizer (Asante et al., 2011). Accordingly, the dependent variable, adoption of fertilizer technology (Y), assumes only two values: 1 if the farmer adopts fertilizer and 0 if the farmer does not adopt. This is empirically expressed as:

$$Y_i = X_i\beta + \mu_i \tag{2.1}$$

where X_i represents a vector of explanatory variables, β_i is a vector of coefficients of the explanatory variables, and μ_i is the error term.

The second hurdle involves the determination of factors that influences fertilizer use intensity using a truncated regression model. This is because only positive observations of the rate of fertilizer applied by smallholder farmers, Q_i, are included in the model. The rate of application is computed as:

$$Q_i = \frac{\text{Quantity of Fertilizer Use (Kg)}}{\text{Total Area of Land (Ha)}} \tag{2.2}$$

Subsequently the truncated regression model is expressed as,

$$Q_i = Z_i\gamma + \varepsilon_i \tag{2.3}$$

where Z_i is the vector of explanatory variables hypothesized to influence fertilizer use intensity, γ is a vector of parameter estimates, and ε_i is the error term.

2.2.3 Description of explanatory variables

Age is expected to influence fertilizer use intensity positively (Adesina and Forson, 1995; Chinu and Tsujii, 2004; Fufu et al., 2006; Olawele et al., 2009). Compared to younger household heads, older household heads are more risk averse and better able to assess the attributes of a technology (Ayamga, 2006). Resource constraints may also be a limiting factor among younger household heads in terms of fertilizer use intensity though such constraints are more dynamic with regards to the decision to adopt innovations (Enete and Igbokwe, 2009).

Male household head are more likely to adopt fertilizer. Females are normally occupied with domestic activities and are also more resource (financial and human) constrained, which negatively impacts both probability and intensity of adoption. It is expected that married household heads will have a higher probability of fertilizer adoption and more intensive use of fertilizers. Married household heads are normally assisted by spouses in production, processing, and marketing decision-making. Marriage also increases a household head's concern for household welfare and food security, which is therefore likely to have a positive effect on the decision to adopt and to increase the intensity of fertilizer use (Nnadi and Akwiwu 2008).

Education is posited to have a positive effect on both fertilizer adoption and the intensity of use since it enables an individual to make independent choices and to act on the basis of the decision, as well as increases the tendency to co-operate with others (Enete and Igbokwe, 2009; Southworth and Johnston, 1967; Schultz, 1945). It is also possible that education could increase the chances of the household head earning non-farm income. Non-farm income may reduce the household's dependency on agriculture and thus its intensity of fertilizer use. It is hypothesized that more experienced farmers are more likely to adopt fertilizer technology and less likely to use fertilizer more intensively. Some agricultural extension programs use experienced farmers in the demonstration of new technologies to increase adoption. Perceived risk of adopting agricultural technologies can affects the extent of use of the technology. Nativity of household head determines access to communal resources, such as land and irrigation facility, which enhance adoption and the intensity of fertilizer use (Amanze, et al., 2010; Olawale et al., 2009; Coady, 1995)

Participation in an agricultural development project is expected to influence farmers' fertilizer adoption and fertilizer use intensity either positively or negatively. Agricultural projects usually provide crucial information to enhance the productive skills of farmers. It is also possible that a farmer may participate in a developmental project for other technical support, thus negatively impacting the fertilizer adoption and use intensity decisions. Household heads that are engaged in farming as their main occupation are more likely to adopt fertilizer. Income of the household head is positively related to fertilizer adoption and use intensity. High transaction costs in terms of transportation normally limit the extent of fertilizer use. Income earning farm households are better able to overcome the financial constraint of adopting and purchase greater amounts of fertilizer. Perception of soil fertility affects the adoption and extent of use decisions either positively or negatively.

Farm size is expected to positively influence the decision to adopt fertilizer. *Ceteris paribus*, larger farms are normally accompanied with a corresponding increase in complementary technologies. Agricultural credit is a major institutional factor limiting technology uptake by most smallholder farmers. Household heads with access to credit are more likely to adopt fertilizer. Intensity of fertilizer use is high especially among household heads with access to input credit. Livestock ownership is used as a proxy for resource endowment (Heyi and Mberengwa, 2012). Farmers who are better endowed with resources will have a higher propensity to adopt and use greater intensity of fertilizer. The household head's membership in an association increases access to information which is important for production and marketing decisions. Most farmer groups engage in group marketing, bulk purchasing of inputs, and credit provision. It is therefore expected that membership of an association will positively affect fertilizer adoption and use intensity.

Household heads with access to inputs are more likely to adopt fertilizer but may not necessarily determine the extent of fertilizer use. Distance to an input market is a major limiting factor for input purchases since it imposes high transaction costs. Fertilizer adoption and use intensity decreases with increasing distance to the nearest input market (Amanze et al., 2010; Zhou et al., 2010). Agriculture officers play a crucial role in the demonstration and dissemination of agricultural technologies. Distance to an agricultural office is expected to negatively impact both the decisions to adoption fertilizer and fertilizer use intensity due to limitations in information.

An interaction term, income with participation in an agricultural development project, is posited to influence the intensity of fertilizer use positively. Fertilizer use intensity is also hypothesized to be positively affected by the interaction term age with agricultural development project. Participation in an agricultural development project by older farm household heads will enhance their information access and as well as productive skills to guide their production activities.

Finally, the interaction term income with gender of the household head is expected to influence adoption and intensity of fertilizer use positively or negatively. Male household head who earn income are more likely to adopt fertilizer and to use fertilizer more intensively compared to female household heads who earn income. Females are generally constrained in terms of resources and will use income to enhance their household's food and nutrition security.

2.3 Results

Out of the sample of 330 selected smallholder farmers, 322 provided data that could be used for the analysis. About 97% of the households applied fertilizers on their farms. Descriptive statistics of the characteristics of the household heads show that nearly all are males, married, and natives of their communities. The average age is 49 years. The majority of the heads are not educated, yet more than 60% are members of farmer based organizations (Table 2.1).

For about 94% of the households, agriculture is the primary livelihood activity. They operate on an average of 2 ha of land and have about 30 years of agricultural experience. Fertilizers adopters apply an average of 207 kg/ha. To access amenities such as agricultural offices, markets, and input shops, they have to travel between 3 km and 13 km.

Table 2.1: Characteristics of sampled households

Characteristics	Overall (N=322)	Non-adopters (N=8)	Adopters (N=314)
Male Gender (%)	97.14	100.00	97.07
Age (years)	49.22	63.13	48.86
Marital status (%)	94.92	100.00	94.79
Educated (%)	23.17	0.00	23.78
Native (%)	97.78	100.00	97.72
Member of an association (%)	66.98	75.00	66.78
Income (USD)	1559.23	1001.9	153.75
Own livestock (%)	16.19	37.50	15.64
Access credit (%)	35.56	37.50	35.50
Distance to market (km)	6.81	8.31	6.77
Distance to agricultural office (km)	13.42	12.00	13.46
Distance to input shops (km)	3.25	5.06	3.21
Access to shops (%)	46.35	25.00	46.91
Agriculture as main (%)	94.29	94.46	87.50
Experience in farming (%)	29.50	45	29.09
Farm size (ha)	1.85	1.1	1.87
Fertilizer rate (kg/ha)	202.04	0	207.31

Table 2.2 shows the results of the Cragg's model. A quick glance at the results shows that different sets of factors influence the probability of adoption and intensity of adoption. The probability of adoption is increased by the distance to the nearest agricultural office and is decreased by increasing age of the household head, farm size, nativity of the household head, and access to credit. On the other hand, the intensity of adoption is decreased by income of the household head, access to input shops, and interaction between income and participation in agricultural development projects, and is increased

by membership in farmer association, increasing distance to the nearest agricultural office, and by the income gender interaction.

Table 2.2: Double hurdle estimates of fertilizer adoption and intensity of use

Variable	1st Hurdle (probit)		2nd Hurdle (truncated)	
	Marginal effect	Std. err.	Marginal effect	Robust Std. err.
Gender	-0.050	0.460	30.874	54.912
Age	-0.005**	0.006	-0.394	0.630
Marital	0.030	0.361	-70.466	45.608
Educational status	0.099	0.245	15.374	24.275
Years of experience	0.000	0.002	0.021	0.046
Nativity	-0.230*	0.416	-54.434	65.642
Income	0.000	0.000	-0.254***	0.007
Farm size	-0.355***	0.103		
Perception of soil fertility	-0.100	0.196	-3.940	21.244
Access to credit	-0.139**	0.188		
Ownership of livestock	-0.044	0.245	-17.251	14.923
Membership of association	0.025	0.197	37.119*	21.868
Distance to agricultural office	0.008*	0.012	1.987**	0.944
Access to input shop	-0.083	0.234	-64.292***	23.593
Distance to input shop	-0.004	0.021	-1.032	1.504
Occupational status			-41.3162	32.613
Distance to market			0.079	0.078
Income*gender			0.026***	0.007
Income*project			-0.022***	0.007
N		319		311
Wald Chi^2 (15)		100.900***		70.590***
Log Pseudo likelihood		-125.182		-1903.434

Note: *10% significant, **5% significant, and ***1% significant.

2.4 Discussion

The study shows a very high adoption incidence rate of about 97%, which is far beyond that reported by Ragasa et al. (2013). This is due to the domain of the study. It uses data drawn from households in the intervention zone of the soil health project of AGRA. The sample may have unintentionally targeted households that benefited directly or indirectly from the activities of the project. It is therefore not necessarily representative of the crop production system in northern Ghana. Nonetheless it provides an important indication of the potential effect of such projects and how they can transform attitudes of farm households.

The probability of the adoption of fertilizer is influenced negatively by the age of the household head. This result implies that older household heads are less likely to adopt fertilizer. Normally younger household heads are more dynamic and innovative in terms of technology adoption (Enete and Igbokwe, 2009). The opposite is true for fertilizer use intensity. It appears that the older household heads among the adopters are more endowed to finance larger quantities of fertilizers.

Nativity has a negative effect on fertilizer adoption. Nativity guarantees access to communal resources as well as the security of the resources. Non-native household heads usually have an informal agreement with land owners with regard to the share of farm produce after harvest. Facing this major limitation non-native household heads may be compelled to adopt and use of technologies, such as improved seed, fertilizer and good agricultural practices that guarantee higher yields.

Contrary to expectation, household head income has a negative effect on fertilizer use intensity. The result contradicted the findings of Feder et al. (1985) and Freeman and Omiti (2003) who found that wealthier farmers are capable of taking on more risks due to additional resources which they can rely upon in case of any unforeseen circumstances. Investment of financial resources, into interest earning assets, and greater demand for food and other social responsibilities are likely to explain the result of lower fertilizer use with increasing income. Male household heads who earn off-farm income are more likely to use fertilizer at greater intensity. An explanation is that these household have better access to resources, such as productive land and credit facilities, relative to their female counterparts. Wanyama et al. (2010) finds a similar. Inaccessibility to production credit limits female-headed households with respect to fertilizer use.

The results also found that fertilizer use intensity by income earning households that participated in an agricultural development project is lower than that of non-participant income earning household heads. The relatively lower use of fertilizer among these farmers may be attributed to a greater dependency on household heads coupled with attitudinal behavior which requires continuous sensitization and education. Farmers normally have wide-ranging intentions for participating in any agricultural development projects rather than aligning themselves to the specific objectives of a project. If a project is unable to meet farmers' expectations they tend to abandon the project's concept and follow their traditional farming practices. A project may contribute towards the adoption of fertilizer, but may not contribute to the intensity of fertilizer use.

Access to credit is negatively associated with the probability of adopting fertilizer. Access to farm credit is a major challenge facing smallholder farmers in the study area. It is possible that farmers with credit access are more likely to divert financial resources to other productive ventures that yield profit. Farm credit may also be used to prepare land, purchase other farm inputs, and support household food requirements. The result implies that to increase adoption of fertilizers, farmers in the study area must be supported with input credit rather than cash credit.

Fertilizer use intensity is positively influenced by membership in a farmer association. Farmer associations serve as platforms for accessing and disseminating information and technology. Most agricultural development projects in northern Ghana (such as the *Northern Rural Growth Program, Millennium Challenge Account Program, Rice Sector*

Support Project, and *Agricultural Value Chain Mentorship Project*) target farmer groups to enhance their business and technical capacity, and subsequently support them with input credit and market opportunities. Farmers belonging to associations and cooperatives have easier access to fertilizer technology, fertilizer coupons, and credit which positively effacts fertilizer adoption and use intensity.

A greater distance to the nearest agricultural office has a positive outcome on fertilizer adoption and intensity. The agricultural office serves as proxy for access to agricultural extension agents. Access to extension agents will increase farmers' awareness and information on the importance of technology adoption (Akpan et al., 2012). However, the results contradict the literature since the latter finds that distance serves as a barrier for technology adoption. It is likely that farmers depend more on neighboring farmers for useful information on fertilizer use than agricultural extension agents who are not as accessible.

The results also show that household heads that have access to input shops are not likely to intensify fertilizer use. It can be deduced from the result that access to input shop is not a guarantee to increase the intensity of fertilizer application. Studies by Akpan et al. (2012), Amanze et al. (2010), Olawale et al. (2009), and Wanyama et al. (2009), suggest that distance to point of sale for fertilizer is an influential determinant of fertilizer use intensity rather than access to an input shop. However, the present study has shown that access to input shop may not necessarily translate to greater fertilizer use intensity by smallholder farmers in northern Ghana.

2.5 Conclusion

This study revealed that the adoption of fertilizer is determined by age, nativity, farm size, access to credit, and distance to the nearest agricultural office. Fertilizer use intensity is determined by the income of the household head, membership in a farmer association, distance to the nearest agricultural office, access to an input shop, non-participation in an agricultural development project by an income earning household, and an income earning male headed household. Participation in an agricultural development project does not necessarily lead to increases in fertilizer adoption and use intensity. Distance to the nearest agricultural office also plays a major role in fertilizer adoption and use intensity in the study area.

Based on the findings in this study, it is recommended that agricultural development programs should target farmer associations as well as support them with technical training to enhance technology uptake. It is also recommended that policies should support farmers to access input on credit to increase the use of fertilizer. Improvements in infrastructure, such as roads are crucial for influencing fertilizer adoption and use intensity.

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Chapter 3: What determines adoption of fertilizers among rice-producing households in northern Ghana?[2]

Alexander Nimo Wiredu, Manfred Zeller, and Aliou Diagne

Abstract

Fertilizers remain important in global food production, yet fertilizer application rates in sub-Saharan Africa are far below the global average. This study examines determinants of the adoption of an important combination of fertilizers among 820 rice-producing households in northern Ghana. Overall, nearly 67% of rice-producing households use at least one type of fertilizer. The combination of nitrogen, phosphorus and potassium (NPK) fertilizer, and ammonium (NH4) fertilizer is the most popular with 44% adoption incidence rate. Results from Cragg's two-step regression models show that different sets of factors affect the probability and intensity of adoption. The factors also vary when fertilizer adoption in general is compared to the adoption of the combination of NPK and NH4 fertilizers. These two decisions also vary when the entire farm operation is compared to the specific farm enterprise. Factors that are found to be important in determining adoption include the *Fertilizer Subsidy Program of Ghana* and expectation about yields. Complementary technologies in the form of good agricultural practices such as drilling seeds, and harrowing fields are also shown to be important determinants of fertilizer adoption. Effective adoption of the combination of NPK and NH4 fertilizers can be achieved by enhancing access to information that will expose farm households to the benefits of complementary technologies, such as improved seeds.

Key words: Fertilizer; adoption; two-step models; Ghana

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3.1 Introduction

Fertilizers are applied to meet specific nutritional needs of crops, and to minimize potential environmental hazards of continuous cropping (Hera, 1996; Verma and Sharma, 2007). Fertilizers increase productivity (Sauer and Tchale, 2009) and investment returns in crop production systems (Olagunju & Salimonu, 2010), and ultimately enhance household, national, and global food availability (Spiertz, 2010). Therefore, fertilizer application is critical for sustaining global food security and well-being.

Strategies that ensure the effective use of fertilizers are very important, particularly in sub-Sahara Africa where low soil fertility continuously constrains crop productivity (Mutegi et al., 2012). The region records the lowest rate of fertilizer application in the world: 10.5 kg/ha compared to global average of 122.1 kg/ha. The rate is also below that of South Asia (176 kg/ha), Latin America & Caribbean (92.2 kg/ha), Middle East & Northern Africa (79.5 kg/ha), and Europe & Central Asia (38.8 kg/ha) (World Bank, 2012). Increasing the adoption of fertilizers should be a core component of agricultural development strategies of countries sub-Sahara African.

A recent study in Ghana reports an average national rate of application of 90 kg/ha for nitrogen, phosphorus, potassium (NPK) compound fertilizer for the 2012 cropping season (Ragasa et al., 2013a). A follow-up study identifies determinants of fertilizer adoption in northern Ghana (Martey et al., 2014), but did not focus on a specific crop production system. To fill this gap, this study examines the determinants of fertilizer adoption in the rice-production system in northern Ghana. In fact, northern Ghana produces about 30% of the country’s rice (SRID/MOFA, 2011) under poor soil conditions (Langyintuo and Dogbe, 2005). Recommendations that improve fertilizer adoption will increase yields, and rice production in this part of Ghana. Since northern Ghana is located within the savannah agro-ecological zone, the recommendations are also useful for the design of food security strategies of areas around the globe with similar agro-ecology and production systems.

For fertilizers to produce optimum yield response, agronomists recommend the use of compound fertilizers and then nitrogen-based fertilizers (Van Asten et al., 2004; Moro et al., 2008). However, the existing literature on fertilizer adoption has examined fertilizer use in general without considering specific combinations (Zhou et al., 2010; Fufa and Hassan, 2006). In addition to fertilizer use in general, this study identifies the determinant of adoption of the most important fertilizer combination for rice production in northern Ghana. This is a major contribution to the literature on fertilizer adoption process.

The methodology for achieving this objective is described in the next section. In Section 3.3, the results of the study are presented, and then discussed in Section 3.4. The conclusion and recommendations are presented in Section 3.5, which includes suggestions for promoting the adoption of fertilizers in general, specific fertilizer combinations, and other packages of agricultural technologies.

3.2 Methodology

3.2.1 Data and sampling

This study is based on data collected through semi-structured interviews (Appendix 1B and 1C) with representatives of a cross-section of rice-producing households in developed rice valleys in the Northern Region of Ghana in 2013. The interviews captured information on household characteristics, farm-level conditions, and input accessibility.

Sampling began with listing of communities within the valleys with the directorates of the Ministry of Food and Agriculture (MOFA) who operate in the valleys. From the list, 82 communities were randomly selected. Within each community, 10 rice-producing households were randomly selected from a list of households provided by the assembly members of the communities. Overall, data on 820 rice-producing households were used for the analysis. This is, however, not representative of the rice production system of northern Ghana because it does not capture households operating in undeveloped valleys, upland ecologies, and irrigated ecologies.

3.2.2 Empirical procedure

The sample includes rice-producing households who use different types and combinations of fertilizers. The adoption incidence for the types and combinations of fertilizers are therefore generated from the ratio of the number of adopting households to the total sample size. Those who use fertilizer have different rates or intensity of application and this is computed as the total quantity of fertilizer applied per area unit area. The adoption incidence rate and the rate of application are computed for their rice enterprise and also for all arable crops combined.

The fertilizer adoption decision process is based on the expected profit framework (Dimara and Skuras, 2003) in which, adoption occurs if the expected profit from fertilizer use, which is latent and thus not directly observed, exceeds the current level of profit (Burnham et al., 1999). This decision can be divided into two parts: the discrete decision of whether to use or not to use fertilizers, and the continuous decisions on the quantities or rates of fertilizer application. When adoption is universal, least squares regression models produce consistent estimates of the determinants of adoption (Zhou et al., 2010). The use of probit and Tobit regression models to separately estimate the determinant of the probability and intensity of adoption (Fufa and Hassan, 2006), may produce misleading recommendations. This is because the latter estimates joint determinants of probability and intensity of adoption (Adesina, 1996; Waithaka et al., 2007). This property of the Tobit model has also been contested because the discrete and continuous decisions are not necessarily joint decisions.

To account for this potential flaw, two-step models, namely Cragg's and Heckman's two-step models are used to estimate the probability and intensity of adoption separately (Mal et al., 2012; Yirga and Hassan, 2013). Among the two-step models, Heckman's model in addition to addressing the separability problem also addresses the problem of selectivity bias by imposing the exclusivity condition in the first step (Heckman 1979). For rice-producing farmers, the discrete decision to use fertilizers and the decision on the rate of fertilizer application may be joint or separate. If the decisions are separate, the intensity of adoption may be characterized by selectivity bias. This study therefore conducts thorough diagnosis of separability and selectivity in the fertilizer adoption decision.

To confirm separability in the adoption decision, a likelihood ratio test is conducted. This required estimation of the following probit, truncated, and Tobit adoption models shown in Equations 3.1, 3.2, and 3.3:

$$z = Prob(z|z^* > 0) = x\gamma + \varepsilon \tag{3.1}$$

$$y = E(y|y^* > 0) = x\beta + \mu \tag{3.2}$$

$$Y = (x\gamma + \varepsilon) + (x\beta + \mu) = x\alpha + \omega \tag{3.3}$$

In Equation 3.1, z identifies fertilizer adoption status with $z = 1$ for adopters, and $z = 0$ for non-adopters. In the equation, z_i^* represents the latent variable for the probability of adoption. Also in the equation, x is a set of explanatory variables in the model, γ the set of coefficients of the explanatory variables, and ε the error term. In Equation 3.2, y represents adoption intensity, y_i^* is the latent variable of adoption intensity, β is the set of coefficients estimates, and μ is the error term. Equation 3.3, the Tobit model, combines the first two equations to obtain the joint coefficient, α, and ω, the error term. The coefficient of the equation explains both the probability and intensity of adoption.

From the three equations, log likelihood ratios are obtained and used to compute the test statistic, L, as:

$$L = 2(LR_{Probit} + LR_{Truncated} - LR_{Tobit}) \tag{3.4}$$

In Equation 3.4, the LRs are the log likelihood ratios of the three equations. The estimated L should be greater than the Chi-square distribution with the degrees of freedom equal to the number of independent variables (including the intercept) in the models to justify the use of any of the two-step models. Dougherty (2002) published statistical tables which includes Chi-square distribution tables.

The Tobit model provides a consistent estimate of the determinants of fertilizer adoption if L is less than the critical value (Mal et al., 2012). Otherwise the two step models are appropriate. As mentioned earlier, Heckman's model also accounts for selectivity. The first step of the model involves estimation of a probit regression model as shown in

Equation 3.1. Using q to represent adoption intensity, q_i^* as the latent variable of adoption intensity, δ as the set of coefficients estimates, and φ as the error term, the second step of the model is the following truncated regression:

$$q = E(q|q^* > 0) = x\delta + \lambda(x\gamma) + \mu \quad (3.5)$$

The second term on the right hand side of Equation 3.5 is the inverse Mills ratio which corrects for selection bias in the truncated regression model. A significant inverse Mills ratio suggests that the intensity of adoption depends on the discrete decision to adopt fertilizers (Marchenko and Genton, 2012), a condition which is not considered in the Cragg's model.

In the absence of selectivity bias, Cragg's model provides a relatively simple approach for estimating the two step model. In this case, the second stage of the model is also a truncated regression without the inverse Mills ratio. This is specified as:

$$q = E(q|q^* > 0) = x\delta + \mu \quad (3.6)$$

In examining the determinants of fertilizer adoption, these models are estimated and compared. The results from the best model are selected and discussed. In general, determinants of fertilizer adoption can be classified into household-level factors, farm-level factors (Yirga and Hassan, 2013), subjective factors (Zhou et al., 2010), environmental factors (Kaliba et al., 2000), access factors (Cavane, 2011), and risk factors (Kaliba et al., 2000). These guided the choice of the explanatory variables for the model.

The variables examined in the model include dummy variables that describe nativity, engagement in off-farm activities, access to extension, participation in the *Fertilizer Subsidy Program of Ghana*, access to external markets, purchase of seeds of improved rice varieties, harrowing, dibbling of seeds, herbicide use, and the expectation of high yields from fertilizer application. Continuous variables, such as the average age of economically active persons in the household, proportion of male members in the household, proportion of educated members in the household, and labor-land ratio in man-days/ha, are also examined. To satisfy the exclusivity condition of Heckman's model, nativity, is assumed to only determine the discrete decision of adoption, but has no effect on the intensity of adoption. The choice of nativity is informed by the fact that native households usually have absolute right to use land resources. To ensure the sustainable use of their land resource, they are more likely to invest in fertilizer while non-natives can easily migrate to other locations to rent lands. In a situation where both native and non-natives decide to adopt fertilizer, the intensity of adoption is not expected to be significantly different.

A potential bias of the specified models is endogeneity of the variable, participation in the *Fertilizer Subsidy Program of Ghana*. This error is corrected by the estimation of a separate probit model of participation in the subsidy on pure exogenous variables including an instrument (Abadie et al., 2002). For the purpose of this study, the number of households who benefited from the subsidy program in each of the sampled communities is used as an instrument. Experience during the field visit showed that there are some communities that are more proactive and aggressive in terms of their negotiation for government interventions, regardless of their location. From the probit model, the predicted probability of participation in the subsidy program that is estimated is used in the adoption models.

3.3 Results

3.3.1 Type and combinations of fertilizers

Computed fertilizer adoption incidence rates and intensities of application are presented in Table 3.1. Overall, about 72% of the sampled rice-producing households apply fertilizer on their arable farm land at a rate of 109 kg/ha. For rice, about 68% of the sampled rice-producing households apply fertilizers at an average rate of about 145 kg/ha. The households use three different types of fertilizers: Nitrogen-Phosphorus-Potassium (NPK) compound fertilizer, ammonium (NH4) fertilizer, and urea ((CO(NH2)2) fertilizer. These fertilizers are either used in isolation, or in a combination.

In general, NPK fertilizer is the most popular with about 69% of households applying it on arable crop fields and about 62% on rice fields. Considering the use of the fertilizers without combining them with others types of fertilizers, about 15% of the households use only NPK on all of their arable fields and on rice fields. Similarly, about 3% of the households use only NH4 on all of their arable fields and about 2% on rice fields. While about 17% use urea only on all their arable fields, about 3% use urea only on their rice fields.

Table 3.1: Fertilizers used

Fertilizer types	All farms		Rice farm	
	Adopters (%)	Intensity (kg/ha)	Adopters (%)	Intensity (kg/ha)
All fertilizers	71.95	109.39	68.17	128.65
		(111.75)		(106.28)
Compound (NPK)	68.78	78.66	61.59	83.73
		(68.32)		(95.63)
Ammonium (NH4)	55.49	49.29	48.54	53.22
		(52.70)		(73.70)
Urea (CO(NH2)2)	6.95	4.18	6.10	6.72
		(19.03)		(29.99)
Compound only	14.51	17.11	15.00	19.21
		(46.87)		(52.49)
Ammonium only	2.68	3.59	2.44	4.75
		(24.58)		(28.40)
Urea only	16.71	1.41	3.41	2.18
		(9.10)		(13.78)
NPK-NH4	52.07	127.95	44.39	136.30
		(105.12)		(153.52)
NPK-urea	4.63	81.82	2.93	89.98
		(68.06)		(101.01)
NH4-urea	3.17	97.04	1.46	100.53
		(131.13)		(133.49)

Note: Figures in parenthesis are standard deviation.

For the combination of fertilizers the use of NPK and NH4 fertilizers is most popular on all arable fields (about 52%) and on rice fields (about 44%). The households apply about 105 kg/ha of the combination of NPK and NH4 on all arable fields and about 136 kg/ha on rice fields. Other combinations that are applied are combinations of NPK and urea, and of NH4 and urea.

3.3.2 Determinants of fertilizer adoption

Since the combination of NPK and NH4 fertilizers is the most common, the factors that affect the adoption of this combination and of fertilizer in general are examined. Four different adoption scenarios are considered. The first involves the estimation of the adoption of fertilizer in general on all arable plots. The second is the adoption of fertilizer in general on rice plots. The third considers the adoption of the combination of NPK and NH4 fertilizers on all arable lands. The fourth scenario considers the adoption of the combination of NPK and NH4 fertilizers on rice plots.

Table A3.1 in the Appendix of this chapter presents the endogeneity correction model for participation in the *Fertilizer Subsidy Program of Ghana*. The subsidy variable in the adoption models is therefore the predicted probability of participation in the subsidy program and is considered exogenous. The results of the separability tests are also presented in Table A3.2 in the Appendix. In all cases, the likelihood ratio test statistics show that the decision to adopt fertilizer can be divided into two steps. The two step regression models are therefore used to examine the determinants of fertilizer adoption. The estimated lambdas from the Heckman two-step models are insignificant, indicating the absence of selectivity bias in the models (Table A3.3 and Table A3.4). As described in the empirical procedure, Cragg's two step model presents a simple and straight forward means of estimating the determinants of the probability and intensity of fertilizer adoption. Subsequent presentations in this section focus on results from Cragg's model.

The results show that different sets of factors affect the probability and intensity of adopting fertilizer in general. Moreover, the set of factors that affect the adoption of fertilizer in general on all arable crop fields differ from the set of factors that affect the adoption on rice fields (Table 3.2). The same trend is observed for the adoption of the combination of NPK and NH4 fertilizers (Table 3.3). For the same field category, the results show that the set of factors that affect the adoption of fertilizer in general differ from those that influence the adoption of the combination of NPK and NH4 fertilizers. In some cases, the same factors have varying effects on the probability and intensity of adoption.

More specifically, Table 3.2 shows the results from Cragg's model for adoption of fertilizer in general on all arable crop fields and on rice fields. For all arable crop fields participation in off-farm income generating activities has negative effect on the probability of adoption. On the other hand, labor-land ratio increases the probability and intensity of adopting fertilizers in general. The two decisions on all arable crop fields are also increased by harrowing of fields. Considering each decision separately, the results show that the probability of adoption increased by participation in fertilizer subsidy program and expectation of high yields from fertilizer application, and decreased by the use of improved seeds. The intensity of adoption is increased by the proportion of educated persons in the household and the dibbling of seeds (Table 3.2).

For rice fields, the probability and intensity of adopting fertilizer in general are both shown to be increased by participation in the fertilizer subsidy program, and decreased buy participation in off-farm income generating activities. The probability of adoption is increased by the expectation of high yields from fertilizer application, higher labor-land ratio and the harrowing of fields, but decreased by use of improved seeds (Table 3.2).

Table 3.3 presents results of Cragg's model for the adoption of the combination of NPK and NH4 fertilizer on all arable plots and on rice fields. The results show that the probability and intensity of adopting the fertilizer combination on all arable crop fields are increased by the number of arable crops cultivated, a higher labor-land ratio, and harrowing of the fields. The probability of adopting the fertilizer combination on all arable crop fields is increased by participation in the fertilizer subsidy program and the expectation of high yields from fertilizer application, and decreased by off-farm income generating activities and use of improved seeds. The intensity of adopting the fertilizer combination on all arable crop fields is shown to be increased by the dibbling of seeds.

Table 3.2: Heckman's model of determinants of the adoption of fertilizers in general

Variables	All plots				Rice plots			
	Step 1		Step 2		Step 1		Step 2	
	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
Subsidy	2.288***	0.258	-0.047	0.175	2.944***	0.287	0.839***	0.194
Extension	-0.150	0.105	0.088	0.074	-0.089	0.113	0.018	0.079
Age of active persons	-0.003	0.010	-0.008	0.007	-0.010	0.011	-0.003	0.008
Proportion of males	-0.220	0.314	0.059	0.221	0.384	0.342	0.002	0.238
Proportion of educated	-0.075	0.202	0.248*	0.147	0.074	0.217	-0.236	0.158
Number of arable crops	0.071	0.046	-0.035	0.032	-0.006	0.050	0.038	0.034
Off farm activities	-0.427***	0.117	0.172**	0.079	-0.454***	0.124	-0.173**	0.088
Expectation of high yield	0.476***	0.170	0.009	0.152	0.470***	0.171	-0.100	0.154
Labor-land ratio	0.032*	0.019	0.077***	0.013	0.034*	0.021	0.001	0.014
Nativity	0.013	0.121			0.140	0.129		
Access to market	-0.081	0.215	0.030	0.141	0.309	0.269	-0.081	0.146
Improved seeds	-0.345***	0.112	0.081	0.078	-0.298**	0.123	0.053	0.083
Harrowing of filed	0.255**	0.109	0.123*	0.072	0.461***	0.123	0.071	0.078
Dibbling of seeds	0.161	0.121	0.277***	0.079	0.120	0.135	0.105	0.087
Herbicides application	0.130	0.118	0.080	0.084	0.136	0.125	-0.076	0.090

Note: *10% significant, **5% significant, and ***1% significant

Table 3.2: Heckman's model of determinants of the adoption of fertilizers in general (continued)

Variables	All plots				Rice plots			
	Step 1		Step 2		Step 1		Step 2	
	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
Tropical livestock units	0.006	0.006	0.000	0.003	0.005	0.007	0.001	0.004
Constant	-1.226***	0.458	4.233***	0.324	-1.287***	0.491	4.393***	0.345
N				820				820
Wald chi^2				129.760***				170.610***
Log likelihood				-981.344				-1099.094
Sigma				0.698***				0.833***

Note: *10% significant, **5% significant, and ***1% significant

Table 3.3: Heckman's model of the adoption of NPK-NH4 fertilizer combination

Variables	All plots				Rice plots			
	Step 1		Step 2		Step 1		Step 2	
	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
Subsidy	2.908***	0.301	0.001	0.167	2.996***	0.282	0.825***	0.199
Extension	0.028	0.116	0.068	0.069	-0.137	0.112	-0.001	0.081
Age of active persons	-0.013	0.012	-0.005	0.007	-0.016	0.011	-0.002	0.008
Proportion of males	-0.189	0.355	-0.073	0.205	0.462	0.337	-0.055	0.242
Proportion of educated	0.080	0.224	0.189	0.138	0.003	0.214	-0.169	0.163
Number of arable crops	0.119**	0.055	-0.077***	0.029	-0.034	0.049	0.037	0.035
Off farm activities	-0.470***	0.130	0.045	0.076	-0.449***	0.123	-0.196**	0.089
Expectation of high yield	0.618***	0.174	0.128	0.139	0.498***	0.171	-0.157	0.162
Labor-land ratio	0.048**	0.022	0.076***	0.012	0.024	0.020	0.007	0.014
Nativity	0.154	0.134			0.156	0.127		
Access to market	0.164	0.274	-0.102	0.130	0.090	0.251	-0.080	0.153
Improved seeds	-0.394***	0.127	0.060	0.073	-0.332***	0.120	0.060	0.085
Harrowing of filed	0.326***	0.127	0.157**	0.068	0.413***	0.119	0.019	0.080
Dibbling of seeds	0.173	0.143	0.284***	0.075	0.053	0.130	0.145*	0.089
Herbicides application	0.174	0.131	-0.030	0.079	0.096	0.124	-0.074	0.092

Note: *10% significant, **5% significant, and ***1% significant

Table 3.3: Heckman's model of the adoption of NPK-NH4 fertilizer combination (continued)

Variables	All plots				Rice plots			
	Step 1		Step 2		Step 1		Step 2	
	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
Tropical livestock units	0.006	0.007	0.001	0.003	0.004	0.007	0.001	0.004
Constant	-1.299***	0.516	4.306***	0.298	-1.038**	0.482	4.427***	0.351
N				820				820
Wald chi^2				173.440***				173.710***
Log likelihood				-1038.881				-1087.605
Sigma				0.744***				0.833***

Note: *10% significant, **5% significant, and ***1% significant

On rice fields, the probability and intensity of adopting the combination of NPK and NH4 fertilizers are shown to increase by participation in the fertilizer subsidy program, and decrease by participation in off-farm income generating activities. Considering the two decisions separately, the results show that the probability of adopting the fertilizer combination on rice fields is increased by the expectation of high yields from applying fertilizer, greater labor-land ratios, and the harrowing of fields, while decreased by dibbling. The intensity of adoption, on the other hand, is only increased by dibbling.

3.4 Discussion

3.4.1 Fertilizer adoption and the decision making process

This study shows that rice-producing households use different types and combinations of fertilizers, with the combination of NPK and NH4 dominating. The estimated fertilizer adoption incidence rate confirms findings by Ragasa et al. (2013a) who report a 68% fertilizer adoption incidence rate in Ghana. Even with the *Fertilizer Subsidy Program of Ghana*, more than 20% of rice-producing households in the study area do not apply fertilizer. Among the adopters, application rates are below recommended rates of 240 kg/ha for NPK and 120 kg/ha for NH4 (Ragasa et al., 2013a). Further interactions with households during the study revealed that some are not fully convinced about the benefits of fertilizer. For adopters, there is a lack of adequate knowledge about the recommended rates and methods of application.

It appears that in addition to the subsidy program other factors contribute to the adoption decisions of farm households. From the interactions on the field, it is obvious that education about fertilizer has not been exhaustive enough, in terms of coverage and content. Therefore, there is a need for additional strategies to enhance the promotion of fertilizers. Relevant agencies including extension service providers should be adequately resourced and trained on the delivery of information on fertilizers.

The results of this study also show that the set of factors affecting adoption of fertilizers in general differ from those affecting adoption of the combination of NPK and NH4 fertilizers. Moreover, for the same fertilizer combination, the set of factors that influence adoption differ for the total land area and for the total rice area. There is a need for separate discussions to guide the development of strategies to address objectives for interventions aimed at promoting fertilizer in general versus specific types of fertilizer. For example, to promote the adoption of fertilizer in general, policy makers may have to encourage participation in the fertilizer subsidy program, which has broad objectives. In addition to the subsidy program, the promotion of a specific fertilizer combination may be achieved through effective extension services which deal directly with individual and are therefore able to treat specific and more detailed techniques such as the application of the combination of NPK and NH4 fertilizers.

This study also shows that regardless of the measure of adoption, rice-producing households make an initial decision of choice (i.e., whether to use fertilizers) before deciding on the amount of fertilizer to apply. The distinction of these decisions provides additional evidence to support the two-step analysis of the adoption of an agricultural technology (Yirga and HASSAN, 2013; Mal et al., 2012).

3.4.2 Factors affecting the adoption of fertilizer in general

Considering the adoption of fertilizers in general on all plots, rice-producing households who participate in the subsidy program are more likely to apply fertilizer in general. The subsidy program has no effect on the intensity of fertilizer adoption in general on all plots. This particular outcome confirms results obtained by Mason et al. (2013) who find a significant effect of participation in a fertilizer subsidy program on the rate of fertilizer application on maize in Zambia.

Unlike arable crop fields, the probability and intensity of adoption of fertilizers in general on rice plots are increased by participation in the fertilizer subsidy program. This actually confirms the assertion made earlier that the effect of the subsidy program can be identified when specific crops are examined, as with Mason et al. (2013). This suggests that evaluating the effect of interventions on total farming activities does not reveal enough information about the effect.

The type of knowledge about technologies also shapes perceptions, expectations, and eventually adoption decisions (Odoemenem and Obinne, 2010; Hsua et al., 2007). As hypothesized, rice-producing households who expect high yields from fertilizers application are more likely to adopt fertilizer. These expectations, however, do not influence the application rate of fertilizer. Exposure to additional evidence of the benefits of fertilizers can strengthen expectations, which can then inform decisions on the rate of fertilizer application.

Agricultural mechanization in Ghana and Africa as a whole is not only low, but has been declining in the last 30 years (Mrema et al., 2008), necessitating the use of manual labor. Moreover, resource poor farm households are unable to pay for the cost of hired labor and therefore rely on family labor for farm operations (Benjamin, 2006). This assertion is also true for this study since large households who have high labor-land ratios are more likely to adopt and apply higher rates of fertilizer in general on all arable crop fields. For resource poor households, lack of adequate finance can limit the use of fertilizer (Mugisha et al., 2004).

The use of technologies as a package yields higher returns. To experience such returns from fertilizer, access to complementary technologies is a necessary condition for adoption (Doss and Morris, 2000). This study, however, shows that rice-producing households who use seeds of improved crop varieties are not likely to use fertilizer in general on all their arable crop fields. Meanwhile, adoption is shown to be increased by dibbling and harrowing of arable crop fields. Observations during the field interviews found that the households expect high yields from the use of improved varieties and may not find the need for fertilizers. However, controlling weeds by harrowing and by use of herbicides eases fertilizers application, and also prevent loss of nutrients to competitive weeds. This argument also applies for dibbling of seeds.

This study shows that households who engage in off-farm income generating activities are not likely to adopt fertilizer in general for their arable crop fields. Yet for adopters, participation in off-farm income activities increases the intensity of application. Due to time constraints, farm households who engage in off-farm income generating activities may have difficulty in considering the adoption of fertilizer, particularly for their entire field. However, for adopters, the extra income from off-farm income generating activities provides the opportunity to increase the rate of fertilizer application. This distinction is possible to ascertain because of the analysis, which considers that the two adoption decisions are not jointly made.

3.4.3 Factors affecting the adoption of a combination of NPK and NH4 fertilizers

Agronomists recommend the application of compound fertilizers and then ammonium or urea fertilizers (Moro et al., 2008). Urea fertilizer is, however, highly volatile and can easily be lost after application (Gioacchini et al., 2002), which may explain its low adoption rate. The combination of compound and ammonium fertilizers is thus an obvious option for rice-producing households in the study area.

The results also confirm earlier observation that there may be limited information when the effect of an intervention is examined on the entire arable crop field of the households. For the NPK and NH4 combination, participation in the fertilizer subsidy program is shown to be positively related to the probability of adoption on all arable crop fields. Participation in the program, however, is shown to increase the probability and intensity of adoption on rice fields. It is possible that the subsidy program, which reduces the price of NPK and NH4 fertilizer by half (Yawson et al., 2010), influences rice-producing households to focus more on crops that have a high response to fertilizer or otherwise have high nutrient requirements.

Complementary technologies are once again shown to be important in the decision to use the combination of NPK and NH4 fertilizers. Harrowing of rice fields influences both discrete and continuous decisions, whereas dibbling influences the continuous decision only. It appears that rice-producing households who use this combination are already convinced about the benefits of fertilizers. However, the use of improved seeds reduces the probability of using the combination of NPK and NH4 fertilizers. The results suggest the need to educate farm households on the yield response of improved varieties to fertilizer and, in particular, from the combination of NPK and NH4 fertilizer. This will enable them to obtain the highest response from the improved variety plus fertilizer.

Resource considerations are necessary when farmers decide to use the combination of NPK and NH4 fertilizers. As a technology package, the combination of NPK and NH4 fertilizers has relatively high resource requirements, particularly labor (Mugisha et al., 2004; Saka et al., 2005). Access to adequate labor resources is therefore necessary to motivate the adoption of the fertilizer combination. Participation in off-farm income activities limits the availability of household labor and therefore has negative effect on the probability of adoption on rice fields.

3.5 Conclusion and recommendations

The results of this study support that of Ragasa et al. (2013b) which report significant increases in the fertilizer adoption incidence rate since the 1990s. Despite this increase, there is still significant fertilizer adoption gap in Ghana, i.e., there still exist a significant proportion of farmers who have not adopted fertilizers. The observed increase is due to a set of factors, including the *Fertilizer Subsidy Program of Ghana*. If possible, strategies to further enhance the adoption of fertilizers should consider all the relevant factors included in the recommendations of this study. With different measures of adoption, this study provides recommendations for the promotion of fertilizer in general and the combination of compound and ammonium fertilizers. This study also proposes improvements to the methodologies of adoption studies in general.

The study shows that the discrete decision to use fertilizer and the decision on the rate of fertilizer application are not the same. Instead, these decisions are influenced by a different set of factors. Estimating the probability of adoption alone does not provide a true understanding of the factors that affect the entire decision making process. On the other hand, assuming that the two decisions are made jointly can be misleading. It is therefore important that future studies on fertilizer adoption and on the adoption of other agricultural technologies include a test for separability to ensure that the appropriate estimation procedure is applied. Otherwise, the set of factors that influence the two decisions may not be adequately captured. Moreover, this study shows that these decisions vary when considering the entire farm and a specific farm enterprise, in this case rice production, separately. Further studies can assess such differences to make tailored recommendations for specific enterprises.

Another important observation of this study is the difference between the adoption of fertilizers in general and the adoption of a specific combination of fertilizers, namely the combination of NPK and NH4 fertilizers. Using fertilizer adoption in general oversimplifies the adoption situation, which does not provide adequate understanding of the adoption processes. There is also the tendency to overestimate or underestimate the effects of some factors on adoption. For example, the results show that the number of arable crops cultivated is not important in determining the adoption of fertilizers in general. However for adoption of NPK and NH4 fertilizer combination, the number of arable crops cultivated is shown to be important, at least for the entire arable crop fields.

Regardless of the type of fertilizer considered, the *Fertilizers Subsidy Program of Ghana* increases the probability of adoption. The effect on the intensity of adoption is observed on specific crop fields. This further confirms the importance of examining the effects by farm enterprise rather than for the entire farm.

Positive expectations about the use of fertilizer on yield are important in the adoption decision for fertilizers in general and for the combination of NPK and NH4 fertilizers. Adequate evidence on the benefits of the combination of NPK and NH4 fertilizers with complementary technologies, such as seeds of improved varieties, can increase adoption incidence rates. Strengthening extension agencies to educate farmers in this regard remains relevant.

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Appendix

Table A 3.1: An endogenous correction model of participation in a subsidy program

	Coef.	Std. Err.	z	P>z
Number of participants in the community	0.130	0.013	10.320	0.000
Average age of economically active persons	-0.012	0.011	-1.160	0.247
Total labor	0.001	0.001	1.070	0.287
Proportion of male in the household	0.007	0.324	0.020	0.982
Proportion of educated in the household	-0.209	0.215	-0.970	0.332
Proportion of economically active in the household	-0.547	0.266	-2.060	0.040
Off farm activities	0.634	0.107	5.910	0.000
Expectation of high yield	0.438	0.180	2.430	0.015
Own land	0.869	0.165	5.270	0.000
Number of crops	-0.003	0.046	-0.070	0.945
Extension	0.376	0.099	3.800	0.000
Information from neighbors	0.179	0.112	1.610	0.108
Sell rice	-0.012	0.180	-0.060	0.949
Use of improved seeds	0.147	0.112	1.310	0.189
_cons	-2.231	0.527	-4.230	0.000
N				820
LR chi-square (18)				212.790
Prob>chi2				0.000
Pseudo R2				0.187
Log likelihood				-461.362

Table A 3.2: Likelihood ratio test

Models	Likelihood ratios			Likelihood ratio statistics
	Probit	Truncated	Tobit	
Adoption of fertilizers in general				
All plots	-376.300	-494.657	-1,515.715	1,289.516***
Rice plots	-408.218	-690.876	-1,583.760	969.332***
Adoption of NPK-NH4 combination				
All plots	-503.763	-665.210	-1,587.429	836.912***
Rice plots	-495.455	-663.762	-1,564.954	811.474***

Note: ***1% significant

Table A 3.3: Heckman's model of fertilizer adoption

Variables	All plots				Rice plots			
	Step 1		Step 2		Step 1		Step 2	
	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
Participation in subsidy program	3.051***	0.316	-0.487	0.535	2.944***	0.287	1.053*	0.657
Extension	-0.032	0.124	0.089	0.076	-0.089	0.113	0.012	0.082
Age of economically active persons	-0.010	0.012	-0.006	0.007	-0.010	0.011	-0.004	0.008
Proportion of males in the household	-0.069	0.384	0.067	0.227	0.384	0.342	0.029	0.252
Proportion of educated in the household	-0.044	0.236	0.254*	0.151	0.074	0.217	-0.231	0.159
Number of arable crops	0.117**	0.059	-0.050	0.037	-0.006	0.050	0.037	0.034
Off farm activities	-0.479***	0.137	0.239**	0.112	-0.454***	0.124	-0.204*	0.127
Expectation of higher yield	0.599***	0.188	-0.110	0.205	0.470***	0.171	-0.059	0.197
Labor-land ratio	0.050**	0.024	0.072***	0.015	0.034*	0.021	0.003	0.015
Nativity	0.100	0.141			0.140	0.129		
Access to market	0.100	0.292	0.027	0.146	0.309	0.269	-0.068	0.152
Improved seeds	-0.429***	0.137	0.135	0.102	-0.298**	0.123	0.034	0.101
Harrowing of fields	0.372***	0.135	0.074	0.094	0.461***	0.123	0.101	0.119
Dibbling of seeds	0.184	0.152	0.250***	0.087	0.120	0.135	0.113	0.090
Herbicide application	0.162	0.140	0.059	0.090	0.136	0.125	-0.066	0.096

Note: *10% significant, **5% significant, ***1% significant

Table A 3.3: Heckman's model of fertilizer adoption (continue)

Variables	All plots				Rice plots			
	Step 1		Step 2		Step 1		Step 2	
	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
Tropical livestock units	0.006	0.007	0.000	0.003	0.005	0.007	0.001	0.004
Constant	-1.536***	0.560	4.727***	0.657	-1.287***	0.491	4.176***	0.725
N				697				820
Wald chi-square				87.170***				14.550
Sigma				0.730				0.840
Lambda				-0.343				0.168

Note: *10% significant, **5% significant, ***1% significant

Table A 3.4: Heckman's adoption models for the combination of NPK-NH4 fertilizers

Variables	All plots				Rice plots			
	Step 1		Step 2		Step 1		Step 2	
	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
Participation in subsidy program	1.915***	0.248	-0.153	0.831	2.180***	0.251	-0.723	1.291
Extension	-0.120	0.104	0.123	0.090	-0.176*	0.105	0.115	0.151
Age of economically active persons	-0.008	0.010	0.000	0.008	-0.011	0.010	0.008	0.013
Proportion of males in the household	-0.162	0.310	0.138	0.234	-0.008	0.312	0.349	0.343
Proportion of educated in the household	-0.053	0.200	0.234	0.149	-0.102	0.203	-0.167	0.231
Number of arable crops	0.079*	0.045	-0.036	0.045	-0.089*	0.046	0.184***	0.074
Off farm activities	-0.278**	0.114	0.150	0.143	-0.335***	0.114	0.157	0.230
Expectation of higher yield	0.457***	0.171	0.020	0.275	0.342**	0.174	-0.428	0.312
Labor-land ratio	0.011	0.018	0.095***	0.014	0.000	0.018	0.020	0.020
Nativity	0.143	0.120			0.172	0.121		
Access to market	0.090	0.214	-0.039	0.138	0.090	0.214	-0.061	0.213
Improved seeds	-0.231**	0.111	0.104	0.124	-0.190*	0.112	0.232	0.164
Harrowing of fields	0.350***	0.107	0.050	0.157	0.407***	0.107	-0.289	0.244
Dibbling of seeds	0.203*	0.119	0.233**	0.116	0.185	0.118	0.058	0.162
Herbicide application	-0.061	0.116	0.138*	0.086	-0.081	0.117	0.044	0.134

Note: *10% significant, **5% significant, ***1% significant

Table A 3.4: Heckman's adoption models for NPK-NH4 fertilizers combination (continue)

Variables	All plots				Rice plots			
	Step 1		Step 2		Step 1		Step 2	
	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
Tropical livestock units	0.004	0.006	0.000	0.003	0.003	0.005	-0.002	0.005
Constant	-1.137***	0.452	4.075***	1.091	-0.774*	0.455	5.205***	1.228
N				820				820
Wald chi-square				106.380***				17.170
Sigma				0.670				1.101
Lambda				-0.111				-0.995

Note: *10% significant, **5% significant, ***1% significant

Chapter 4: Impact of fertilizer subsidy on land and labor productivity of rice-producing households in northern Ghana[3]

Alexander Nimo Wiredu, Manfred Zeller, and Aliou Diagne

Abstract

This study provides empirical evidence of the impact of the *Fertilizer Subsidy Program of Ghana* on partial factor productivity using data from a cross section of 820 rice-producing household in northern Ghana. Estimated local average treatment effect impact parameters show that the fertilizer subsidy increases land productivity but decreases labor productivity. The main conclusion is that on its own the fertilizer subsidy program is not a strong enough instrument for improving the productivity of farm households. Overall strategies for the agricultural sector should seek to transform the sector by introducing labor saving technologies and training farm households on sustainable land use. Farm households should also be encouraged to participate in off-farm activities, without losing interest in agriculture.

Key words: Fertilizer subsidy; impact; productivity; rice; local average treatment effect (LATE); northern Ghana

[3] A manuscript from this chapter has been submitted for consideration for publication in *Agroecology and Sustainable Food Systems.*

4.1 Introduction

In the past decade, the agricultural sector in sub-Saharan Africa has experienced significant improvements. While a variety of factors may have accounted for the observed productivity growth, changes in the policy environments in sub-Saharan African countries have been critical (Nin-Pratt et al., 2012). Sustaining and improving upon this trend require consolidation of gains made, learning from lessons, and introducing relevant modifications to current strategies. The availability of relevant information on the processes and outcomes of existing interventions, such as the Comprehensive Africa Agriculture Development Program (CAADP) (CFS, 2013) and input subsidy programs (Dorward and Chirwa, 2011), is critical.

Despite criticisms about their effectiveness, agricultural input subsidies have been adopted in most countries in sub-Saharan Africa to directly target farm households with the intention of improving productivity and well-being (Jayne and Rashid, 2013). Fertilizer subsidy programs in particular have been widely implemented across African economies with the initial intention of mitigating the effect of the global food and input price hikes, which occurred in 2006, on farm households (AU, 2006). The outcomes of the subsidy programs are expected to reflect in improved growth and economic transformation of the economies involved.

In 2008, the Government of Ghana introduced a country-wide subsidy on four types of inorganic fertilizers, namely, NPK-15:15:15, NPK-23:10:05, urea, and sulfate of ammonia. In addition to mitigating the effect of global price hikes, the program was expected to promote access to and use of fertilizers, increase farm-level productivity, and ultimately contribute to reduction in poverty and food insecurity among resource-poor farm households (Yawson et al., 2010; Banful, 2008). The program was targeted at all arable crop farmers who initially received vouchers from staff of Ministry of Food and Agriculture (MOFA) to enable them to buy fertilizers at almost half the market price (Druilhe and Barreiro-Hurlé, 2012). Evaluations of the effectiveness of the program by Banful (2008) and Yawson et al. (2010) revealed poor distribution of the vouchers, thus limiting access to fertilizers. This finding informed the replacement of the voucher system with an annual announcement of the prices of subsidized fertilizers by the Government. Under the revised scheme, farmers decide to participate in the program by purchasing subsidized fertilizer at a sales outlet.

The essence of encouraging fertilizer use among farmers through the subsidy programs is to increase farm-level productivity, which will subsequently translate into improved welfare indicators. Therefore, for any evaluation of these programs, productivity is an outcomes of interest (Brambilla and Porto, 2006; Escribano and Guasch, 2005; Restuccia et al., 2008). In the case of the *Fertilizer Subsidy Program of Ghana*, the impact on farm households in the northern zone is expected to be very high. The zone is characterized by low soil fertility, erratic rainfall, and inadequate access to credit (Armah et al., 2011), which constrain productivity. Among arable crops produced in the northern zone, rice is the only crop that Ghana is not self-sufficient in, which is similar to most African countries (Seck, 2011). Information on the extent to which the subsidy program has improved the productivity of rice-producing households in the northern zone will therefore be useful in the decision to continue the allocation of resources to the program by the Government of Ghana. This study is the first to evaluate the impact of the fertilizer subsidy program on the farm-level productivity of rice-producing households in northern Ghana.

Studies on other countries offer insight into the effects of fertilizer subsidy programs. One study finds that a fertilizer subsidy in the Philippines increased rice productivity (Rosegrant and Herdt, 1981). In Africa, fertilizer subsidy programs have been found to benefit farm households and overall economies. For example, through descriptive analyses Dorward and Chirwa (2011) find that the fertilizer subsidy program of Malawi improved smallholder maize productivity. In another study, Dorward and Chirwa (2013) show positive impacts of the subsidy program on wages and maize prices. Ricker-Gilbert et al. (2011) also suggest that fertilizer use can be increased if the rural poor are targeted by the Malawian fertilizer subsidy program. Similarly, farm households in Nigeria who benefited from fertilizer subsidy have been shown to better optimize the use of complementary agricultural technologies (Liverpool-Tasie and Salau, 2013). Although these studies provide useful insights into the performance of fertilizer subsidy programs, they fail to establish clear causality between the fertilizer subsidy programs and productivity.

By definition, productivity refers to the output obtained from the use of inputs. Two productivity indices, Total Factor Productivity (TFP) and Partial Factor Productivity (PFP), are identified in the literature (Key and McBridge, 2003). In addition to accounting for the overall effect of inputs in a production system, TFP can be decomposed into other measures of efficiency (O'Donell, 2011). Different PFP measures, on the other hand, can produce conflicting policy recommendations if the effect of an intervention is diverging. However, if carefully constructed, PFP measures can stand as legitimate measures of the variation in the outputs of a production system (Nin et al., 2003). In Ghana, a typical rice-producing household cultivates rice and other crops, using the same set of hand tools (Akramov and Malek, 2012), such as hoes, cutlasses, and knapsack sprayers, on all plots. In most cases, farm households are unable to accurately estimate the percentage of these tools they used on each crop. As such, computing TFP may be erroneous. For this reason, PFP indices are considered more realistic measures of the productivity in the rice production system in Ghana, by this study.

The *Fertilizer Subsidy Program of Ghana* was not randomly assigned and it was also not targeted at specific farmers within the arable crop subsector. Instead, all arable crop farmers were offered the opportunity to participate in the program. This implies that the fertilizer subsidy program was a non-random and endogenous treatment. Therefore, this study assesses the impact of the program using instrumental variable based regression approach (Mendola, 2007). In addition to the estimated impact of the subsidy program, this study provides information to guide strategies to improve farm-level productivity in the rice production system in Ghana.

4.2 Methodology

4.2.1 Data and sampling

This study is based on data from a cross-section of rice-producing households and communities in northern Ghana. Through household and community surveys conducted in 2013, the data captures information on crop production activities as well as on characteristics of rice-producing communities and households (Appendix 1B and 1C). It focuses on the rice production system in the Northern Region of Ghana, which is the largest of the three regions in the northern part of the country (MOFA, 2012).

Sampling of communities was conducted from a list of communities in developed rice valleys in the Northern Region, from which 82 communities were randomly selected. Selected members of these communities participated in focus group discussions, out of which lists of rice-producing households were obtained. Within each community, ten rice-producing households were randomly selected and interviewed. A total of 820 households were therefore selected for the interviews. This sample, however, is not representative of the rice production system in northern Ghana since it does not include farmers operating in undeveloped valleys, upland ecologies, and irrigated ecologies.

4.2.2 Computing partial factor productivity indices

Productivity as a measure of performance provides the opportunity for comparing economies, industries, firms, and farming systems (Brambilla and Porto, 2006; Escribano and Guasch, 2005; Restuccia et al., 2008). Given the nature of the rice-production system, partial factor productivity (PFP) is a reasonable measure of performance. According to Yiridoe et al. (2006), the rice-based production system of northern Ghana is characterized by poor soil fertility and low levels of adoption of improved technologies and mechanization. Improving land and labor input use could enhance the overall performance of rice-producing households in this part of the country. For this reason, two PFP indices, namely land productivity $Y_{i,ld}$ and labor productivity $Y_{i,lb}$, are constructed.

Given that the rice-production process $Q_i = f(q_{i,j})$, which is a relationship between output Q_i, and various combinations of inputs $q_{i,j}$ the PFPs of households are computed as ratios between the output and a specific input (Holden et al., 2001). The PFPs indices for land and labor are therefore expressed as,

$$Y_{i,ld} = \frac{Q_i}{q_{i,ld}} = \frac{\sum q_{i,j}}{q_{i,ld}} \quad (4.1)$$

$$Y_{i,lb} = \frac{Q_i}{q_{i,lb}} = \frac{\sum q_{i,j}}{q_{i,lb}} \quad (4.2)$$

where $q_{i,ld}$, and $q_{i,lb}$, represent the rice area and man-days of labor, respectively. The terms on the right hand side of the above two equations suggest that inputs are also expressed in ratios. For example, in the land productivity equation labor per unit area is used instead of total labor and in the labor productivity equation, land area per unit of labor is used instead of total land area. Apart from inputs, PFPs are also expected to be influenced by non-input factors $W_{i,j}$, which describe the characteristics of rice-producing households (Holden et al., 2001). Equations 4.1 and 4.2, can be rewritten to include these non-input factors as:

$$Y_{i,ld} = \frac{Q_i}{q_{i,ld}} = \frac{\sum q_{i,j}}{q_{i,ld}} + \sum W_{i,j} \quad (4.3)$$

$$Y_{i,lb} = \frac{Q_i}{q_{i,lb}} = \frac{\sum q_{i,j}}{q_{i,lb}} + \sum W_{i,j} \quad (4.4)$$

The variables in Equations 4.3 and 4.4 are selected based on hypotheses about their effect on productivity. The labor-land ratio, measured in man-days/ha, is expected to positively affect land productivity. The land-labor ratio is measured in ha/man-day and is also expected to have a positive effect on labor productivity. The seed-land ratio in kg/ha and seed-labor ratio in kg/man-day are expected to have a positive effect on land and labor productivity, respectively.

The proportion of males in the household and proportion of educated persons in the households are expected to increase productivity. Labor productivity is also expected to be positively affected by household labor availability, which is measured as the total number of months that households are available for farm work. The average age of economically-active household members is hypothesized to have a quadratic relationship with productivity. Therefore, the square of the average age of economically active household members is included in the model. Rice-producing households who purchase seeds of improved varieties are expected to have higher land productivity. This variable is presented separately in the labor productivity model as the purchase of seeds and use of improved varieties. Other dummy variables hypothesized to positively influence productivity are land ownership, extension, membership of association, participation in a rice project, and engagement in off-farm income-generating activities.

4.2.3 Estimating the impact of the fertilizer subsidy program on productivity

The impact of participating in the *Fertilizer Subsidy Program of Ghana*, P, on productivity, Y, is estimated using the treatment effect methodological framework (Cameron and Trivedi, 2005). In this framework, rice-producing households have two potential productivity outcomes from the program, where $Y_{i,1}$ represents the outcome of participating, i.e., $P_i = 1$, in the program and $Y_{i,0}$ represents the outcome of not participating, i.e., $P_i = 0$. Thus, the average impact of the program I_i can be expressed mathematically as $E(Y_{i,1}|P_i = 1) - E(Y_{i,0}|P_i = 0)$ and can be summarized as:

$$\begin{aligned} I_i &= E(Y_{i,1}|P_i = 1) - E(Y_{i,0}|P_i = 1) + E(Y_{i,0}|P_i = 1) - E(Y_{i,0}|P_i = 0) \\ &= E(Y_{i,1} - Y_{i,0}|P_i = 1) + \{E(Y_{i,0}|P_i = 1) - E(Y_{i,0}|P_i = 0)\} \\ &= ATE_i + \varepsilon_i \end{aligned} \quad (4.5)$$

where ATE represents the average treatment effect and ε is the unexplained bias caused by the way program was assigned.

If the program were exogenous and randomly assigned, then $E(\varepsilon) = 0$ and $I = ATE$. However, this is not the case. Instead of random assignment, rice-producing households had the opportunity to decide whether to participate in the program. Since anticipated benefits from participating in the program may affect the decision, participation in the program is endogenous and thus $E(\varepsilon) \neq 0$ and $I \neq ATE$ (DiPrete and Gangl, 2004; Abadie et al., 2002). An appropriate estimation approach was therefore necessary to minimize the bias in the error term, as well as to produce a consistent estimate of the impact of the fertilizer subsidy program on land and labor productivity of rice-producing households.

To deal with the non-random endogenous error term in Equation 4.5, an instrumental variable (IV) regression procedure is used to estimate the impact of the program. The procedure assumes the existence of a variable Z_i an instrument that predicts participation in the program, but does not predict productivity (Cameron and Trivedi, 2005). Due to the open availability of the subsidy program, some communities are more likely to have participants in the program because of their location and program exposure. Therefore, the instrument used in this study is a dummy variable representing communities that have households participating in the subsidy program (hereafter, called subsidy communities). Any household participating in the subsidy program is expected to belong to a subsidy community. Non-participating households may belong to a subsidy community or a non-subsidy community.

For rice-producing households residing in a subsidy community, $Z_i = 1$, and for those residing in a non-subsidy community, $Z_i = 0$. To ensure that the instrument satisfies the condition mentioned above, correlation coefficients between Z_i and P_i, and between Z_i and Y_i are constructed. With these conditions satisfied, the IV estimand identifies the average treatment effect of the subsidy program on the subpopulation of rice-producing households who live in subsidy communities and participate in the program. In order words, it represents the impact of the subsidy program on households who participated in the subsidy program because they were better placed to be participants. This estimand is referred to as the local average treatment effect (LATE) (Abadie, 2003). Introducing the instrument into Equation 4.5, the LATE parameter is re-expressed as:

$$\begin{aligned} I &= E\left(Y_{i,1} - Y_{i,0} | P_i = 1, Z_i = 1\right) + \left\{E\left(Y_{i,0} | P_i = 1, Z_i = 1\right) - E\left(Y_{i,0} | P_i = 0, Z_i = 1\right)\right\} \\ &= LATE_i + \varepsilon_i \end{aligned} \tag{4.6}$$

4.2.4 Estimation procedure

Without considering the effects of covariates, the LATE estimator of the impact of the program is obtained with the Wald estimator (Cameron and Trivedi, 2005) and is given by:

$$\mathrm{LATE}_{i,\mathrm{WALD}} = \frac{E(Y_i|Z_i=1)-E(Y_i|Z_i=0)}{E(P_i|Z_i=1)-E(P_i|Z_i=0)} \tag{4.7}$$

In addition to the non-parametric Wald estimator, the LATE impact parameter is estimated with the local average response function (LARF) estimator. The LARF estimator is a semi-parameter estimator, which allows for the identification of LATE conditional on a set of covariates which influence participation in the subsidy program and productivity. Details of LATE estimation by LARF are in Abadie (2003).

4.3 Results

4.3.1 Farm and productivity measures

Characteristics of the sampled rice-producing households by participation in the fertilizer subsidy program and by their status within or outside of a subsidy community are presented in Table 4.1. The results show that about 88% of rice-producing households are within a subsidy community and that about 56% of rice-producing households participated in the subsidy program. All participating households were within a subsidy community. These households constitute about 64% of the sampled households within the subsidy communities. The observed distribution of participants within the subsidy communities indicates that the variable subsidy community satisfies the exclusivity condition, such that households participating in the subsidy program belong to subsidy community. It therefore stands as a legitimate instrument in the process of accounting for endogeneity bias in the estimation of the impact of the program.

In general, there are some variations in the farm characteristics of rice-producing households when comparing households that participated in the program to those who did not as well as when comparing households in a subsidy community to those outside of one. For example, nearly the same proportions of households, about 89%, own arable crop land. Apart from rice, rice-producing households cultivate at least two additional crops. Rice occupies about one-third of the arable land area, which is about four ha.

Table 4.1: Household and production characteristics

		By participation		By subsidy Community	
	Overall	Non participants	Participants	Outside	Inside
Subsidy community (%)	87.80	72.38	100.00		
Participation (%)	55.85			0.00	63.61
Own land (%)	89.02	91.99	86.68	88.00	89.17
Number of crops	3.00	2.881	3.096	2.85	3.02
Total crop area (ha)	3.94	4.21	3.73	4.45	3.87
Rice area (ha)	1.35	1.45	1.28	1.38	1.35
Seeds (kg/ha)	129.39	125.13	132.76	145.66	151.98
Adoption of improved varieties	70.49	69.89	70.96	65.00	71.25
Buy seed (%)	35.61	37.57	34.06	34.00	35.83
Expectation of high yield	90.61	86.19	94.10	78.00	92.36
Use fertilizer (%)	67.56	36.46	92.14	23.00	73.75
Fertilizer rate (kg/ha)	164.17	74.67	234.91	13.64	90.68
Labor (man-days/ha)	103.75	95.04	110.64	85.55	111.61
Production (kg)	1721.27	1778.44	1676.08	1615.28	1735.99
Land productivity (kg/ha)	1275.02	1226.51	1309.44	1170.49	1285.92
Labor productivity (kg/man-day)	16.59	18.71	15.15	18.88	15.55

On the average, rice-producing households plant about 129 kg/ha of seeds, with an average of 104 man-days/ha of labor for all field operations. About 70% of households use improved varieties and about 36% buy certified seeds. Fertilizers are used by about 68% of households, even though over 90% expect high yields from fertilizer application. Households apply an average of about 164 kg of fertilizer/ha. Fertilizer application is, however, higher among households who participate in the program relative to non-participants. Similarly, the rate of fertilizer application is higher among households in subsidy communities compared to those in non-subsidy communities.

For every hectare of rice area cultivated, rice-producing households obtain an average of about 1,275 kg/ha of paddy rice. On the other hand, they obtained 16.59 kg/man-day of labor used. Land productivity is relatively higher for participating households and also for those in subsidy communities. The opposite is observed in the case of labor productivity.

4.3.2 Estimated impact of the subsidy program and productivity determinants

Between the two LATE estimators, the LARF has a significant coefficient while that of the Wald estimator does not. This indicates that observed covariates are necessary for estimating the LATE impact parameter (Table 4.2). Table 4.2 also shows the OLS LARF model of determinants of land and labor productivity.

The results show that rice-producing households who participate in the subsidy program obtain about 29 kg more rice per hectare. Apart from the subsidy program, a unit increase in land-labor ratio increases land productivity by about 3 kg per hectare. In addition, households that purchase seeds of improved rice varieties obtained about 510 kg more rice per hectare. Households who owned land[4] have 426 kg more rice per hectare, while households with off-farm employment have about 305 kg more rice per hectare. Land productivity decreases with an increase in the proportion of educated persons in the household.

Unlike land productivity, the results show that participation in the subsidy program has a negative impact on labor productivity. Labor productivity also decreases with an increase in the proportion of educated persons in the household. An increase in the land-labor ratio increases labor productivity by about 106 kg per hectare. Moreover, labor availability increases labor productivity by 4 kg per hectare.

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[4] Land owners acquire land through inheritance or by purchasing the land. There are other households who do not own land but instead rent-in their farm lands. Rental agreements include cash payment or shared cropping.

Table 4.2: Estimated impacts of subsidy on land and labor productivity

	Land productivity		Labor productivity	
	Coef.	Std. Err.	Coef.	Std. Err.
LATE by Wald	262.635	18374.63	-1.548	1005.95
LATE by LARF	29.373***	5.3e-07	-14.745***	1.00e-08
OLS Local average respond function model				
Subsidy	29.373	203.352	-14.745***	5.645
Labor-land ratio (man-days/ha)	2.644***	0.737		
Land-labor ratio (ha/man-day)			105.631***	18.920
Seed-land ratio (kg/ha)	-0.219	0.389		
Seed-labor ratio (kg/man-day)			-0.186	0.116
Purchase improved seeds	509.919***	161.593		
Adoption of improved varieties			6.810	4.331
Buy seeds			2.852	3.914
Own land	426.098**	199.952	3.339	5.560
Extension	-177.974	150.360	1.275	4.234
Association	12.566	157.773	3.436	4.386
Rice project	125.396	156.264	4.033	4.303
Proportion of males	263.876	446.943	14.485	12.386
Proportion of educated persons	-895.446**	461.185	-32.746***	12.762
Average age of economically active persons	138.356	99.450	2.476	2.745
Age square	-2.177	1.524	-0.037	0.042
Off-farm income activity	304.939**	141.183	2.002	3.910
Household labor availability			4.459***	1.218
Constant	-1634.363	1652.414	-32.906	45.819
F-statistics		2.81***		4.400***
R-squared		0.076		0.130

Note: *10% significant, **5% significant, ***1% significant. Sample of 458 households.

4.4 Discussion

4.4.1 Impact of the fertilizer subsidy program on productivity

The results show that the *Fertilizer Subsidy Program of Ghana* has diverging impacts on land and labor productivity. Land productivity increased with participation in the program, yet labor productivity decreased. Without a thorough analysis and explanation of these findings, contradictory policy recommendations could be made and this would justify criticisms by opponents of partial factor productivity measures.

By inducing fertilizer use, which subsequently translates into high yields, the estimated positive impact of the subsidy program on land productivity was expected. This gain was, however, modest and corroborates findings in Lunduka et al. (2013). The estimated land productivity gains from the subsidy program, about 29kg/ha, represents an increase of about 2% relative to non-participating households. To further improve on these gains, it important to intensify sensitization on yield enhancing practices in the implementation of the program.

To the best of our knowledge there is no evidence in the literature on how labor productivity may be affected by a fertilizer subsidy. A possible explanation for the negative impact of the subsidy on labor productivity can be deduced from the nature of the rice-production system. As mentioned in the introductory section of this chapter, the rice production system in the study area is characterized by low level of mechanization (Akramov and Malek, 2012). Compared to land which is relatively fixed, the availability of fertilizer motivates households to employ more man-days of labor for its application (shown in Table 4.1). Again, labor employment increases with increase in output. However it appears that the increase in output is not enough to compensate for the extra labor employed.

Interventions, such as improved labor management and work conditions, have been shown to enhance labor productivity (Dearden et al., 2006; Niemla et al., 2002). In addition to training households in labor management, facilitating access to labor-saving technologies such as easy-to-use fertilizer spreaders, and harvesters, could minimize dependence on labor for farm operations. With a reduction in labor use for fertilizer application and other field operations, the overall productivity of rice-producing households could be enhanced.

4.4.2 Determinants of productivity

In addition to the divergent impact of the subsidy program on productivity, different sets of factors were shown to influence productivity. As Holden et al. (2001) argue land and labor resources are also important determinants of the productivity of rice-producing households in northern Ghana. Since land is virtually fixed, access to adequate labor resources to effectively undertake field operations increases land productivity. On the other hand, rice-producing households who optimize labor use per unit of area are found to have higher returns to labor. The implication of these results is that there is the need for farmers to obtain adequate amount of labor resources. However, below or above a given threshold, productivity can be compromised. This further justifies the need for labor-saving technologies to undertake field activities more effectively.

Land productivity is also shown to be higher among households who purchase seeds of improved rice varieties. The results show that there are higher returns to not only the use of improved varieties but also quality seeds of improved varieties. A similar observation is made by Minten and Barrett (2008) who highlight the importance of improved agricultural technologies in an effort to attain higher productivity. To reach the full benefit of the fertilizer subsidy program, it is also important to encourage the adoption of complementary technologies among farm households.

Similar to the findings in Rahman and Rahman (2008), this study reveals that ownership of land and resources increases productivity. Households who rent-in land usually obtain access to fragments of land which may negatively affect productivity. Another plausible explanation, which has also been expressed by Place and Otsuka (2002), is based on the relationship between land ownership and investment. As land resources grow scarce, land owners have to take action to ensure the sustainable use of available land by investing in productivity enhancing practices. On the other hand, households who rent-in land are at liberty to relocate and therefore may not see the need to make such investments. Both cases require efforts to ensure land security through land titling. Meanwhile, it is important to encourage land owners to continue investing in sustainable practices. At the same time, itinerant households should be specifically targeted and sensitized on the importance of such practices.

Even though the results found that the availability of household labor resource increases labor productivity, both land and labor productivity decrease when the proportion of educated members in the household increases. This is contrary to the hypothesis that education induces improved understanding and application of good management practices, which translates into higher performance at the farm-level (Alene and Manyong, 2007). It is clear from the results that instead of contributing their knowledge to agricultural production, educated household members engage in off-farm income generating activities.

This phenomenon may be attributed to the content of the educational system, which may not promote or encourage agriculture. Another reason may be that educated household members find off-farm income activities more attractive (De Janvry and Sadoulet, 2001) compared to agriculture, which is characterized by drudgery and low-levels of mechanization. Either explanation suggests the need to encourage participation in the agricultural sector through the formal educational system. Attracting youth to stay in agriculture will also require the modernization of present systems. This further emphasizes the point made hitherto on the need for labor saving technologies for the agricultural production system in northern Ghana.

Despite the above explanation on the diversion of knowledge and labor to off-farm income generating activities, participation in such activities was shown to be important for rice-producing households, which is supported by De Janvry and Sadoulet (2001). Since farm operations are time bound, off-farm income can be a means of financing such operations. Income from such activities can pay for the cost of labor and the purchase of other agricultural inputs, such as seeds, and fertilizers. In northern Ghana-where the climate is characterized by a single rainy season, it is important to encourage farm households to engage in off-farm employment activities during the non-agricultural seasons to obtain income to finance agricultural activities.

4.5 Conclusion and recommendations

This study provides empirical evidence of the impact of the *Fertilizer Subsidy Program of Ghana* on land and labor productivity. The results found that participation in the subsidy program increases land productivity modestly, but reduces labor productivity. The main recommendation is that the subsidy program alone is not a strong enough tool for improving the productivity of rice-producing households.

Although the availability of household labor increased productivity, the more educated the household becomes, the lesser the contribution to agriculture due to the tendency to engage in off-farm employment activities. Participation in off-farm employment activities, however, provided means of financing agricultural activities and hence improves land productivity. Farmers should be encouraged to participate in off-farm employment activities, particularly in the non-agricultural seasons. At the same time, agriculture and the education system should be modified to encourage participation among youth and the educated.

Modification of agriculture is essential, particularly through the availability of labor-saving technologies. This is because, as this study has shown, the availability of an adequate amount of labor increases land productivity. It is important that reasonable combination is achieved, so that labor productivity is not compromised. The importance of complementary technologies and education for sustainable production cannot be ignored in the effort to modernize agriculture in northern Ghana and sub-Saharan African as a whole.

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Chapter 5: Food security and fertilizer subsidies: Empirical evidence from rice-producing households in northern Ghana[5]

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Abstract

Food insecurity will continue to be a global challenge as population grows and food production resources increasingly become scarce. This study evaluates the impact of the *Fertilizer Subsidy Program of Ghana* on food security among a sample of 740 rice-producing households in northern Ghana. It applies the local average treatment effect estimation procedure to determine impacts of the subsidy program on the intake of calories, proteins, and fats. Participation in the fertilizer subsidy program has positive impacts on food security. The impact is highest during the lean period, suggesting that the program improves food stability. Strengthening existing institutions to educate farm households on the importance of food nutrients, encouraging them to cultivate an appropriate crop mix, and facilitating participation in off-farm income generating activities can help improve food security.

Keywords: Fertilizer subsidy; food security; Ghana; impact; nutrients

[5] A revised version of this chapter under review with *Food Security*.

5.1 Introduction

Food insecurity will continue to be a global challenge as population grows and food production resources become increasingly scarce. Available evidence shows that significant progress has been made towards the reduction of global food insecurity and malnutrition. For example, between 1992 and 2011, the proportion of underweight children below the age of 5 years in Ghana has decreased from about 25% to 13% (FAO et al., 2013). While this achievement is remarkable, more effort is needed to ensure that all people have access to adequate amount of nutritious food for an active life (World Food Summit, 2006).

Different strategies are being implemented to strive for the attainment of food security. Globally, strategies seek to increase smallholder-sensitive investments in agriculture, mitigate the effects of price volatilities, address gender and nutrition needs, and develop sound institutional frameworks to facilitate access to food. In sub-Saharan Africa, for example, the Comprehensive Africa Agriculture Development Program (CAADP) is part of regional strategies to improve support to national and local food security programs (CFS, 2013). Global and regional efforts are enhanced by country specific strategies, such as the *Fertilizer Subsidy Program of Ghana* (Banful, 2008).

Fertilizer subsidy programs are part of strategies adopted by countries across sub-Saharan Africa to mitigate the effect of the global food crises which occurred in 2006. In Ghana, the program was also intended to encourage fertilizer use, and to increase productivity and production of arable crops (Banful, 2008). Increases in productivity and the production are subsequently expected to generate higher incomes and enhanced food security among farm families (Yawson et al., 2010). The program provided a universal subsidy (Jayne and Rashid, 2013), and initially involved the distribution of vouchers to enable farmers to purchase NPK-15:15:15, NPK-23:10:05, urea, and sulfate of ammonia fertilizers at about 50% of market prices. The voucher system was ineffective because it limited access to fertilizers (Yawson et al., 2010). To ensure unlimited access to fertilizers under the program, the voucher system was replaced in 2009 by annual announcements of subsidized prices.

Continued investment in the subsidy program requires information on the extent to which it has achieved its intended objectives. In a process evaluation, Banful (2008) and Yawson et al. (2010) show that ineffective distribution of vouchers limits access to fertilizers among arable crop farmers. Other studies on the effectiveness of input subsidy programs in eastern Africa recommend the inclusion of complementary investments in research and development and relevant infrastructure to unearth the full potentials of subsidy programs (Jayne and Rashid, 2013; Jayne et al., 2013; Druilhe and Barreiro- Hurlé, 2012). These studies, however, do not provide indications of impacts of subsidy programs on the well-being of intended beneficiaries.

Available evidence suggest that subsidy programs of sub-Saharan Africa affect fertilizer demand (Ricker-Gilber et al., 2009), production, productivity (Lunduka et al., 2013; Mason et al., 2013), food availability (Dorward and Chirwa, 2011), incomes (Dorward and Chirwa, 2013), and poverty (Awotide et al., 2013). The results of these studies provide insights on the performance of subsidy programs. While some of these studies provide evidence on the causal linkages between subsidy programs and their intended outcomes, others are based on descriptive analyses of potential effects of the subsidy programs.

For example, in a descriptive analysis, Lunduka et al. (2013) doubt the potential of subsidies to reduce food insecurity in Malawi due to a modest increase in maize production. An earlier descriptive study by Dorward and Chirwa (2011), however, shows that the subsidy program potentially increases food availability. Apart from these descriptive studies, Mkwara and Marsh (2011) establish causality between the fertilizer subsidy program of Malawi and national food security. Since the subsidy programs of sub-Sahara Africa target producers, it is important to determine how these programs perform at the micro-level. This study therefore aims to contribute to literature by providing empirical evidence of the causal impacts of *Fertilizer Subsidy Program of Ghana* on food security among rice-producing households in northern Ghana.

Measures such as food expenditures (Feleke et al., 2005), food balance scales, and calorie intake (van der Veen and Gebrehiwot, 2011; Babatunde et al., 2010), individual perceptions (Rahim et al., 2011), and dietary diversity scores (Moursi et al., 2008) are used to describe the food security status of individuals, households, communities, and countries. Among these measures, computed dietary diversity scores, based on different types of food consumed, provide information on the nutritional value of food consumed. However, it does not provide information on the quantity of food consumed. On the other hand, food and non-food expenditures, calorie intake, and perception provide information on the adequacy of food consumed. These measures, however, are limited in terms of the information they provide on the nutritional value of the food consumed. A food security index that captures both nutritional value and adequacy can be useful for future investigation.

For this reason, this study assesses food security by exploring adequacy and nutritional quality of food consumed by rice-producing households. Impacts of the *Fertilizer Subsidy Program of Ghana* on the nutritional value of the food consumed are estimated with the instrumental variable local average treatment effect (LATE) estimator. Since participation in the fertilizer subsidy program is a decision made by households, the use of the LATE estimator is appropriate to control for the possible endogeneity of participation (Abadie, 2003).

The remainder of this chapter is organized as follows: Section 5.2 presents the methodology and explains the computation of the quantities of food nutrients consumed; Section 5.3 presents the results from the analysis; Section 5.4 presents the discussions of the results; and Section 5.5 presents the conclusion and provides recommendations.

5.2 Methodology

5.2.1 Study area, sampling, and data

This study was conducted in northern Ghana. The area consists of three regions where the incidence of food insecurity is highest in the country (WFP, 2013), despite being the largest producer of cereals, including rice, in the country (MOFA, 2012). The impact of the fertilizer subsidy program is therefore expected to be higher in this area compared to other areas of Ghana. Northern Region, the largest of the three regions of northern Ghana, was selected for survey.

Selection of rice-producing communities and households began with listing communities in developed rice valleys in the region. From this list, 82 communities were randomly selected for community-level interviews. Within each selected community, 10 households were randomly selected from lists generated during the community interviews. In all, a total of 820 households were interviewed. Due to resource constraints, during the final round of interviews, only a subsample of 740 households from 74 randomly selected communities were interviewed for the food security modules of the survey. This sample is therefore representative of rice-producing communities and households in the developed rice valleys of the Northern region. However, it does not represent the rice system in the entire Northern Region which includes communities and households operating in undeveloped rice valleys and in upland rice ecologies.

Data was collected through interviews with representatives of the selected rice-producing households and communities. Using semi-structured modular questionnaires (Appendix 1B and 1C), the data collected describe community and household characteristics, household livelihoods, and food consumption patterns. The food consumption data consists of recall of food ingredients consumed by the household in the 24 hours prior to the interview. This round of data collection was repeated for periods of abundance, normal and low food availability. Preliminary discussions with members of selected communities reveal that there is an abundance of food after harvest. The period of normal food availability after harvest spans between four and eight months. Then, before the next harvest period, households experience a food shortage. This cycle guided the timing of the interviews on food consumption.

5.2.2 Examining household food security status at the household-level

Four pillars of food security, namely availability, access, utilization, and stability, are assessed in the literature (Ecker and Breisinger, 2012). Availability of food can be viewed as the existence of adequate food stocks for consumption. Access to food implies the ability to acquire sufficient quality and quantities of food. Food utilization is the capacity to make use of food for a productive life (Codjoe and Owusu, 2011). Food stability is the continuous availability, access, and utilization of food (Ecker and Breisinger, 2012). In this study, two pillars, food access and food stability are assessed.

Food access is examined because it relates to the actual food consumed by the sampled rice-producing households. It is computed as the nutritional value of the food consumed to account for both adequacy and nutritional content of food consumed. Quantities of the three macro nutrients in food namely, calories, protein, and fats, are considered. Using $Q_{i,j}$ to represent the quantity of the jth ingredient consumed, $I_{cal,j}$, as the equivalent caloric value per unit of the ingredient, $I_{pro,j}$ as the equivalent protein value per unit of the ingredient, and $I_{fal,j}$ as the equivalent fat value per unit of the ingredient, the total intake of calories, $Y_{i,Tcal}$, proteins, $Y_{i,Tpro}$, and fats, $Y_{i,Tfal,j}$ are computed, respectively as:

$$Y_{i,Tcal} = \sum Q_{i,j} * I_{cal,j} \qquad (5.1)$$

$$Y_{i,Tpro} = \sum Q_{i,j} * I_{pro,j} \qquad (5.2)$$

$$Y_{i,Tfat} = \sum Q_{i,j} * I_{fal,j} \qquad (5.3)$$

To separate rice-producing households who have adequate intake of these nutrients from those who have below adequate intake, household food access status is computed for calories $I_{i,cal}$, proteins, $I_{i,pro}$, and fats, $I_{i,fat}$. To do this, household requirement of calories, $Y_{i,cal}$, proteins, $Y_{i,pro}$, and fat, $Y_{i,fat}$, are computed as:

$$Y_{i,cal} = M_{i,cal} + F_{i,cal} + C_{i,cal} \quad (5.4)$$

$$Y_{i,pro} = M_{i,pro} + F_{i,pro} + C_{i,pro} \quad (5.5)$$

$$Y_{i,fat} = M_{ifat} + F_{i,fat} + C_{i,fat} \quad (5.6)$$

In Equations 5.4, 5.5, and 5.6, the variables $M_{i,cal}$, $M_{i,pro}$, and $M_{i,fat}$, represent the calorie, protein, and fat requirements, respectively, for male members of a given household. Those of females and children are given by $F_{i,cal}$, $F_{i,pro}$, and $F_{i,fat}$, and $C_{i,cal}$, $C_{i,pro}$, and $C_{i,fat}$. The computation also accounts for different age and health conditions (Latham, 1997). Thus in terms of calories a household is food insecure if $Y_{i,Tcal} < Y_{i,cal}$ so that $I_{cal,j} = 1$ or 0 otherwise. For households who are food insecure in terms of protein $I_{pro,j} = 1$ if $Y_{i,Tpro} < Y_{i,pro}$, or 0 otherwise. Also for those who are food insecure in terms of fat $I_{fat,j} = 1$ if $Y_{i,Tfat} < Y_{i,fat}$, or 0 otherwise. For each of the nutrients, the incidence of food insecurity is computed as the ratio of the total number of households who have consumption below their required rate to the total number of sampled households.

Since rice-producing households largely depend on agriculture for subsistence, access to food varies throughout the year. As mentioned earlier, during the community interviews three periods, namely abundance, normal, lean were identified. During the harvest period in October, households have abundant supply of food. The period of abundance last until January when a significant proportion of food has been consumed or sold. The normal period is between February and May, and is followed by the lean period between June and September. During the lean period, household food reserves are significantly reduced resulting in rationing. The cycle repeats after harvest. To examine stability, quantities of the food nutrients consumed are computed for these three periods.

In addition to the nutritional value of food consumed, the count of different food ingredients consumed is also calculated to examine household dietary diversity (Moursi et al., 2008). The extent of variation from the mean food count is calculated to check its suitability for regression analysis. The distribution of food counts are computed within four expenditure percentiles.

5.2.3 Estimating food security impacts of the fertilizer subsidy program

5.2.3.1 The local average treatment effect impact estimator

The treatment effect methodological framework is used to establish the causal effect (Cameron and Trivedi, 2005) of participation in the fertilizer subsidy program on computed nutritional values of the food consumed. The methodology is based on the premise that a given rice-producing household has two potential outcomes for participating in the subsidy program. To illustrate this, P_i is used to represent participation in the program and is assigned the value of 1 for participants and 0 for non-participants. The variable Y_i represents the computed nutritional values of food such that $Y_{i,1}$ is observed when $P_i = 1$, and $Y_{i,0}$ is observed when $P_i = 0$. From these notations, the effect of the program on a selected household, Δ_i, is:

$$\Delta_i = E(Y_{i,1} - Y_{i,0} | P_i = 1) + \{E(Y_{i,0} | P_i = 1) - E(Y_{i,0} | P_i = 0)\}$$
$$= ATE_i + \mu_i \quad (5.7)$$

In Equation 5.7, ATE_i is the average treatment effect impact parameter and μ_i is the error term representing the unexplained bias caused by the way the program is assigned among the sampled rice-producing households.

If fertilizer subsidies are randomly assigned to rice-producing households, it follows that $E(\mu_i) = 0$ and $\Delta_i = ATE_i$. However, subsidies were not randomly assigned and were not targeted at specific groups. Instead, households have the privilege to decide whether to participate in the program or not. By this design, it is possible that expectations about the potential benefits, among other factors influenced the decision to participate. Because participation can be influenced by the expectation of outcomes, it is endogenous and therefore $E(\varepsilon) \neq 0$ and I ≠ ATE (DiPrete and Gangl, 2004).

To account for the non-random endogenous error term in Equation 5.7, there is the need to control for the bias of participation in the subsidy program (Adeoti, 2009). This requires the use of an instrument Z_i, which predicts participation, but does not predict the computed nutrient value of the food ingredients (Cameron and Trivedi, 2005). The instrument is constructed from the nature of the subsidy program and with insights from experiences during the field survey. Even though the program is universal, members of some communities are more likely to participate in the program compared to members of other communities.

Observations during the field survey for example, reveal that communities within the same location have different understandings and approaches to farm operations. It is also possible for such differences to be exhibited in terms of the manner with which members of such communities seek information and their attitudes toward interventions, such as the fertilizer subsidy program. A variable which identifies communities that have members participating in the subsidy program is therefore used as an instrument. The instrument was captured in the community interviews by asking about the number of households that participated in the subsidy program.

To ensure that this variable satisfies the exclusivity condition (Abadie, 2003), all households that participate in the subsidy program are expected to belong to a subsidy community. A correlation test is conducted between the instrument, participation in the subsidy program, and the computed nutritional values of the food ingredients consumed. The instrument is assigned the value of 1 for households who reside in a subsidy community and is assigned the value of 0 for those who reside outside of a subsidy community. This dummy instrument identifies the impact of the subsidy program on the subpopulation of rice-households who participate in the program because they are unintentionally targeted. The parameter estimated by this instrument is the local average treatment effect (LATE) parameter (Abadie, 2003). To derive the LATE impact parameter Equation 5.7 is re-expressed as:

$$\Delta_i = E\left(Y_{i,1} - Y_{i,0} | P_i = 1, Z_i = 1\right) + \left\{E\left(Y_{i,0} | P_i = 1, Z_i = 1\right) - E\left(Y_{i,0} | P_i = 0, Z_i = 1\right)\right\}$$
$$= LATE_i + \varepsilon_i \quad (5.8)$$

5.2.3.2 Estimation of the LATE impact parameter and other determinants of food security

Two alternative approaches are explored in the estimation of the LATE impact parameter. The first approach assumes that the effects of observed covariates are negligible. Thus, LATE is estimated with a non-parametric WALD estimator (Cameron and Trivedi, 2005) as shown in the following equation:

$$LATE_{i,WALD} = \frac{E(Y_i|Z_i=1)-E(Y_i|Z_i=0)}{E(P_i|Z_i=1)-E(P_i|Z_i=0)} \quad (5.9)$$

The second approach is a semi-parametric estimation procedure involving the estimation of the local average response function (LARF) estimator of the LATE impact parameter. The LARF estimator allows for the identification of the LATE, conditional on a set of covariates. The procedure is extensively treated in Abadie (2003). In addition, the LARF estimator provides information on other determinants of food security.

Apart from the subsidies program, government interventions, such as the food-for-work program of Ethiopia, can increase the probability that households become food secure (van der Veen and Gebrehiwot, 2011). Factors that describe the characteristics of households and their livelihood activities, namely, household size, education, gender, age, marital status, income (or expenditures), wealth, land resources, farm size, type of farming system, and improved technology use, also influence food security (Rahim et al., 2011; Babatunde et al., 2010; Feleke et al., 2005). Other factors, including the availability of roads infrastructure and irrigation facilities, have been shown to influence food security as well (Rahim et al., 2011; van der Veen and Gebrehiwot, 2011). These factors inform the choice of the explanatory variables used in the LARF estimation.

Among the list of explanatory variables considered in this study, participation in a rice project, participation in off-farm income generation activities, membership in a farmer based association, obtaining information from neighbors, and access to extension are dummy variables that are expected to increase the intake of food nutrients. Continuous variables, such as the household size, average age of economically active persons in the household, proportion of economically active persons in the household, proportion of male members in the household, proportion of educated persons in the household, household per capita expenditure, total land area allocated to arable crop production, the number of arable crops produced, and total livestock units are expected to increase intake of the food nutrients.

5.3 Results

5.3.1 Value of food consumed

About 56% of the sampled rice-producing households participate in the fertilizer subsidy program. While all participants live in subsidy communities, about 28% of the non-participants live outside subsidy communities (Table 5.1). This satisfies the exclusivity condition for selecting the subsidy community as the instrument for the LATE impact estimation.

The main contents of Table 5.1 are computed food security indices of the sampled rice-producing households, which include daily requirements of the three major nutrients, the amounts of the nutrients consumed, and the incidence of food insecurity. For a given day, the sampled rice-producing households require about 2,170 kilograms of calories per capita, about 45 grams of proteins per capita, and about 60 grams of fats per capita. The daily requirements of the nutrients among the participants are not significantly different from those of non-participants.

The computed consumption and incidence of food insecurity are presented for the three periods. The amount of nutrients consumed and the incidences of food insecurity vary across the periods. The quantities of nutrients consumed by participants are not significantly different from those of non-participants. Similarly, the distribution of food insecure households among the participants is not different from those of non-participants.

During the normal period, the households consume about 51% more calories and 85% more proteins, and 29% less fats than they require. The consumption of fats is always below the amount required by the households.

Table 5.1: Per capita food required and consumed, and incidence of food insecurity

	Overall (N=740)	Non-Participants (N=324)	Participants (N=416)	Prob.
Living in subsidy community (%)	87.84	72.22	100.00	-
<u>Calories</u>				
Requirement (kcal/day)	2,169.98	2,178.65	2,163.16	0.31
Consumed in abundance period (kcal/day)	3,360.89	3,322.77	3,390.91	0.73
Consumed in normal period (kcal/day)	3,278.01	3,088.04	3,427.61	0.15
Consumed in lean period (kcal/day)	2,838.23	2,762.49	2,897.87	0.46
Food insecurity in abundance period (%)	34.46	33.44	35.27	0.60
Food insecurity in normal period (%)	36.76	37.42	36.23	0.74
Food insecurity in lean period (%)	46.49	46.93	46.14	0.83
<u>Proteins</u>				
Requirement (g/day)	45.39	45.61	45.22	0.42
Consumed in abundance period (g/day)	83.80	84.06	83.59	0.95
Consumed in normal period (g/day)	81.24	84.32	78.82	0.32
Consumed in lean period (g/day)	77.21	78.78	75.96	0.74
Food insecurity in abundance period (%)	30.00	29.75	30.19	0.90
Food insecurity in normal period (%)	31.89	31.60	32.13	0.88
Food insecurity in lean period (%)	39.59	41.72	37.92	0.30
<u>Fats</u>				
Requirement (g/day)	59.54	59.85	59.29	0.26
Consumed in abundance period (g/day)	42.48	40.22	44.25	0.32
Consumed in normal period (g/day)	42.40	38.86	45.18	0.11
Consumed in lean period (g/day)	37.32	35.71	38.58	0.41
Food insecurity in abundance period (%)	75.14	78.83	72.22	0.04
Food insecurity in normal period (%)	75.54	78.83	72.95	0.06
Food insecurity in lean period (%)	77.70	80.67	75.36	0.09

The results show that at any point in time, some rice-producing households do not have access to adequate quantities of the three major food nutrients and are therefore food insecure with respect to a specific food nutrient. The incidence of food insecurity is generally lower among households who participate in the subsidy program. For the three food nutrients, the incidence of food insecurity is highest for fats and relatively lower for calories and proteins. With regards to the three periods the incidence of food insecurity increases during the lean period and declines during the period of abundance.

During the normal period, about 37% of households do not have access to adequate quantities of calories. The incidence decreases to about 34% in the period of abundance and increases to about 46% in the lean period. For proteins, the incidence of food insecurity decreases from 32% during the normal period to about 30% in the period of abundance, however, it increases to about 40% during the lean period. The incidence of food insecurity with respect to the intake of fats increases from about 75% in the period of abundance, to 76% in the normal period, and to 78% in the lean period.

5.3.1.1 Computed food count

The number of food items consumed, also referred to as food count, are presented in Table 5.2. The results are presented for each of the three periods and for four expenditure percentiles. In general, food counts do not vary greatly across the participating, period, and expenditure percentile categories.

For the whole sample, the results show an average food count of about eight for the period of abundance and normal period, and about seven for the lean period. For the period of abundance, the food count is about seven in the first percentile and about seven in the fourth percentile. A similar trend is observed for the normal and lean periods. With the exception of the lean period of the first percentile, the dispersion of the food count is around 30%. Moreover, food counts of the participants are not significantly different from those of the non-participants. This suggests that the dispersion of the food count is relatively low. Subjecting data with such low variance to regression is likely to produce insignificant results. Therefore, the subsequent analysis of the impact of the subsidy program on food intake is limited to the computed value of food nutrients consumed.

Table 5.2: Household food count

Scores	Overall	Non-Participants	Participants	Prob.
Abundance	7.87 (0.31)	7.72 (0.32)	7.99 (0.31)	0.14
Normal	7.53 (0.35)	7.37 (0.36)	7.65 (0.34)	0.16
Lean	7.13 (0.37)	7.01 (0.38)	7.22 (0.37)	0.30
1st expenditure percentile				
Abundance	7.19 (0.39)	7.15 (0.38)	7.23 (0.40)	0.85
Normal	6.69 (0.46)	6.58 (0.47)	6.80 (0.46)	0.62
Lean	6.35 (0.50)	6.25 (0.50)	6.45 (0.51)	0.67
2nd expenditure percentile				
Abundance	7.82 (0.27)	7.69 (0.28)	7.91 (0.25)	0.49
Normal	7.59 (0.31)	7.28 (0.36)	7.80 (0.27)	0.14
Lean	7.18 (0.33)	6.93 (0.38)	7.35 (0.29)	0.24
3rd expenditure percentile				
Abundance	8.17 (0.24)	7.89 (0.26)	8.38 (0.22)	0.09
Normal	7.99 (0.26)	7.87 (0.26)	8.08 (0.25)	0.53
Lean	7.61 (0.26)	7.53 (0.28)	7.67 (0.25)	0.64
4th expenditure percentile				
Abundance	8.32 (0.34)	8.27 (0.32)	8.36 (0.35)	0.82
Normal	7.84 (0.36)	7.89 (0.33)	7.80 (0.38)	0.84
Lean	7.37 (0.38)	7.47 (0.34)	7.30 (0.41)	0.69

Note: Coefficient of variation is in parenthesis.

5.3.2 Estimated impacts of the fertilizer subsidy program on food consumption

The LATE estimates of the impact of the fertilizer subsidy program on the quantities of food nutrients consumed are presented in Table 5.3. The table shows results from the WALD and LARF estimators of the LATE impact parameters for calories, proteins, and fats intake for the three periods. The results of the WALD estimators are positive but not significant. Those of the LARF estimators are positive and significant. Observed covariates are therefore necessary in the estimation of the LATE impact of the *Fertilizer Subsidy Program* of Ghana on food security.

The estimated impacts show that participation in the subsidy increases the daily per capita intake of calories by about 400 kcal during the normal period. Participation in the program also increases per capita intake of proteins and fats by about 4 g and 8 g, respectively, during the normal period. The impacts of the subsidy on nutrient intake are high during the period of abundance and the lean period.

Table 5.3: Estimated impacts of subsidy on food consumption

	LATE by Wald		LATE by LARF	
	Coefficient	Std. error	Coefficient	Std. error
Calories				
Abundance	550.36	72,147.30	420.03***	6.56e-07
Normal	400.61	870,387.80	180.31**	5.52e-07
Lean	552.41	138,265.30	367.88***	4.18e-07
Proteins				
Abundance	12.79	791.84	13.92***	1.11e-08
Normal	3.52	1,627.22	14.97***	2.20e-08
Lean	23.96	15,026.69	25.51***	1.21e-08
Fats				
Abundance	14.87	2,071.33	12.39***	7.70e-09
Normal	8.26	1,772.65	2.32***	0.21
Lean	15.04	12,909.56	15.30***	8.70e-09

Note: ***1% significant.

5.3.3 Estimated determinants of food consumption

In addition to the effects of the fertilizer subsidy program, the determinants of food security in terms of the quantity of nutrients consumed are presented in Tables 5.4, 5.5, and 5.6. In Table 5.4, the results are presented in terms of the intake of calories, proteins, and fats during the period of abundance, while those for the normal and lean period are presented in Tables 5.5 and 5.6, respectively. Factors affecting the intake of the food nutrients are described within each cardinal period. The factors affecting each of the nutrients are then compared across the periods.

In the period of abundance, the intake of calories, proteins and fats are decreased by increases in the size of the rice-producing households and the proportion of educated persons in the household. Intake of nutrients is increased when households access information from neighboring farmers. The number of arable crops produced also increases the intake of calories and proteins. Intake of fats, on the other hand, is decreased by off-farm income generating activities and increases in per capita expenditures. During the period of abundance, the intake of calories is increased by the age of economically active persons in the household.

During the normal period, intake of the three nutrients is decreased by the size of the rice-producing households, and is increased by the proportion of economically active persons in the household and by access to information from neighbors. Intake of calories and fats is increased by the age of economically active persons in the household. Calorie intake during the period is decreased by the proportion of educated persons in the household whereas per capita expenditures decrease the intake of fats.

Again, intake of the three nutrients is decreased by the size of rice-producing households and is increased by access to information from neighbors during the lean period. Access to extension increases intake of both calories and proteins in the lean period. Calorie intake in the period is increased by the proportion of males and decreased by the proportion of educated household members. Per capita expenditure and off-farm activities decrease the intake of fats in the lean period.

Even though some factors affect intake of all the nutrients in all periods, the combinations of factors vary across nutrients and also across periods. For example, calorie intake in the three periods is decreased by household size and the proportion of educated persons in the household. Intake of calories in the three periods, on the other hand, is increased by the average age of economically active persons in the household and access to information from neighbors. The number of arable crops produced increases calorie intake only in the period of abundance. Similarly, the proportion of economically active persons increases calorie intake in the normal period. In the lean period, calorie intake is increased by the proportion of males and access to extension.

Just like calories, the intake of proteins is increased by access to information from neighbors and decreased by household size across the three periods. In the period of abundance, protein intake is decreased by the proportion of educated persons in the households and is increased by the number of arable crops produced. In the normal period, protein intake is increased by the proportion of economically active persons in the household. Protein intake is increased by access to extension in the lean period.

Again for the three periods, fat intake is decreased by household size and off-farm employment activities. The intake of fats for the three periods is increased by access to information from neighbors. In the abundance period, fat intake is decreased by the proportion of educated persons and per capita expenditures. Per capita expenditure also decreases the intake of fat in the period of abundance and lean period. The proportion of educated persons decreases fat intake in the period of abundance. On the other hand, proportion of economically active persons in the household increases fat intake in the normal and lean periods. In the normal period, the average age of economically active persons in the households increases fat intake.

The results show that the factors that influence food consumption vary across the three nutrients and across the three periods. This indicates that different approaches are required to increase the consumption of different nutrients at different periods.

Table 5.4: Determinants of nutrient intake in the period of abundance

	Calories		Proteins		Fats	
	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error
Participation in the subsidy program	420.03	325.83	13.92*	7.78	12.39	7.76
Household size	-250.87***	22.84	-5.14***	0.55	-2.73***	0.54
Average age of economically active persons	57.21***	22.35	0.74	0.53	0.80	0.53
Proportion of active persons	329.81	577.96	13.57	13.79	9.47	13.77
Proportion of males	79.28	714.28	3.29	17.05	21.50	17.01
Proportion of educated	-1142.00**	472.89	-21.56*	11.29	-21.47*	11.26
Per capita expenditure	20.75	16.85	0.38	0.40	-0.69*	0.40
Off-farm employment activities	51.60	224.66	-4.81	5.36	-11.32**	5.35
Area of land under arable crops	-12.22	43.84	-1.09	1.05	-0.43	1.04
Number of arable crops grown	188.45*	110.76	5.77**	2.64	3.10	2.64
Access to extension	320.87	237.19	8.26	5.66	3.42	5.65
Membership in a farmer association	120.20	249.66	-1.22	5.96	0.31	5.95
Information from neighbors	920.94***	230.41	18.79***	5.50	15.95***	5.49
Participation in rice project	-202.73	240.93	-5.12	5.75	-8.62	5.74
Total livestock unit	-4.37	9.83	-0.17	0.23	-0.06	0.23
Constant	2989.79***	960.12	74.62***	22.91	23.50	22.87

Note: *10% significant, **5% significant, ***1% significant.

Table 5.5: Determinants of nutrient intake in normal period

	Calories		Proteins		Fats	
	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error
Participation in the subsidy program	180.31	525.98	14.97	13.87	2.32	7.68
Household size	-274.05***	36.88	-6.72***	0.97	-2.3***6	0.54
Average age of economically active persons	88.78***	36.07	1.12	0.95	1.41***	0.53
Proportion of active persons	2497.55***	932.99	85.60***	24.59	29.74**	13.62
Proportion of males	-1375.99	1153.05	-18.95	30.40	19.09	16.84
Proportion of educated	-1269.42*	763.38	-7.96	20.12	6.94	11.15
Per capita expenditure	-1.63	27.21	-0.17	0.72	-0.55	0.40
Off-farm employment activities	56.21	362.67	-10.14	9.56	-17.49***	5.30
Area of land under arable crops	37.46	70.77	-0.26	1.87	-0.98	1.03
Number of arable crops grown	-207.87	178.80	-1.62	4.71	3.51	2.61
Access to extension	206.87	382.88	15.98	10.09	6.00	5.59
Membership in a farmer association	-8.98	403.02	-13.36	10.62	-5.85	5.88
Information from neighbors	1489.89***	371.95	42.92***	9.81	9.87*	5.43
Participation in rice project	135.16	388.93	1.71	10.25	-5.80	5.68
Total livestock unit	0.34	15.87	-0.05	0.42	-0.05	0.23
Constant	2970.80*	1549.91	92.84**	40.86	-3.55	22.63

Note: *10% significant, **5% significant, ***1% significant.

Table 5.6: Determinants of nutrient intake in lean period

	Calories		Proteins		Fats	
	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error
Participation in the subsidy program	367.88	276.20	25.51*	15.39	15.30**	6.41
Household size	-221.29***	19.36	-5.61***	1.08	-1.80***	0.45
Average age of economically active persons	58.92***	18.94	0.14	1.06	0.36	0.44
Proportion of active persons	101.36	489.94	23.44	27.30	18.80*	11.38
Proportion of males	1134.24*	605.49	31.63	33.74	7.27	14.06
Proportion of educated	-922.62**	400.87	4.37	22.34	-1.43	9.31
Per capita expenditure	-13.80	14.29	-0.53	0.80	-0.58*	0.33
Off-farm employment activities	71.06	190.45	-7.95	10.61	-11.29***	4.42
Area of land under arable crops	42.88	37.16	0.91	2.07	-0.35	0.86
Number of arable crops grown	-16.52	93.89	-5.77	5.23	1.37	2.18
Access to extension	457.76**	201.06	36.85***	11.20	2.56	4.67
Membership in a farmer association	115.48	211.63	-9.25	11.79	-1.51	4.91
Information from neighbors	1001.75***	195.32	33.97***	10.88	11.35***	4.54
Participation in rice project	-224.75	204.24	-3.69	11.38	0.80	4.74
Total livestock unit	-2.88	8.33	0.06	0.46	0.07	0.19
Constant	2123.05***	813.89	71.81	45.35	16.67	18.90

Note: *10% significant, **5% significant, ***1% significant.

5.4 Discussion

5.4.1 The food security situation among rice-producing households in northern Ghana

Considering food count as an indicator of food security, the rice-producing households are shown to consume about 7 different food items regardless of their participation status, the period, and expenditure category. Moreover, the variation in the food count is relatively low. The *Fertilizer Subsidy Program of Ghana* is therefore not expected to affect dietary diversity.

The computed nutritional values of food ingredients consumed by the sampled rice-producing households, on the other hand, provide important information on the adequacy and quality of food consumed. Comparing the nutritional requirements of the households to the amount consumed, the results show that at any point in time, some households are food insecure. The incidence of food insecurity, however, varies by food nutrients, and periods. The design of food security interventions should therefore consider prevailing nutritional needs at different periods.

The study shows that the majority of rice-producing households have access to adequate amount of calories and proteins. On the other hand, the majority of households lack access to an adequate amount of fats. A possible explanation for this is that rice-producing households produce arable crop mainly for home consumption. These crops include cereals, legumes, and sometimes fruits, which have low fat contents (Latham, 1997). To improve the intake of fats among households, two approaches can be explored. First, farm households can be encouraged to include crops rich in fats in the bundle of crops they cultivate for subsistence. Another option is to encourage households to diversify their crop production to include cash crops. The proceeds from the sale of cash crops can be used to purchase food ingredients that are rich in fats. Moreover, households can be educated on the importance of consuming adequate quantities of fats. These strategies can also be applied to households who consume inadequate quantities of calories and proteins.

Considering the periods, the study shows that quantities of the three food nutrients consumed are reduced during the lean period, causing an increase in the incidence of food insecurity. This implies that for some households who have access to an adequate quantity of the food nutrients in the normal period, conditions in the lean period move them into a state of food insecurity. Households who are food secure in the normal period, but food insecure in lean period have unstable access to food. According to World Food Program (2013), due to the dependence on erratic rainfall, farm households in northern Ghana face seasonal effects which limit access to adequate food year round. This phenomenon was observed during the field survey. Households usually have access to food in abundance immediately after harvest. The food stock diminishes gradually until it is almost exhausted a few months prior to the next harvest. This explains the observed instability in this study. The possible cause of this is that the households may be unable to produce adequate quantities of food to sustain their food needs throughout the year. Even where they produce enough food, observations during the field survey show that households are engaged in poor post-harvest management practices, which have been associated with nearly 22% of losses in the cereal production system of Ghana (Appiah et al., 2011). Therefore, in addition to building capacities to increase food production, training and support for the adoption of effective post-harvest management practices can be useful in the development of effective food security strategies.

5.4.2 Impact of the fertilizer subsidy program on food security

In addition to macro-level evidence of the impact of fertilizer subsidies (Mkwara and Marsh, 2011), this study shows that the *Fertilizer Subsidy Program of Ghana* increases the nutritional value of food consumed by rice-producing households in northern Ghana. By implication, participation in the subsidy program, which improves access to fertilizers and potentially increases farm production, and eventually increases access to food? The study shows that the impact of the program is higher during the lean period. By implication, the *Fertilizer Subsidy Program* seems to improve the stability of food security. Establishing this link, however, requires an in-depth examination to identify the pathways of this effect.

Regardless of the positive impact of the subsidy program on the quantities of food nutrients consumed, some participating households still do not have an adequate consumption of food, particularly during the lean period. Ensuring an adequate intake of food at all times requires additional strategies that can increase access and maintain the stability of food consumption among rural households.

5.4.3 Determinants of food security

To inform the development of effective and holistic strategies to enhance food security, other factors that influence access to the quantities of food nutrients consumed are examined. Factors, namely, household size, age of economically active persons, proportion of economically active persons in the household, the proportion of educated persons in the household, the proportion of males in the household, participation in off-farm income generating activities, household per capita expenditure, the number of arable crops produced, access to extension, and access to information from neighbors influence consumption of the three food nutrients in various ways.

The results show that as household size increases, per capita consumption of the three food nutrients decreases. This confirms findings by Ajoa et al. (2010) who show that household size increases food insecurity. Farm households operate a fixed land resource and production is largely fixed such that an additional member reduces the food share of other household members. Given this resource limitation, it is important for larger households to adopt strategies to improve their productivity to satisfy their food needs.

As the average age of economically active persons in the households increases, the consumption of the three food nutrients increases. Particularly for the lean period, the intake of calories is important to compensate for the high energy expenditure associated with critical farm operations such as harvesting. On the other hand, economically active persons who are much older are likely to be engaged in off-farm employment activities, which can provide additional income to purchase additional food to complement farm production.

The results of this study do not entirely support the hypothesis that the intake of food nutrients, particularly fats, increases with increases in income. Unlike Du et al. (2004) who find that increases in the intake of food increases with income in China, this study show that households who have higher expenditures or additional income sources have low fat intake. This contradiction can be explained by differences in the study agents. While this study focuses on rural farm households, the study by Du et al. (2004) focuses on urban households. As observed during the field study, rural households are more likely to acquire life-style assets like mobile phones, television, and vehicles with increases in income. This may not be the case in urban China where increases in income from formal employment can encourage consumption of fast foods to save time for other activities (Du et al., 2004).

Intake of all three nutrients is shown to be higher for rice-producing households who have access to information through extension and neighboring farmers. These institutions provide information that significantly contribute to increased arable crop production and hence food consumption. Food security strategies can also be linked to existing farmer based organizations and extension agencies. Their capacities can also be enhanced to deliver information on good nutrition.

Contrary to expectations, the number of arable crops grown reduces the consumption of calories and proteins, and has no effect on the intake of fats. A possible explanation for this is that rice-producing households are unable to ensure proper management of many crops, which can result in lower productivity. Even though this may seem to contradict and earlier suggestion to include fat-rich food crops in the crops grown by rice-producing households, the explanation is that rice-producing households should be guided to identify and produce crop combinations that can provide adequate quantities of the food nutrients they require rather than just increasing the number of food crops produced.

The study shows that households with a higher proportion of educated persons have a lower intake of calories in the lean period. A similar result is obtained by Monteiro et al. (2001), who find that educated persons are more health conscious and therefore consume lesser calories to decrease obesity. It appears that educated persons in the rice-producing households are also more health conscious and therefore contributed to the lower intake of calories and proteins. While it is important to intensify education on healthy diets, it is also important to educate members of rural society on the importance of an adequate intake of food nutrients. This can be achieved through linkages with local institutions, such as farmer based organizations and development projects.

5.5 Conclusions and recommendations

This study shows that participation in the *Fertilizer Subsidy Program of Ghana* increases food security at the micro-level and therefore makes important contribution to the literature. The results show that participation in the subsidy program increases the intake of: calories by an average of about 323 kcal per capita, proteins by an average of 18 g per capita, and fat by an average of 10 g per capita. More importantly, the impact is highest during periods when rice-producing households have limited access to food. Despite the positive impact, some participating households remain food insecure. Additional strategies are therefore required if the full effect of the subsidy program is to be achieved. In terms of the quantity and quality of food consumed, most households consume adequate quantities of calories and proteins. Intake of fats, however, is inadequate among the majority of households. Cultivation of crop combinations that provide enough food to satisfy the food and nutritional needs of households is imperative.

This study also shows that the incidence of food insecurity increases during the lean period, suggesting that access to food is unstable. It is important to identify and target food security interventions at such periods to stabilize food security among beneficiaries. Since farm-level production alone is unable to provide the food needs of households, it is important to encourage members of households to participate in off-farm income generating activities. These activities can provide additional incomes for the purchase of necessary food crops to complement food from the farm.

Moreover, education on the importance of food nutrients will help improve consumption, particularly among households who can afford higher expenditures yet have the tendency to consume less nutritious food. Existing institutions should be engaged and strengthened to deliver education on proper nutrition.

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Chapter 6: Discussions and conclusions

6.1 Overview of the thesis research

Agricultural input subsidies have been re-introduced in sub-Saharan Africa, despite criticisms of their effectiveness as policy instruments. Apart from the initial intension of mitigating the effect of the global price hikes which peaked in 2008 (Druilhe and Barreiro-Hurlé, 2012), the new input subsidy programs are expected to increase access and use of improved agricultural inputs, particularly fertilizer, for increased farm-level performance among beneficiaries. Eventually, the food security and incomes of households, communities, and economies are expected to improve (Banful, 2008).

The existing literature shows that the new subsidy programs have made some gains. For example, the subsidy programs of Malawi and Zambia have been shown to increase food production (Lunduka et al., 2013) and reduce food prices (Ricker-Gilbert et al., 2013). Subsidies for hybrid maize seeds, in particular, have been associated with high private and social benefit-cost ratios, and improved well-being at the household level (Mason and Smale, 2013). Almost all of the studies on subsidies, with the exception of Awotide et al., (2013) who examine seed voucher subsidies, have focused on countries in eastern Africa.

The motivation of this research is based on the need to fill this knowledge gap by evaluating impacts of the *Fertilizer Subsidy Program of Ghana* on farm-level productivity and food security among rice-producing households in northern Ghana. Understanding the fertilizer adoption decision process is an important component of this thesis. The thesis focuses on the rice production system in northern Ghana because rice is a commodity of strategic economic importance in Ghana and in Africa as a whole, and the subsidy program is crucial for the rice development strategy of Ghana. On the other hand, northern Ghana, which produces about 30% of domestically produced rice, is characterized by declining soil fertility, low productivity (Langyintuo and Dogbe, 2005), and a high incidence of food insecurity (WFP, 2013). The subsidy program is therefore expected to have high impact on farm performance and well-being of rice-producing households in this part of the country.

The following section presents a discussion summarizing the major findings of the research themes of the thesis. This is followed by a sections main conclusions, recommendations, and then limitations of the research.

6.2 Major findings

The thesis essentially evaluates impacts of *Fertilizer Subsidy Program of Ghana* on farm-level productivity and food security among rice-producing households in northern Ghana. To address this primary objective, four main working objectives are addressed in separate chapters: the first explores fertilizer adoption decisions among farm households in northern Ghana; the second objective re-examines fertilizer adoption decisions by controlling for participation in the fertilizer subsidy program; the third evaluates the impact of the subsidy program on land and labor productivity using an instrumental variable based regression approach; and the fourth uses a similar regression procedure to examine the impact of the subsidy program on food security.

The research begins with an exploratory study to examine the determinants of fertilizer adoption among smallholder farmers. The study finds a rather high adoption incidence rate of 97% for fertilizer. This is attributed to the methodology. First, the study focuses on smallholder farmers in the domain of a soil health project from the Alliance for a Green Revolution in Africa (AGRA), so the data is not representative of the agricultural production system, since all the interviewed households are likely to be beneficiaries of the project. Results from Cragg's double hurdle regression model finds, for example, that distance to the nearest agricultural office increases adoption, while income decreases the intensity of adoption. These results contradict expectations from the literature. Again, the regression methodology which fails to account for selectivity bias may have contributed to this outcome. Moreover, the study's recommendations, which include regular training of members of farmer based organizations, does not target any particular agricultural production system. Despite the study's flaws, it presents relevant lessons that inform the approach employed in evaluating the impact of the fertilizer subsidy program.

6.2.1 Adoption of fertilizers under the fertilizer subsidy program

For a more robust and focused analysis of fertilizer adoption decisions, this thesis focuses on randomly selected rice-producing households in northern Ghana. Two aspects are unique in our analysis. Unlike earlier studies which treat all fertilizers the same, this thesis shows that rice-producing households use different types and combinations of fertilizers, with the combination of NPK and NH4 dominating. However, in spite of the operational subsidy program, about 30% of households do not use fertilizers, confirming Ragasa et al. (2013). Moreover, fertilizer application among adopters is still below the recommended rates of 240 kg/ha for NPK and 120 kg/ha for NH4 (Ragasa et al., 2013).

The study show that fertilizer adoption decisions occur in two stages. In the first stage, rice-producing households make a decision of whether to use fertilizers or not to use fertilizers. In the second stage, they decide on the intensity of application. This implies that these two separate decisions can be explored to achieve different goals regarding strategies to improve fertilizer adoption. Similarly, factors that must be explored to promote the adoption of fertilizers in general differ from those to promote the adoption of a specific fertilizer combination. While this study provides additional evidence to support a two-step analysis of agricultural technology adoption (Yirga and Hassan, 2013), it also presents the need for adoption studies to examine technologies as a package.

Participating in the fertilizer subsidy program is shown to increase the probability and the intensity of adoption of both fertilizer in general and the combination of NPK and NH4 fertilizers. These results confirm those obtained by Mason et al. (2013) which find a positive relationship between a fertilizer subsidy and the rate of fertilizer application in Zambia.

6.2.2 Impacts of the fertilizer subsidy program on productivity

In Chapter 4, the fertilizer subsidy program is shown to increase land productivity modestly, as in Lunduka et al. (2013), and to decrease labor productivity. Relating these results to that on adoption, it appears that the subsidy program encourages more households to use fertilizers, particularly NPK and NH4 fertilizers which is the most common combination. However, the rate of fertilizer application is unable to translate into higher levels of land productivity. On average, land productivity of the sampled rice-producing households, 1,309.44 kg/ha, is still below the national and global average of 2,538.58 kg/ha and 4,547.80 kg/ha, respectively (SRID/MOFA, 2013).

In the case of labor productivity, the negative impact of the subsidy program can be explained by the nature of the rice-production system, which is characterized by a low level of mechanization (Akramov and Malek, 2012) and thus a high-intensity of labor use. This implies that rice-producing households who had access to fertilizers under the subsidy program increased their labor to apply fertilizer. Yield increases are, however, not enough to compensate for the additional labor employed for fertilizer application.

6.2.3 Food security impacts of the fertilizer subsidy program

Chapter 5 reveals that at any point in time, some rice-producing households are food insecure. The incidence of food insecurity is highest during the lean period and lowest during the peak period. Uneven access to food throughout the year can be explained by the dependency on rainfall which is seasonal and uncertain (WFP, 2013). While the majority of rice-producing households have access to adequate amount of calories and proteins, the majority lack access to an adequate amount of fats. As subsistent farm households, the crop mix cultivated reflects these consumption patterns.

The results show that the fertilizer subsidy program increases the intake of: calories by an average of about 323 kcal per capita, proteins by an average of 18 g per capita, and fat by an average of 10 g per capita. This supports evidence from a macro-level analysis in Malawi (Mkwara and Marsh, 2011). Interestingly, the impact is highest during the lean period, implying that the subsidy program is critical for the stability of food security. It also appears that the modest increase in productivity from the subsidy program translates into the intake of higher quantities of food nutrients.

6.3 Main Conclusions

This thesis provides evidence of the impacts of *Fertilizer Subsidy Program of Ghana* in northern Ghana by answering the following questions: Are fertilizer adoption decisions in two steps?; How does the subsidy program influence fertilizer adoption?; Does participation in the program increase land and labor productivity?; and What is the impact of the program on food security?

The study has shown that the subsidy program increases the probability and intensity of adoption of fertilizers in general and of the recommended fertilizer combination of NPK and NH4 fertilizers, on rice fields and also on all arable crop fields. The subsidy program, however, has diverging impacts on land and labor productivity on rice fields: it increases land productivity modestly, but reduces labor productivity. Certainly, the overuse of labor due to increased access and use of fertilizer accounts for this result. Data limitations did not allow this study to examine the impact of the subsidy program on the productivity of other arable crops. The author therefore cannot confidently conclude that the subsidy program improved productivity and production of all arable crops produced by rice-producing households in the study area. Nevertheless it is possible to cautiously state that the subsidy program, which increases fertilizer adoption on all arable crop fields, could also increase land productivity of the arable crops.

This study has shown that the nutritional values of foods consumed by households increase by participation in the subsidy program. The impact is shown to be highest during the lean period. Given the observed impact of the program on rice productivity, it could be argued that the modest gain in productivity of rice and possibly the other arable crops has translated into observed food security gains. On the other hand, discussions in community interviews revealed that rice-producing households who were able to buy more subsidized fertilizers than needed re-sold excess fertilizer at a higher price. This observation was also made by Jayne et al. (2013). Income from the re-sale of subsidized fertilizer is likely to be used to purchase food. This could also be a potential channel through which the positive impact of the subsidy on food security is realized. Regardless of the channel, it is can be concluded that the *Fertilizer Subsidy Program of Ghana* has significant impact food security among rice-producing households in the study area.

6.4 Key recommendations

Based on the above analyses and discussions, some recommendations are presented for considerations by policy makers and researchers. Since adoption gap still exist in the presence of the *Fertilizer Subsidy Program of Ghana*, it is important to link such programs with training on recommended practices. Currently, the program is not adequately linked with such training programs and instead runs in a parallel and disconnected fashion.

For researchers, it is important to find reasons why improved agricultural technologies are not universally adopted at recommended rates by intended beneficiaries. In this thesis, rice-producing households are shown to adopt combinations of fertilizers. The factors that affect the adoption of fertilizers in general and the combination of specific fertilizers differ. It is therefore important that future studies on technology adoption to consider technology as a package and also for different crop enterprises. This holds the key to unlocking the true reasons for incomplete adoption of agricultural technologies.

As with fertilizer adoption, the effect of input subsidy programs on productivity can be improved when such programs are tied to training on good agricultural practices. Apart from increasing productivity, this will also ensure the effective use of inputs. The availability of labor-saving technologies is also important if the overuse of labor resources is to be minimized to increase labor productivity.

Although the subsidy program improves food security, a substantial proportion of rice-producing households are food insecure during the three periods of the year. Farm households should be encouraged to identify a crop-mix that can adequately meet their food and nutritional needs. To maintain the stability of food consumed, it is important that food security interventions identify and target lean periods.

While the subsidy program is shown to improve micro-level indicators of performance and welfare, it is also important for the government to assess other policy options that could contribute to similar outcomes. For example comparing the cost effectiveness of the subsidy program to that of rice imports could guide the government on decisions to allocate its scarce financial resources.

6.5 Limitations of the study

To guide similar research in the future, some limitations of this research are identified here. The first is that this study focuses on rice-producing households in lowland rice ecologies. In Ghana, there are other rice ecologies and conditions, such as irrigated and upland rice ecologies with some variations in terms of technologies used. The recommendations from this study are therefore limited since they cannot be directly extrapolated to all ecologies. Similarly, the focus on northern Ghana, which is characterized by savanna agro-ecology, limits the extent to which the recommendations can be applied to other parts of Ghana. Nevertheless, the hypotheses, findings, and recommendations of the study are still useful for analyses of other (rice) production systems of neighboring countries, such as Ivory Coast, Burkina Faso, Togo, Benin, and Nigeria, which have similar ecologies. It may also be useful for regions across the globe with similar ecologies.

Regarding the methodology, this study is limited in terms of the data collected and applied. The study was conceived after the subsidy program had already commenced, and baseline data to assess the situation at the household- and farm-level before the subsidy had been implemented was not available. Therefore, the study was not able to use analytical methods, such as difference-in-differences regression.

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Appendices

Appendix 1: Survey instruments

Appendix 1A: Household Questionnaires for Exploratory Research

1. Name of household head (surname first): …………………………………………………………
2. Name of respondents (first names only; if multiple respondents separated by coma): ………………………………………………………………………
3. Nativity of household head: ……………………….
4. Household category: ………………………………

A. **Household social capital** (Kindly provide details of your membership of the following associations/cooperatives of household members)

Association Code	Membership 1=Yes 2=No	Years of membership	Rank (1=least; N=Most)		Meetings attended 2012	Contribution		Benefits	Contacts per year
			Most important	Participation		Cash (GH c)	Value in-kind		

B. Household structure

ID	First names only	Sex	Age (1 if <1)	Marital status	Family bond with the head	Resident years in village (=age if since birth)	Number of months available for farm work	Highest level of education	Main occupation	Secondary activity	Years of experience in farming	Sick cases in the last 12 months (N)
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

C. Household Resources

1. Type of dwelling of the household ……………….
2. Occupancy status ………………….
3. Rent for tenant (GH¢) ………………………
4. Source/types/modes

a. Water ……………

b. Lighting ……………

c. Fuel used for cooking ………..

d. Type of sanitation …………

e. Mode of disposal of refuse …………

D. Household Resources

1. How many of the following assets/livestock does the household own?

Asset	Quantity	Estimated current Value (GH ₵)	Asset	Quantity	Estimated current Value (GH ₵)
Motor vehicle			Fan		
Motor cycle			Rifles		
Bicycle			Foam mattress		
Tractor			Utensils		
Tractor plough			Furniture/sofa		
Tractor harrow			Sewing machine		
Draft animals			Cows		
Animal plough			Bulls		
Animal harrow			Young Bulls		
Animal scotch cart			Heifer		
Grain storage facility			Sheep		
Cutlass			Chicken		
Hoe			Other: …………….		
Sickle			Other: …………….		
Knapsack sprayer			Other: …………….		
Shovel/spade			Other: …………….		
Television			Other: …………….		
Radio			Other: …………….		
Water pump			Other: …………….		
Water containers			Other: …………….		
Generator			Other: …………….		
Mobile Phones			Other: …………….		

2. Provide information on the use of tools and equipment

Asset	Quantity	Purchase value (GH ₵)	Life span (year)	Percentage use on		
				Maize	Soybean	Cowpea
Tractor						
Tractor plough						
Tractor harrow						
Animal plough						
Animal harrow						
Animal scotch cart						
Wheel barrow						
Power tiller						
Combine harvester						
Grain storage facility						
Cutlass						
Hoe						
Knapsack sprayer						
Shovel/spade						

3. Provide information on land resources and use

Field	Plot	Land resource (crop/use)	Area	Tenure	If rented how much	If shared what %	Soil fertility
1	1						
1	2						
1	3						
1	4						
1	5						
1	6						
1	7						
1	8						
1	9						
1	10						
2	1						
2	2						
2	3						
2	4						
2	5						
2	6						
2	7						
2	8						
2	9						
2	10						
3	1						
3	2						
3	3						
3	4						
3	5						
3	6						
3	7						
3	8						
3	9						
3	10						

E. Agricultural production

1. Preference of crop varieties and technologies

Characteristics	Crops				
	Maize	Soybean	Cowpea	Rice	Yam
Yield					
Palatability					
Grain color					
Grain size					
Grain shape					
Pod color					
Pod size					
Pod shape					
Plant vigor					
Earliness					
Drought tolerance					
Field pests tolerance					
Storage pests tolerance					
Infertility tolerance					
Striga tolerance					
Shattering					
Ease of threshing					
Maturity					
Seed dormancy					
Seed					
Complementary technologies					
Land					
Labour					
Seed of technology					
Complementary technologies					
Demand					
Grain price					
Taste					
Marketability					

2. Provide information on the inputs you use for the cultivation of maize in 2012

a. Crop establishment (Section I)

Input	Maize	Rice	Soybean
Varieties (multiple choice)			
Land area (ha)			
Proportion under improved varieties			
Cropping system			
Crop used as intercrop			
Crop used for rotation			
Land preparation			
Method			
Labour for slash and burn (man-days/ha)			
Wage for slash and burn (Gh c/day)			
Charge for ploughing (Gh c/ha)			
Charge for harrowing			
Seeds use			
Type of seeds			
Quantity of seeds used (kg/ha)			
Price of seeds (GH ¢/kg)			
Source of seeds			
Mode of acquisition			
Method of planting/seeding			
Time of planting			
Labour for planting (man-days/ha)			
Wage for planting (Gh c/ha)			
Do you treat your seeds before storage?			
Do you treat your seeds before planting?			

b. Integrated pest and disease management (IPDM) (Section II)

Input	Maize	Rice	Soybean
Weed control			
Number of times			
Method (multiple choice)			
Timing (multiple choice)			
Total quantity if herbicides (lit/ha)			
Source if herbicides			
Total labour if herbicides (man-days/ha)			
Wage if herbicides (Gh c/day)			
Total charge if mechanical (man-day/ha)			
Total labour if manual (man-days/ha)			
Wage if manual			
Insect control			
Number of times			
Method (multiple choice)			
Timing (multiple choice)			
Total quantity if insecticides (lit/ha)			
Source if insecticides			
Total labour if insecticides (man-days/ha)			
Wage if insecticides (Gh c/day)			
Total quantity if bio-extract (lit/ha)			
Total labour if bio-extract (man-days/ha)			
Wage if bio-extract (Gh c/day)			
Disease control			
Number of times			
Method (multiple choice)			
Timing (multiple choice)			
Total quantity if fungicides (lit/ha)			
Total labour if fungicides (man-days/ha)			
Wage if fungicides (Gh c/day)			
Total quantity if bio-extract (lit/ha)			
Total labour if bio-extract (man-days/ha)			
Wage if bio-extract (Gh c/day)			

c. Integrated soil fertility management (ISFM) (Section III)

Input	Maize	Rice	Soybean
Fertilization			
Do you plow in plant residue?			
Do you plow in green manure?			
Type of fertilizers			
Source of fertilizer			
Mode of acquisition			
Name if compound			
Method if application			
Timing of application if compound			
Quantity if compound (kg/ha)			
Price of compound (GH ¢/kg)			
Labour if compound (man-days/ha)			
Name if urea/ammonia			
Method of application if urea/ammonia			
Timing of application if urea/ammonia			
Quantity if urea/ammonia (kg/ha)			
Price if urea/ammonia (GH ¢/kg)			
Labour if urea/ammonia (man-days/ha)			
Wage if urea/ammonia (Gh c/day)			
Name if organic			
Method of application if organic			
Timing of application if organic			
Quantity if organic (kg/ha)			
Price if organic (GH ¢/kg)			
Labour if organic (man-days/ha)			
Wage if organic (Gh c/day)			

d. Harvest and post-harvest activities (Section IV)

Input	Maize	Rice	Soybean
Harvesting			
Method			
Charge for mechanical in Gh c/ha)			
Labour for manual (man-days/ha)			
Charge for manual (Gh c/day)			
Quantity of sold			
Farm gate price (Ghc/ha)			
Market price at harvest			
Expected market price after 3 months			
Price in village before next planting			
Period of sales			
Place of sales			
Who determines price?			
If you, how:			
Threshing			
Quantity of labor (man-days/ha)			
Wage of labour (Gh c/day)			
Winnowing			
Quantity of labor (man-days/ha)			
Wage of labour (Gh c/day)			
Storage			
Bagging/container (multiple choice)			
Treatment (multiple choice)			
Structure (multiple choice)			
Quantity of labor (man-days/ha)			
Wage of labour (Gh c/day)			

3. Crop marketing Decisions

How do you plan to dispose your produce?

Season	Quantity (kg)					
	Harvest	Consumed	Sold	Given out as gift	Stored	Loss in store
Maize						
Soybean						
Cowpea						

Note: consumed + sold + gift + stored + loss=harvest

4. Access to credit

a. Did you receive any cash and/or input credit in the 2012 crop season for crop production?

Type of credit	**Approximate value(GH¢)**	**Source (Code 1)**	**Timeliness 0=No 1=Yes**	**Form of repayment (code 2)**	**Approximate value (GH¢)**

b. If you did not receive credit provide **reason(s)**? ……. 0=N/A 1=No facility 2=Did not look for credit 3=No collateral 5=High interest rate 6=other (specify)…………………………………………………..

F. Income and Expenditure Profile of Household

1. What are the sources of income for your household in 2010?

Category	Amount (GH¢)	Category	Amount (GH¢)
Sales of millet		Sales garden eggs	
Sales of sorghum		Sales of livestock	
Sales of maize		Shea fruits collection	
Sales of rice		Shea processing	
Sale of groundnut		Dawadawa processing	
Sale of cowpea		Food processing	
Sale of soybean		Petty trading	
Sale of Bambara		Craftsmanship	
Sales of cassava		Laborer	
Sales of yam		Permanent employment	
Sales of sweet potato		Pension	
Sales onion		Remittances	
Sales okra		Other……………	
Sales tomato		Other……………	
Sales pepper		Other……………	

2. Approximately how much did you spend on the following in 2010/2011

Category	Amount (GH¢)	Expenditure category	Amount (GH¢)
Staple foods		Water	
Snacks		Electricity	
Tobacco/Alcohol		Remittances to relatives	
School fees		Social contributions	
School uniform		Transport	
School books		Repair of house	
School furniture		Rent	
Medical expenses		Miscellaneous	
Clothing		Other (Specify ……….………………………)	
Fuel			

3. Do you have access to adequate amount food throughout the year? 1=Yes 2=No

4. Which **months** of the year do you experience severe shortages (multiple choices)? 1=January 2=February 3=March 4=April 5=May 6=June 7=July 8=August 9=September 10=October 11=November 12=December

How did you cope with the shortage? (multiple choice) 1=reduce consumption 2=ration food 3=buy more food 4=sell assets to buy food 5=sell livestock to buy food 6=sell livestock to buy food 7=work off farm to generate income 8=other: …………………………………..

G. Income and Expenditure Profile of Household

1. Approximately what quantities of the following food did your household consume in the last 12 months (including harvest, purchases, gifts, food aid, etc………) also target female in the households

	Estimated quantity per day	Estimated days per week	Estimated weeks per month
Millet (Kg)			
Sorghum (Kg)			
Rice (Kg)			
Maize (Kg)			
Cowpea (Kg)			
Soy bean (Kg)			
Groundnut (Kg)			
Yam (Kg)			
Cassava (Kg)			
Potato (Kg)			
Okra (Kg)			
Onion (Kg)			
Tomato (Kg)			
Palm Pulp (Kg)			
Fish (Kg)			
Meat (Kg)			
Eggs (Kg)			
Orange (Kg)			
Mangoes (Kg)			

End of interview: Thank you for your cooperation

Appendix 1B: Household questionnaire for rice survey

Date of interview	Date	[ ][ ]	Month [ ][ ]	Year	[2][0][ ][ ]	Interviewed by	________________
Date checked	Date	[ ][ ]	Month [ ][ ]	Year	[2][0][ ][ ]	Checked by	________________
Date entered	Date	[ ][ ]	Month [ ][ ]	Year	[2][0][ ][ ]	Entered by	________________

Name of Household Head:____

District: ______________________Code: __________ (see the district code on the right)

Village: __________________________Code: __________ (see the village code on page 26)

District Code	
Central Gonja	1
East Gonja	2
Savelugu-Nanton	3

Contact (mobile phone number):_________________

GPS measurement At the respondent's residential house (homestead):

GPS Number:__________Location: ± __________m; Latitude: N ° ’ ”; Longitude: W ° ’ ”;

Record Number:_; Date and Time_; Elevation: _____m

Section 1. Experience and Knowledge about Lowland Rice Development Project

RP01 Have you ever participated in any project related to rice production? 1=Yes, 2=No [go to **RP20 next page**] **RP01**______________

(If RP01=Yes, then continue to RP15. If RP01=No, skip to RP20)

RP02 If **PR01=**Yes, what is the name of the project? Select from the below. **RP02**______________

1. LRDP (Lowland Rice Development Project)
2. RSSP (Rice Sector Support Project)
3. MiDA (Millennium Development Authority)
4. JICA Project (Sustainable Development of Rained Lowland Rice Production Project)
5. Other, specify the name____
6. Unknown

RP03 If **PR01=**Yes, from which year to which year did you participate in the Project? **RP03**From ____________________ to ____________________

RP04 Do you have any experience in rice production before the participation in the Project? 1=Yes, 2=No **RP04**______________

RP05 Is the Project involved in the allocation of rice plots? 1=Yes, 2=No **RP05**______________

RP06 If **PR05=**Yes, how large is the plot allocated to you by the Project: **RP06**_________________acres

RP07 Do you still use the plot allocated to you by the Project? 1=Yes, 2=No **RP07**______________

RP08 If**RP07**=No, who is cultivating the plot? Select from the below: **RP08**______________

1. A farmer who used to cultivate rice on the site before the Project
2. A new farmer who obtained the plot after the Project
3. One of other group members
4. One of other Project participants
5. No one (abandoned)

RP09 Is the Project involved in the construction of bunds? Select from the below. **RP09**______________

1. Yes, the Project constructed/constructs bunds for me; 2. Yes, the Project taught/teaches how to construct bunds; 3 No

RP10 If **PR09=**1, the Project constructed bunds in the past, are the bunds still in place? Select from the below. **RP10**______________

1. Yes, well maintained by a group of cultivators; 2. Yes, well maintained by the respondent; 3. No, partially disappeared; 4. No, totally disappeared

RP11 Did you use (are you using) credit provided by the Project? 1=Yes, 2=No, never [go to **RP15 below**] **RP11**_____________

RP12 If **RP11**=Yes, what did you use it for? Select from the below: **RP12**_____________

1. chemical fertilizer 2.herbicide/weedicide 3.seed 4.hiring tractors 5.hiring labor 6.bags 7.others, specify

RP13 If **RP11**=Yes, is it every year during the Project period? 1=Yes, 2=No, not every year **RP13**_____________

If it is 2=NOT every year, please tell us the reason: ____

RP14 If **RP11**=Yes, did you always pay back the credit? Select from the below: **RP14**_____________

1=Yes, always 2=Yes, but some delay 3=No, not always

If it is 3=NOT always, what happens after the default? Select from the below: **RP15**_____________

1. The group becomes non-eligible for the credit
2. The respondent became non-eligible for the credit (group remained eligible)
3. Others, explain: ____

RP15 If **RP11**=No, never, tell us why you never used credit?____

RP20 If **RP01**=No, Was/are there any project related with rice production in the village? 1=Yes 2=No 3=Unknown **RP20**_____________

If **RP20**=Yes, please tell us why you did/do not participate: ____

RP21 If **RP01**=No, Have you ever heard about rice related project in other villages? 1=Yes, 2=No **RP21**_____________

RP22 If **RP21**=Yes, from whom? Select from the below: **RP22**_____________

1=neighbors in the same village 2=someone coming from a non-Project village 3=someone from a Project village

4=extension agent 5=others, specify

RP22 Have you ever seen the Project site, either in this village or other villages? 1=Yes, 2=No **RP22**_____________

If**RP22**=Yes, where is it? Reply the name of the place (the name of the village and the name of the valley)

____

If **RP22**=Yes, what was most impressive about it?

____

Section 2a. Demography (May 2012–April 2013)

A "household" includes all members of a common decision making unit (usually within one residence) that are sharing income and other resources. Members are those who were born to but should not have independent decision making unit apart from this household. Also include workers or servants as members of the household if they stayed in this household at least one month in the last 12 months. Use an extra sheet if necessary.

Person ID	Name	Sex 1=M 2=F	Age in years	Relation to head: See Code below	Marital status: See Code below	Health Status 1=able bodied 2=partly disabled 3=fully disabled 4= aged 5=sick	Highest grade completed See Code Sheet on p. 6	Still in school now? 1=yes 2= no	Engaged in off-farm activities in the last 12 months? 1=Yes, 2=No		Number of months living at home in the last 12 months?	If less than 12 months (**D10<12**), why? See Code below
									Self-employment (business or self-employment activities)	Employment (salaried employment, paid farm labor, or other casual/wage labor)		
ID	**Name**	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**	**D10**	**D11**
1												
2												
3												
4												
5												
6												
7												
8												
9												

Section 2a. Demography (May 2012–April 2013) continued

Person ID	Name	Sex 1=M 2=F	Age in years	Relation to head: See Code below	Marital status: See Code below	Health Status 1=able bodied 2=partly disabled 3=fully disabled 4= aged 5=sick	Highest grade completed See Code Sheet on p. 6	Still in school now? 1=yes 2= no	Engaged in off-farm activities in the last 12 months? 1=Yes, 2=No		Number of months living at home in the last 12 months?	If less than 12 months (**D9<12**), why? See Code below
									Self-employment (business or self-employment activities)	Employment (salaried employment, paid farm labor, or other casual/wage labor)		
ID	**Name**	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**	**D10**	**D11**
10												
11												
12												
13												
14												
15												

Code for D3:
0=Head
1=First wife
2=Second Wife
3=Third wife
4=Fourth wife (or above)
5=Son/Daughter
6=Son/Daughter-in-law
7=Father/Mother
8=Father/Mother-in-law
9=Brother/Sister
10=Brother/Sister-in-law
11=Grandparent
12=Grandparent-in-law
13=Grandson/daughter
14=Uncle/Aunt
15=Uncle/Aunt-in-law
16=Cousin (father side)
17=Cousin (mother side)
18=Other relative
19=Other non-relative
20=Worker

Code for D4:
1=Single
2=Monogamously married
3=Polygamous married
4=Widowed
5=Separated
6=Divorced
7=Other (specify)

Code for D11:
1=To find a job/working
2=To attend school
3=Married away
4=Passed away
5=Born-in
6=Married-in
7=Visiting relatives/gone back home
8=Medication/hospitalized
9=Missing
10=Worker left
11=Other (specify)

Section 2b.Household Head and Spouses

	Person ID Refer to Section 2a	Where was he/she born? 1=in this village 2=NOT in this village	If he/she was born outside this village (i.e. **DQ1=2**), where is it?		In which year did he/she settle in this village?	Ethnicity See Code below	Religion See Code below
			Name of village/town/city	Region in Ghana or Country See Code below			
	ID	**DQ1**	**DQ2**	**DQ3**	**DQ4**	**DQ5**	**DQ6**
Household Head							
First Wife							
Second Wife							
Third Wife							
Fourth Wife							

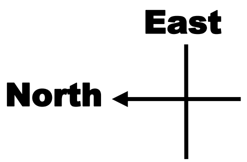
Code for DQ3:
1=Northern
2=Upper East
3=Upper West
4=Brong-Ahafo
5=Volta
6=Eastern
7=Central
8=Western
9=Greater Accra
10=Ashanti
11=Ivory Coast
12=Togo
13=Benin
14= Burkina Faso
15=Niger,
16=Other place, specify

Code for DQ5:
1=Nanumba
2=Dagomba
3=Mamprusi
4=Wala
5=Builsa
6=Frafra
7=Talensi
8=Kusase
9=Gonja

Section 3a. Map of Parcels in 2012 Cropping Year

Draw a map of all the parcels that this household had access to (excluding communal grazing lands) as of 2012. Please add all parcels that this household has obtained access to (i.e., acquired, rent-in, sharecropping-in, etc.) in the cropping season in 2012to the map.

When drawing this map, face East and draw directions. Make sure to include homestead, fallowed land, abandoned land, leased out land, tree planted area, etc. And give each parcel a short name (**PNAME**) and number, which becomes **Parcel ID (PID)**. Indicate the homestead and entrances, names of parcels, and sizes of parcels in the map **(Probe for rented-out parcels)**.



Parcel Name	Parcel ID	Size in Acres	Distance from homestead to this parcel (km)	Did you rent-out any part of this parcel in 2012? 1=Yes 2=No
PName	**PID**	**LT1**	**LT2**	**LT3**
	1			
	2			
	3			
	4			
	5			
	6			
	7			
	8			
	9			
	10			

Section 3b.Land Tenure

Make sure to include all the parcels owned/operated (owned-and-operated, owned-but-not-operated, and not-owned-but-operated parcels) by the HH.

Parcel Name Refer to Section 3a	Parcel ID Refer to Section 3a	Tenure system See Code below	How did <u>this household</u> acquire this parcel? See Code below	Year of acquisition?	If **LT4=3 (rented-in) or LT3=1 (rented-out)**				If you were to buy/rent-in this parcel without homestead**,**		Are you allowed to do this without getting permission from others?		
					How much GHC did you pay to the land owner or receive from the tenant?	How many years have you been renting-in/out this parcel continuously?	Relation with land owner/tenant 1=relative 2=friend 3=neighbor 4=other (specify)	Residence of land owner/tenant 1=same village 2=same district 3=other	How much GHC are you willing to pay to buy?	How much GHC are you willing to pay to rent-in per season?	To sell this parcel? 1=Yes 2=No	To rent out this parcel? 1=Yes 2=No	To inherit this parcel? 1=Yes 2=No
Pname	**PID**	**LT4**	**LT5**	**LT6**	**LT7**	**LT8**	**LT9**	**LT10**	**LT11**	**LT12**	**LT13**	**LT14**	**LT15**
	1												
	2												
	3												
	4												
	5												

Code for LT4:

1=owned family land

2=allocated family land

3=rented-in

4=village chief

5=government

6=other (specify)

Code for LT5:

1=purchased

2=rented-in for fixed payment

3=received as gift

4=received as inheritance

Section 3c.Plot Characteristics

Make sure to include all the parcels owned/operated (owned-and-operated, owned-but-not-operated, and not-owned-but-operated parcels) by the HH.

Parcel Name Refer to Section 3a	Parcel ID Refer to Section 3a	Slope of this parcel See Code below.	Is this parcel bunded? 1=Yes, big bund 2=Yes, mini bund 3=No, no bund	Main water source for crop production. See Code below.	Do you use a pump to get water from the source? 1=Yes, owned 2=Yes, rental 3=No	What is the major type of soil of this parcel? 1=sandy 2=loamy 3=clay 4=laterite 5=other, specify	What is the local name of the soil of this parcel?	Primary use (largest areas) of this parcel See Code below				
								Rain season 2012	Rain season 2011	Rain season 2010	Rain season 2009	Rain season 2008
Pname	**PID**	**LT16**	**LT17**	**LT18**	**LT19**	**LT20**	**LT21**	**LT22**	**LT23**	**LT24**	**LT25**	**LT26**
	1											
	2											
	3											
	4											
	5											

Code for LT16:
1=flat
2=moderate
3=steep

Code for LT18:
1=rain-fed
2=flood from river
3=flood from swamp
4=diversion of river water
5=water stored in pond/tank
6=borehole/well
7=dam
8=other (specify)

Code for LT22-26:
1=rented-out
2=fallow
3=tree plantation
4=virgin land
5=grazing
6=maize
7=rice
8=cereals other than maize/rice
9=legumes
10=root/tuber
11=vegetables
12=fruits
13=banana
14=flower
15=other crop (specify)
16=borrowed-out

Section 4.Crop Income in the Rainy Season 2012

Ask about all crops produced in the rainy season 2012. Start with a parcel and a crop in the parcel, then ask for crops intercropped with the crop. And move on to next crop. Use extra sheets in necessary.

Parcel ID Refer to Section 3a	Plot ID Refer to Section 3a	Crop Name	Cropping system 1=Pure stand 2=Inter-cropping	Decision maker's ID (person ID in sec.2a)	Area under this crop (acres)	Total cost of seed (GHC)	Total cost of fertilizer (GHC)	Total cost of herbicide (GHC)	Total cost of insecticide (GHC)	Total rental cost for tractor & animal (GHC)	Total Harvest			How many years have you grown this crop on this parcel (years)
											Amount	Unit See <u>Unit Code below</u>	Unit Price at harvest (GHC)	
PID	**LID**	**CName**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**

Unit Code for C9

1=90 kg bag
2=50 kg bag
3=25 kg bag
4=10 kg bag
5=2 kg bag
6=kg
7=grams
8=liters
9=tones
10=numbers
11=bunch (banana)
12=wheelbarrow
13=cart load
22=head load

Section 5a.GPS Measurement of Plots <u>for Rice Production</u> in the Rainy Season 2012

For the questions in Sections5a, 5b, and 5c, identify all the rice plots in the rainy season 2012 listed in the table of Sections 3 and 4. Transfer the parcel IDs (PID), parcel names (PName), and plot IDs (LID) before asking questions.

Parcel ID	Parcel Name	Plot ID	Is the plot in the Project site? 1=Yes 2=No	Walking time from homestead to this plot (minutes)	Plot Measurement by GPS													
					GPS Number	Location (±m)	Latitude			Longitude			Record Number	Date and Time		Elevation (m)	Name	Area (ha)
							Degree	Minutes	Second	Degree	Minutes	Second		Date	Time			
PID	**PName**	**LID**	**G0**	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**	**G7**	**G8**	**G9**	**G10**	**G11**	**G12**	**G13**	**G14**	**G15**
						±m	N°	’	”	W°	’	”				m		ha
						±m	N°	’	”	W°	’	”				m		ha
						±m	N°	’	”	W°	’	”				m		ha
						±m	N°	’	”	W°	’	”				m		ha

Section 5b.Land Preparation and Sowing for Rice Production in the Rainy Season 2012 (Part 1)

Transfer the plot IDs (LID), parcel names (PName), and parcel IDs (PIDs) before asking questions.

			Tree Cutting/Removing Stumps			Ploughing							Harrowing before sowing				
				If 1=Yes,			If 4/5=by tractor,			When did you plough in the rainy season 2012				If 4/5=by tractor,			
Parcel ID	Parcel Name	Plot ID	Did you cut trees and/or remove stumps in this plot before ploughing in cropping season 2012 1=Yes 2=No	How many people worked?	How many days worked?	Did you plough before sowing? See code below	How much GHC did you pay for hiring tractor for ploughing?	Where was it from? See code below	How did you find the tractor? See code below	Month (number 1 -12)	Day (approximate)	How many days after the first major rain?	Did you harrow before sowing? See code below	How much GHC did you pay for hiring tractor for harrowing in total?	Where was it from? See code below	Was it the same tractor as hired for ploughing? 1=Yes 2=No	How did you find the tractor? See code below
PID	**PName**	**LID**	**RT01**	**RT02**	**RT03**	**RT04**	**RT05**	**RT06**	**RT07**	**RT08**	**RT09**	**RT10**	**RT11**	**RT12**	**RT13**	**RT14**	**RT15**

Code for RT04
1=No ploughing before sowing
2=by hand
3=by animal
4=by tractor (once)
5=by tractor (twice)

Code for RT06/13
1=in the same village
2=from a near-by village
3=from the district capital
4=from Tamale
5=unknown (travelling)

Code for RT07/15
1=phone call to the owner
2=phone call to the operator
3=phone call to a middleman
4=direct contact with the owner
5=direct contact with the operator
5=direct contact with a middleman
6=tractor came to the village
7=through MOFA office
8=other, specify

Code for RT11
1=No harrowing before sowing
2=by hand
3=by animal
4=by tractor (once)
5=by tractor (twice)

Section 5b.Land Preparation and Sowing for Rice Production in the Rainy Season 2012 (Part 2)

Transfer the plot IDs (LID), parcel names (PName), and parcel IDs (PIDs) before asking questions.

Parcel ID	Plot ID	**Herbicide use for land preparation**		**Soil-covering after sowing**		**Bund construction/repairing**		**Continuous use of the same plots for rice production**				**Experience of Natural Disaster**			
		Did you use herbicide for preparation of this rice plot in the cropping season of 2012? See code below	If Yes (2-8), how much GHC did you pay for the herbicide in total?	Did you do soil-covering (turning the soil) after sowing? See code below	If 4 or 5=by tractor, how much GHC did you pay for the hiring tractor for soil-covering in total?	Did you construct or repair the bund at the beginning of cropping season 2012? See code below	If 4 or 6=by tractor, how much GHC did you pay for the hiring tractor for bund in total?	When was the first time you used this plot for rice production?	Since the first year of use, have you used this plot continuously up to now? 1=Yes 2=No	If 2=No, when did you restart usage for the last time (e.g. the most recently)?	After the rice production in 2012, for how many years do you expect to use this plot for rice production continuously? Please guess a number even if it is not yet known.	Since you started to use this plot continuously, how often (**number of years**) did you have flood or drought in this plot?			
												You could not sow/plant due to flood	After sowing/ planting you had flood and no harvest	You could not sow/plant due to water shortage	After sowing/ planting you had drought and no harvest
PID	**LID**	**RT16**	**RT17**	**RT18**	**RT19**	**RT20**	**RT21**	**RT22**	**RT23**	**RT24**	**RT25**	**RT26**	**RT27**	**RT28**	**RT29**

Code for RT16
1=No herbicide use for land preparation
2=Yes, once before ploughing only
3=Yes, once between ploughing and sowing only
4=Yes, after sowing only (but not during the growing stage)
5=Yes, twice 2 & 3
6=Yes, twice 2 & 4
7=Yes, twice 3 & 4
8=Yes, three times

Code for RT18
1=No soil-covering
2=by hand
3=by animal
4=by tractor (once)
5=by tractor (twice)

Code for RT20
1=No, no bund
2=Construction in the past, but no repairing in 2012
3=Construction in the past, and repaired by hand
4=Construction in the past, and repaired by tractor in 2012
5=Constructed in 2012 manually by him/herself
6=Constructed in 2012 using a tractor by him/herself
7=Constructed in 2012 by the project

Section 5c.Input use for Rice Production in the Rainy Season 2012

Transfer the plot IDs (LID), parcel names (PName), and parcel IDs (PIDs) before asking questions.

Parcel ID	Parcel Name	Plot ID	Sowing/Planting									Fertilizer Use				Herbicide		Other Chemicals	
										When did you sow/plant in the rainy season 2012		1st application		2nd application					
			Name of the Rice Variety See code below	How did you obtain the seed for the rainy season 2012?	From whom did you obtain the seed for the rainy season 2012?	Quantity of seed used on this plot (kg)	How did you select seed before sowing/planting? See code below	Did you soak seed into water before sowing/planting? 1=Yes 2=No	How did you sow rice in this rice plot in cropping season 2012? See code below	Month (number 1 -12)	Day (approximate)	Type of fertilizer See code below	Quantity used (kg)	Type of fertilizer See code below	Quantity used (kg)	Did you use herbicide for weeding during the rice growing stage? 1=Yes 2=No	Total cost of herbicide used (GHC)	Did you use insecticide/fungicide? 1=Yes 2=No	Total cost of other chemicals (GHC)
PID	**PName**	**LID**	**IP01**	**IP02**	**IP03**	**IP04**	**IP05**	**IP06**	**IP07**	**IP08**	**IP09**	**IP10**	**IP11**	**IP12**	**IP13**	**IP14**	**IP15**	**IP16**	**IP17**

Section 5d.Family and Hired Labour Used for <u>Rice Production</u> in the Rainy Season in 2012

Do not forget to include all the rice plots in the rainy season 2012 listed in sections 5a, 5b, and 5c.

Parcel ID	Parcel Name	Plot ID	Activity Specify if the code is 12, 15, 16, or 17.	Activity Code See below	Family Labour Use For Rice Production in the Rainy Season 2012									Exchange Labour			Hired labour		
					Adult Men			Adult Female			Children (under 15 years old)								
					Number	Days	Hours a day	Number	Days	Hours a day	Number	Days	Hours a day	Number	Days	Hours a day	Number	Days	Cost (GHC)
PID	**PName**	**LID**	**RL1**	**RL2**	**Rl3**	**RL4**	**RL5**	**RL6**	**RL7**	**RL8**	**RL9**	**RL10**	**RL11**	**RL12**	**RL14**	**RL14**	**RL15**	**RL16**	**RL17**

Code forRL1

1=clearing field

2=repairing bunds

3=repairing canals

4=1st ploughing

5=2nd ploughing

6=1st harrowing

7=2nd harrowing

8=sowing/planting

9=soil covering

10=1st weeding (manual)

11=2nd weeding (manual)

12=water management (opening/closing channel, watering, pumping, etc.)

13=scaring birds

14=harvesting

15=post-harvest activities (threshing, bagging, transporting outputs, etc.)

16=chemical application (fertilizer, pesticide, herbicide, etc.)

17=other (specify)

FOR THIS SECTION, ASKS ABOUT RICE ONLY

Section 5d.Family and Hired Labour Used for Rice Production in the Rainy Season in 2012 (continued)

Do not forget to include all the rice plots in the rainy season 2012 listed in sections 5a, 5b, and 5c.

Parcel ID	Parcel Name	Plot ID	Activity Specify if the code is 12, 15, 16, or 17.	Activity Code See below	Family Labour Use For Rice Production in the Rainy Season 2012									Exchange Labour			Hired labour		
					Adult Men			Adult Female			Children (under 15 years old)								
					Number	Days	Hours a day	Number	Days	Hours a day	Number	Days	Hours a day	Number	Days	Hours a day	Number	Days	Cost (GHC)
PID	**PName**	**LID**	**RL1**	**RL2**	**Rl3**	**RL4**	**RL5**	**RL6**	**RL7**	**RL8**	**RL9**	**RL10**	**RL11**	**RL12**	**RL14**	**RL14**	**RL15**	**RL16**	**RL17**

Code forRL1

1=clearing field
2=repairing bunds
3=repairing canals
4=1st ploughing
5=2nd ploughing
6=1st harrowing
7=2nd harrowing
8=sowing/planting
9=soil covering
10=1st weeding (manual)
11=2nd weeding (manual)
12=water management (opening/closing channel, watering, pumping, etc.)
13=scaring birds
14=harvesting
15=post-harvest activities (threshing, bagging, transporting outputs, etc.)
16= chemical application (fertilizer, pesticide, herbicide, etc.)
17=other (specify)

FOR THIS SECTION, ASKS ABOUT RICE ONLY

Section 5f.Sales of Rice Harvested in the Rainy Season in 2012

S0 How many times did you sell rice grown in 2012?   . (Ask each sales activity separately and record it in the corresponding row in the table below)

																	S7 =1	If**S7**=2 or 3 (parboiled rice was sold)					If**S7**=3 (milled rice was sold)					
																			If **S15**=2 (parboiled other than home)									
SalesID	Rice variety code	Month of sales (1-12)	Week of sales (1-4)	Was rice sold from one plot? 1-Yes, 2-No	If **B1**=2, From how many plots was rice originated?	Plot ID (LID) for largest amount of rice sold	Plot ID (LID) for 2nd largest amount of rice sold	Plot ID (LID) for 3rd largest amount of rice sold	Where was paddy rice stored? 1=Homestead, 2=Storage facility other than home within	In what form was rice sold?1-paddy, 2-parboiled but not milled, 3-milled rice (parboiled), 4=other)specify	Quantity sold (kg) in a form of rice answered in S7	To who was the rice sold? See Code below	Was phone call made to this buyer before selling time to get market information? 1-Yes, 2-No	Where did the transaction (rice sales) take place? Code	Name of the place where rice sales was made (if rice was sold within village, put "1")	Price of rice per kg (GHC) of a form of rice answered in S7	Transportation cost from the place where paddy rice was stored to the place where paddy was sold (GHC)	Was rice parboiled at home? 1-Yes, 2-No	Name of the place where rice was parboiled (if rice was parboiled within village, put "1")	Distance from place where paddy was stored to the place where rice was parboiled (km)	Total transportation cost from place where paddy was stored to the place where rice was	Total cost of parboiling (GHC) (other than	Name of the place where rice was milled (if rice was milled within village, put "1")	Distance from place where paddy was stored to the place where rice was milled (km)	Total milling fee (GHC)	Transportation cost from place where rice was parboiled to place where rice was milled (GHC)	Transportation cost from place where parboiled rice was stored to place for milling (GHC)	Other cost paid for milling rice (uploading, offloading costs etc.) (GHC)
SD	**VC**	**SM**	**SW**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**	**S14**	**S15**	**S16**	**S17**	**S18**	**S19**	**S20**	**S21**	**S22**	**S23**	**S24**	**S25**

Section 7a. Livestock Production in the last 12 months (between May 2012 and April 2013)

Livestock Type	Live stock Code	April 2013		May 2012		Change in Number in the last 12 months		
		Number Owned	Total value in GHC	Number Owned	Total value in GHC	Number Consumed at home	Number bought	Number sold
LSNAME	**LCODE**	**LV1**	**LV2**	**LV3**	**LV4**	**LV5**	**LV6**	**LV7**
Cows	1							
Bulls	2							
Young bulls	3							
Heifer	4							
Calves	5							
Goats	6							
Sheep	7							
Chicken	8							
Donkeys	10							
Ducks	11							
Turkeys	12							
Guinea Fowls	13							
Rabbits	14							

Section 7b.Production of Other Livestock Products and Expenditure (between May 2012 and April 2013)

Livestock Products	Live stock Product Code	Number of months producing this product in the last 12 months	Average Production per month during production months		Amount sold per month (use the same unit in LP3)	Price received per unit on the largest sale (use the same unit in LP3)	How much in GHC did you earn in total in the last 12 months?
			Quantity	Unit See Code below			
LPNAME	**PCODE**	**LV8**	**LV9**	**LV10**	**LV11**	**LV12**	**LV13**
Milk	1						
Eggs	2						
Goat milk	5						
Hides/skin	6						
Meat	7						
Manure	8						
Draft animal rental service	9						

Code for LV10: 1=kg, 2=liter, 3=tray (30 eggs), 4=number, 5=90 kg bag, 6=tons, 7=wheelbarrow, 8=cart

LV7: How much did you spend on feed/fodder for livestock production? ______________ GHC

LV8: How much did you spend on health care (veterinary service, animal medicine, and vaccines)? ______________ GHC

LV9: How much did you spend on hired labour for livestock production (milking, grazing, watering, etc.)? ______________ GHC

LV9: How much did you spend for maintaining barns, fences, zero-grazing stalls? ______________ GHC

Section 8.Self-employment and Wage/Salaried Labour Activities (including farm labour) in the Last 12 Months

If D8 or D9 in section 2a is YES, list the names of all members who were engaged in off-farm activities (including farm labourer).

If one is engaged in more than one activity, select the 3 most important activities the one is engaged in.

Person name	Person ID	Activity name	Biz Code	How many years of experience?	If he/she is regular monthly wage earner: Number of months worked in the last 12 months	If he/she is regular monthly wage earner: Monthly wage in GHC	If he or she earns seasonal earnings/sales, classify each month's gross earnings/sales from business or seasonal labour employment as: 0= No Earning/Sales Month 1= Low Gross Earning/Sales Month 2= High Gross Earning/Sales Month — 2012								2013				Low gross earnings/ sales month: Gross earnings/ sales per month	Low gross earnings/ sales month: Cost* per month	High gross earnings/ sales month: Gross earnings/ sales per month	High gross earnings/ sales month: Cost* per month
Name	**ID**	**BName**	**BIZ**	**B1**	**B2**	**B3**	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	**B4**	**B5**	**B6**	**B7**

Section 9.Non-labour Income, Remittance, Credit (self-help, Susu, etc) and Food Aid Received

Z0: Did any member of this household receive remittance, credit or food aid in the past 12 months? 1=Yes 2=No (skip this section)

Combine all transactions from one source.

Type	Type code	Classify each month according to the amount received: 0 = nothing received 1= low/medium amount 2= high amount												Average amount received per month in a high amount month	Average amount received per month in a low/medium amount month	Major source See code below	Main purpose See code below
		2012								2013							
Type	**Z1**	Ma y	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	**Z2**	**Z3**	**Z4**	**Z5**
Remittance/cash assistance	1																
Rent revenue (housing, shops, land, etc.)	3																X
Pension	4																X
Susu	5															X	
Credit (cash)	6																
Food Aid	7																X

Section 10. Consumption and Expenditure on Major Items (Non-Durable Goods) in the Past 12 Months

Product Consumed		Total consumption including from own production/gift and purchase. Then, the respondent estimates its total value in the market.			Product Consumed		Total expenditure (GHC)
		Quantity	Unit (code)	Total Value (GHC)			
	EX0	**EX1**	**EX2**	**EX3**		**EX0**	**EX4**
LAST ONE WEEK					**LAST ONE MONTH**		
Maize grain	1				Salt	24	
Maize meal/flour	2				Coffee/Tea: powder	25	
Millet/Sorghum	3				Drinks (including alcohol)	26	
Wheat flour	4				Tobacco/Cigarettes	27	
Rice	5				Electricity	28	
Cassava (Fresh form)	6				Cellular phone charge	29	
Cassava (Processed)	7				Firewood	30	
Sweet potatoes	8				Cow dung	31	
Irish potatoes	9				Charcoal	32	
Yam	10				Kerosene/Gas	33	
Beans	11				Soap/washing products	34	
Bread	12						

Unit Code for EX2
1=90 kg bag
2=50 kg bag
3=25 kg bag
4=10 kg bag
5=2 kg bag
6=kg
7=grams
8=liters
9=tones
10=numbers
11=bunch (banana)
12=wheelbarrow

Section 11.Household Assets

Asset		Number of items currently owned	Total value (GHC) (current value)	In the past 12 months		Asset		Number of items currently owned	Total value (GHC) (current value)	In the past 12 months	
				Number of items **purchased**	Number of items **sold**					Number of items **purchased**	Number of items **sold**
ITEM	**A0**	**A1**	**A2**	**A3**	**A4**	**ITEM**	**A0**	**A1**	**A2**	**A3**	**A4**
Farm Equipment						**Other Items**					
Tractor	1					Bicycle	14				
Plough sets	2					Radio	15				
Carts	3					(Car) Battery	16				
Wheelbarrows	4					TV	17				
Borehole	5					Mobile Phone	18				
Spray pumps	6					Solar panel	19				
Diesel pumps	7					Chair	20				
Water tanks	8					Table	21				
Trailles	10					Mosquito net	23				
Grinders	11					Motorcycle	24				
Hand hoe	12					Vehicle	25				
Milking churns	13										
Storage facility (building)	50										

On the respondent's house

A5:	Is this house owned?	1= yes	2=no	**A5** ____________			
A6:	How old (how many years) is this house?		____________________ years old				
A7:	If the same house is constructed now, how much would it cost in GHC? ______________________________ GHC (just guess it)						
A8:	Roof material?	1=grass thatched	2= iron sheet	3=roofing tile	4=wood	5=cement/concrete	6=other
A9:	Wall material?	1=mud	2=bricks/stones	3=wood	4=iron sheet	5=other ____________________________	
A10:	Floor Material?	1=cement	2=earth	3=other ______________________________			

Section 12.Extension and Training in the Last Two Years

ET0: Did any member of this household receive agricultural training or have contact with extension agents concerning agriculture in the last two years, i.e. in the rainy season of 2011 and 2012? 1=yes 2=no (skip this section)

Name of household member	Person ID	Training or extension? 1=training 2=extension	Provider of training/extension See Code below	What kind of training/extension? 1= rice production 2= other crop production (specify) 3= other (specify)	Number of days of training/ number of visit of extension during the rainy season of 2011?	Number of days of training/ number of visit of extension during the rainy season of 2012?
NAME	**ID**	**ET1**	**ET2**	**ET3**	**ET4**	**ET5**
Training						
		1				
		1				
		1				
		1				
Extension						
		2				
		2				
		2				
		2				

Code for ET2: 1=agricultural extension agents from government (e.g. MOFA staff), 2=extension worker from NGO, 3=extension worker from private companies, 4=fellow farmers, 5=other (specify)

Section 13. Membership in Farmers' Group and/or Local Organization

OR0: Is any member of this household a member of group and /or organization **currently**? 1=yes (answer up to OR6) 2=no

OR1: Has any member of this household resigned membership **during the last 2 years**?

Name of household member	Person ID	Name of Group/ Organization	Primary activity of this Group/ Organization See Code below	Number of members in the group/ organization	Annual membership fee (GHC)	Major benefit received from this group/ organization See Code below.	Month and year you became a member	Month and year you stopped being a member	Reason to have resigned the group /organization. See Code below.
NAME	**ID**	**OR1**	**OR2**	**OR3**	**OR4**	**OR5**	**OR6**	**OR7**	**OR8**

Code for OR2:
1=Income generating for group members,
2=Group marketing of products,
3=Group production of products,
4=Group access to inputs and extension services,
5=Mobilizing saving and credit for group members,
6=Promotion of improved farming practices,
7=Mutual support/Social services,
8=Other (specify)

Codes for OR5:
1=Easier access to inputs,
2=Easier access to markets of products,
3=Easier access to extension services,
4=Easier access to credit,
5=Easier access to transport,
6=Better input and output prices,
7=Other (specify)

Code for OR8:
1=No benefits,
2=Time consuming,
3=Group dissolved,
4=Failed to raise subscription,
5=Internal conflicts,
6=Other (specify)

Section 14: HPRD- Food consumption during last year

HPRD 1: Experience of food insecurity in the household (2012)

	Abundance period	Period of average availability	Lean period
Number of meals per day (on average)			
If less than 3, give reasons			
Number of days per month you took only two meals per day because of lack of money/food			
Number of days per month you took only one meal per day because of lack of money/food			
Number of days without food in the period because of lack of money/food			
Number of months in which you did not have enough food to meet your family's needs (cut the size of your meals)?			
Whose meals were reduced during these months? 1=son; 2=daughter; 3=adult male, 4=adult female,; 4=Other (specify)			

HPRD 2: Dishes eaten and ingredients for each dish by period

Periods	Major ingredients		Minor ingredients		Fruit	
	Code	Quantity (kg) per day	Code	Quantity (kg) per day	Name	Average number per week
Abundance period						
Period of average availability						
Lean period						

Code of major ingredients: 1=rice, 2=maize, 3=millet, 4=sorghum, 5=cassava, 6=ground nut, 7=fonio, 8=cowpea, 9=onion, 10=tomato, 11=sweet potato, 12=sesame, 14= eggplant, 16=okra, 17=banana, 18=mango, 19=orange, 20=cashew nut, 21=potatoes, 22=yam, 23=Bambara nut, 24=leafy vegetables, 25=peanuts, 26=okra, 27=palm nut, 28=cowpea (leaves), 30=fish and seafood, 31=meat , poultry, offal, 31=insects/caterpillars, 32=snail, 33=egg, 34=oil/fats, 35=milk and milk products, 36=Guinea sorrel (bissap), 37=lettuce, 38= spaghetti/macaroni, couscous, 39=Other specify**, Code of minor Ingredients:** 1=Salt, 2=pepper, 3= garlic, 4= Other specify**,**

Section 15: Information on Fertilizer Subsidy Program

FS 1: Are you aware of the government fertilizer subsidy program? 1=Yes 2=No

FS 2: If yes, what your sources of information on the program? (multiple choice) 0=NA 1=Mass Media 2=MoFA/Extension 3=MoFA/Project
4=Other projects (specify) 5=NGOs 6=Research 7=Input dealers 8=Neighbors within the community 9=Neighbors outside the community

FS 3: Would you like to pay a higher price to obtained adequate amount of fertilizer that will satisfy your household needs? 1=Yes 2=No

FS 4: If FS3=1=Yes, much how much more would you like to pay? ……………………………… Ghc

FS 5: What are your perceptions about the benefits of fertilizers? (Multiple choice)
0=Indifferent 1=high yield 2=vigorous growth 3=early maturity 4=other specify…………………………………………………………..

FS 6: What are your perceptions about the problems of fertilizers? (Multiple choice)
0=no idea 1=increase soil acidity 2=increase weed growth 3=increase plants pests/diseases problems 4=other specify………

FS 4: Refer to IP10, IP11, IP12 and IP13, if farmer used fertilizer, provide information on fertilizer use on rice.

Type	Quantity (kg) Needed	Quantity (kg) under subsidy	Subsidy price (Gh c/kg)	Quantity (kg) outside subsidy	Market price (Gh c/kg)	Quantity (kg) from credit	Quantity (kg) received as as gift	Quantity applied on rice (equal to IP11+IP13)	Quantity used on other fields	Quantity given as gifted	Quantity sold
NPK											
Activa											
Ammonia											
Sulfane											
Urea											

FS 3: Was the total amount of fertilizers you obtained adequate for the needs of your household? 0=No, not adequate 1=Yes, enough 2=Yes, more

FS 4: If FS 3=0=No, what

FS 8: If FS1=2=No, why did you not use fertilizers?…….
………...…………………
………
……...

Section 16: Agricultural production and use

HP1.: NB: productions are crops quantities directly harvested. In the case where the product is not sold, please use the market price at the time when the product is use

Crop (code1)	2012												
	Production (kg)	Production use					Person who decides this distribution	Sale price (GHc per kg)	Sale place (code 2)	If sale at home or market			Person who controls these productions' income
		Consumption (%)	Sale (%)	Seed (%)	Donation (%)	Other use (specify)				Transport cost	Road tax	Market tax	

Code1: Code type of crop 1=rice, 2=maize, 3=millet, 4=sorghum, 5=cassava, 6=peanut, 7=fonio, 9=cowpea, 10=tomatoes, 11=sweet potatoes, 12=sesame, 13=cotton, 14= eggplant, 15= pepper, 16=okra, 17=banana, 18=mango, 19=orange, 20=cashew, 21=Potatoes, 22=yam, 23= Bambara nut, 24= other (specify)

<u>Code 2: Selling place:</u> 1=at home, 2=field, **3**=village market, 4=other market, 5=Other (specify)

Section 17: Risk Attitudes

RA: On a scale of 0 to 5, tell us your risk attitude. What percentage of your crop lands will be exposed to the following risk conditions?

Risk	Rice		All crops	
	Rank	Proportion of land (%)	Rank	Proportion of land (%)
Very early planting				
Late planting				
Sowing poor quality seeds				
Adoption of new technology				
Late application of fertilizers				
Late harvesting				

Appendix 1C: Community questionnaire for rice survey

ID Number of the village:____

Name of the village on the list:____

GPS measurement at the village center where a group interview is conducted:

GPS Number: ;Location: ± m

Latitude: N ° ' " (example N09° 35' 52.4");

Longitude: W ° ' " (example W000° 58' 29.8");

Record Number: __________; Date and Time:__________________; Elevation: _____m

0.1 Date of interview	Date			Month			Year	2	0		

Interviewed by:____

0.1 Date of verification	Date			Month			Year	2	0		

Verified by:____

0.1 Date of Data Entry	Date			Month			Year	2	0		

Entered by:____

1. On the Village

1.1 Name of the village by villagers:________________________________

(Please ask the spelling of the village name actually used by the villagers)

2. Village Location

2.1 District:____

2.2 How do villagers usually go to the center of Tamale? Answer the most popular medium (the most popular combination of media). .

Medium	Time (minutes)	Fare (one adult)	Example	Example
Walk				
Bike taxi			10	1 GHC
Bush taxi				
Mini bus				
Bus			30	5 GHC
Other 1, specify				
Other 2, specify				
Total to go to Tamale			40	6 GHC

Village Population (current and 10 year ago)

	3.1	3.2	3.3
	Current estimates	Around 2010[1]	Around 2000[1]
1 Number of Houses			
2 Number of Households			
3 Number of population			

[1] If censuses 2000/2010 are available, use them. Otherwise, ask villagers to estimate them.

Since 2000, has this village been merged with other villages? 1. Yes 2. No

3.4.1.1 If 1. Yes, in which year and with which villages?

Year:________________; Names of the villages merged:____________________________

3.4.2 **Since 2000,** has this village been separated? 1. Yes 2. No

3.4.2.1 If 1. Yes, in which year and which villages were separated?

Year:________________; Name of the villages separated:___________________________

3.5.1 What are the largest ethnic groups in the village?

Name of the group:______________________________; percentage:_____________________%

Name of the group: ______________________________; percentage:_____________________%

3.5.2 Are there any minor ethnic groups in the village? 1. Yes (specify below) 2. No

Name of the group: ______________________________; number of households:_____________

Name of the group: ______________________________; number of households:_____________

In this village do the minor ethnic groups form a residential zone of their own? 1. Yes 2. No

3.6 In-migration and out-migration **in the past 13 years (since the year 2000)**

	Families that have **newly settled** in this village (including in farm zones)	Families that have **moved out** from this village (including in farm zones)
1 Number of families?		
2 Mainly which regions/countries are they from or have they gone to? Use the codes below		
3 Among the above, which is the majority (select one among the above)? Use the codes below		

1) Northern, 2) Upper East, 3) Upper West, 4) Brong-Ahafo, 5) Volta, 6) Eastern, 7) Central, 8) Western, 9) Greater Accra, 10) Ashanti, 11) Ivory Coast, 12) Togo, 13) Benin, 16) Other place, specify

5.Rice Production Technologies in This Village

Average size of rice plot in the lowlands of this village:

5.1.1 Rice plot without project_________________acres/person

5.1.2 Rice plot intervened by a project, if any ____________acres/person

5.1.3 Are the rice producers shifting rice plots? 1. Yes 2.No, fixed plot

5.1.3.1 If Yes, how often do they shift on average? Once in _________years

5.1.3.2 If No=fixed plot, since how many years ago have rice cultivators in this village stopped shifting? Since ( ) years ago (roughly)

5.2 Current Technologies in this village

5.2.1 **Bund around rice plot**

5.2.1.1 Does any rice producer in this village have a **bund** for rice production? 1. Yes 2. No

If Yes, what percentage of rice producers in this village **currently has a bund**? %

5.2.1.2 Did any rice producer in this village have a **bund** for rice production 10 years ago? 1. Yes 2. No

If Yes, what percentage of rice producers in this village **had a bund 10 years ago**? %

5.2.1.3 If bunds (including mini-bunds) exist in this village, when and how was it introduced?

When: ____________________________years ago How? Select from the below: _______________

1. Project (e.g. LRDP, RSSP, JICA) carried out in this village constructed the bunds for them
2. Project (e.g. LRDP, RSSP, JICA) carried out in this village taught them how to create bunds
3. NGO taught them how to create bunds (name of NGO: ___________________________)
4. Rice producers in other villages taught them how to create bunds
5. Rice producers in this village created the bunds by themselves after having seen bunds in other villages
6. Other case, explain: ____

5.2.2 **Land Preparation: Ploughing by Tractor**

How many tractors are available for ploughing rice field in this village?

Current number: ____________; Number 10 years ago: ___________________

5.2.1.2 How many tractors are available for ploughing rice field around this village?

Current number: ____________; Number 10 years ago: ___________________

5.2.1.3 Does any rice producer in this village **currently** use **tractor for ploughing** rice field? 1. Yes 2. No

If Yes, what percentage of rice producers in this village **currently** use **tractor for ploughing** rice field? _____%

5.2.1.4 Did any rice producer in this village use **tractor for ploughing** rice field **10 years ago**?

1. Yes 2. No

If Yes, what percentage of rice producers in this village used **tractor for ploughed** rice field **10 years ago**? _____%

5.2.2.1 Rental price of tractor for ploughing rice field in rainy season 2012

____________________ GHC/acre for one passage

5.2.3 **Land Preparation: Harrowing/Leveling before Sowing by Tractor**

5.2.3.1 How many tractors are available for harrowing in this village?

Current number: ___________; Number 10 years ago: ________________

5.2.3.2 How many tractors are available for harrowing around this village?

Current number: ___________; Number 10 years ago: ________________

5.2.3.3 Does any rice producer in this village **currently** use **tractor for harrowing** before sowing rice?

1. Yes 2. No **If Yes**, what percentage of rice producers in this village **currently** use **tractor for harrowing** before sowing rice? _______%

5.2.3.4 Did any rice producer in this village use **tractor for harrowing** before sowing rice**10 years ago**?

1. Yes 2. No **If Yes**, what percentage of rice producers in this village used **tractor for harrowing** before sowing rice **10 year ago**? _______%

5.2.3.5 Rental price of tractor for harrowing in rainy season 2012________________ GHC/acre for one passage

(Please reply the rental price even if no one uses tractor for harrowing in this village)

Dibbling in line

5.2.4.1 Does any rice producer **currently dibble rice seeds in line** in this village? 1. Yes 2. No

If Yes, what percentage of rice producers in this village **currently dibble in line**? ____%

5.2.4.2 Did any rice producer in this village **dibble rice seeds in line** 10 years ago? 1. Yes 2. No

If Yes, what percentage of rice producers in this village **dibbled in line 10 years ago**? _______%

5.2.4.3 If dibbling of rice seed is practiced in this village, when and how was it introduced?

When: __________________________years ago How? Select from the below: ______________

1. Project (e.g. LRDP, RSSP, JICA) carried out in this village taught them
2. NGO taught them how to create bunds (name of NGO: ___________________________)
3. Rice producers in other villages taught them
4. Rice producers in this village adopted it after having seen it in other villages
5. Other case, explain: ____

5.2.5 Drilling Rice Seed

5.2.5.1 Does any rice producer **currently do drilling rice seed** in this village? 1. Yes 2. No

If Yes, what percentage of rice producers in this village **currently does drilling**? ___%

5.2.6 Covering Rice Seed with Tractor after Sowing

5.2.6.1 Does any rice producer in this village **currently** use **tractor for covering rice seed** after sowing? 1. Yes 2. No **If Yes**, what percentage of rice producers in this village **currently** use **tractor for covering rice seed** after sowing? _____%

5.2.6.2 Did any rice producer in this village use **tractor for covering rice seed** after sowing **10 years ago**? 1. Yes 2. No **If Yes**, what percentage of rice producers in this village used **tractor for covering rice seed** after sowing **10 years ago**? _____%

5.2.6.3 Rental price of tractor for soil covering in rainy season 2012_______________ GHC/acre for one passage

(Please reply the rental price even if no one uses tractor for soil covering in this village)

5.2.7 Herbicide Use for Land Preparation of Rice Field

Does any rice producer in this village **currently** use **herbicide for land preparation of rice field** (not for weeding during rice growing stages)? 1. Yes 2. No **If Yes**, what percentage of rice producers in this village **currently** uses **herbicide for land preparation**? _____%

5.2.7.2 When do the rice producers in this village apply herbicide for land preparation? Give the current percentage of rice producers for each time.

Before ploughing:___%; Between ploughing and sowing:____%; After sowing:___%

(Total may exceed 100% if any producers apply more than once)

5.2.7.3 Did any rice producer in this village use **herbicide for land preparation** (not for weeding during rice growing stages) **10 years ago**? 1. Yes 2. No **If Yes**, what percentage of rice producers in this village used **herbicide for land preparation 10 years ago**? _____%

5.2.8 Use of Chemical Fertilizer

5.2.8.1 Does any rice producer in this village **currently** use **chemical fertilizer**? 1. Yes 2. No

If Yes, what percentage of rice producers in this village **currently** uses **chemical fertilizer**? _____%

5.2.8.2 Which fertilizer do the rice producers in this village use? Give the current percentage of rice producers for each type of fertilizer.

NPK (compound fertilizer):____%; Urea:____%; Ammonium Sulfate:___%

(Total may exceed 100% if any producers apply more than one type of fertilizer)

5.2.8.1 Did any rice producer in this village use **chemical fertilizer10 years ago**? 1. Yes 2. No

If Yes, what percentage of rice producers in this village used **chemical fertilizer 10 years**

ago? _____%

5.2.9 Use of Tarpaulin for Rice Threshing

5.2.9.1 Does any rice producer in this village **currently** use **tarpaulin** when he/she threshes rice (include the use of rental tarpaulin)? 1. Yes 2. No **If Yes**, what percentage of rice producers in this village **currently** use **tarpaulin for rice threshing**? _____%

5.2.9.2 If a rice producer in this village rents a sheet of tarpaulin for rice threshing, how much is the rental fee? _____GHC/day

Did any rice producer in this village use **tarpaulin** when he/she threshes rice (include the use of rental tarpaulin)**10 years ago**? 1. Yes 2. No **If Yes**, what percentage of rice producers in this village used **tarpaulin for rice threshing 10 years ago**? _____%

Curriculum Vitae

Contact information

Name: Alexander Nimo Wiredu

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Educational Background

- Doctoral Student, Faculty of Agricultural Sciences (Agricultural Economics), University of Hohenheim, Stuttgart, Germany. 2013-2015. Thesis title: "Impacts of fertilizer subsidy on farm-level productivity and food security: A case study of rice-producing households in northern Ghana".
- Master of Philosophy in Agricultural Economics, University of Ghana, Accra, Ghana. 2005-2007. Thesis title: "Effect of improved cocoa technologies on the productivity of small holder cocoa farmers in the Ahafo-Ano districts of Ashanti region of Ghana".
- Bachelor of Science in Agriculture (Agricultural Economics), University of Ghana, Accra, Ghana. 2000-2004. Dissertation title: "An assessment of the comparative advantage in large and small-scale broiler production in the Greater Accra Region of Ghana".

Other relevant training

- Mastering Metrics: An Empirical Strategies Training Workshop. University of Rome Tor Vergata and Joshua D. Angrist, Ravello, Amalfi Coast, Italy, 12th-15th June 2015.

- Ethic in Food Security and Development Research and Action. Center for Development Research (ZEF), University of Bonn, Bonn, Germany, and Food Security Center, University of Hohenheim, Stuttgart, Germany, 7th-8th April 2015.
- Leadership Development. Center for Development Research (ZEF), University of Bonn, Bonn, Germany, and Food Security Center, University of Hohenheim, Stuttgart, Germany, 16th-20th June 2014.
- Intercultural Working. Center for Development Research (ZEF), University of Bonn, Bonn, Germany, and Food Security Center, University of Hohenheim, Stuttgart, Germany, 6th-8th December 2013.
- Certificate Course on How to Manage, Design and Conduct Impact Evaluation. Center for Learning on Evaluation and Results, International Initiative for Impact Evaluation, and University of Witwatersrand, Johannesburg, South Africa, 23rd July - 3rd August 2012.
- Impact Evaluation and Value Chain Analysis. ICRISAT, Niamey, Niger, 8th - 13th August 2012.
- Data management with STATA. Africa Rice Center, Addis Ababa, Ethiopia, 26th - 31st July 2010.
- Training of District-Level Facilitators of Farmer Field Fora. Root and Tuber Improvement and Marketing Programme of Ministry of Food and Agriculture, Kumasi, Ghana 7th - 11th September 2009.
- Impact Assessment Methodology. Africa Rice Center, St Louis, Senegal, 20th - 24th April 2009.

Professional expertise and interests

- Development program evaluation
- Food security, poverty, livelihood, production, and farming systems analysis
- Agricultural development policy analysis
- Project design, management, and monitoring and evaluation (M&E)
- Integrated Agricultural Research for Development (IAR4D)
- Establishment of commodity value chains, and innovative platforms

- Development, management, and analysis of socioeconomic survey data
- Leadership and conflict resolution
- Interdisciplinary, intercultural, and ethical research approach
- Teaching, training, and mentoring

Employment history

- Savanna Agricultural Research Institute (SARI) of Council for Scientific and Industrial Research (CSIR), Nyankpala, Ghana. April 2008-present. Position: Research Scientist-Agricultural Economics. Job description: Technology evaluation and dissemination, monitoring and evaluation (M&E), impact evaluation, training, and capacity building.
- Department of Agricultural Economics & Agribusiness, University of Ghana. Accra, Ghana. July 2004-August 2005. Position: Research and Teaching assistant. Job description: Design and implementation of socioeconomic surveys, and data management, data analysis, and conduct of tutorials sessions.
- Action Secondary and Technical School, Accra, Ghana, 2003-2007. Position/Job description: Tutor. Duties: Teaching of science subjects (Agriculture and Biology).

Other professional experiences

- National focal person: Africa Rice Policy, Innovation, and Impact Task Force, Ghana. 2009-2012.
- Agricultural economist: Institutional Biosafety Committee, CSIR-SARI, Nyankpala, Ghana. 2009-2012.
- Visiting scientist (Impact specialist/Database manager), Africa Rice Center (AfricaRice), Cotonou, Benin. September 2009 and November/December 2010.
- Visiting Scientist (Agricultural Economist), International Institute of Tropical Agriculture (IITA), Kano, Nigeria. October 2009.

Leadership experiences

- Head: Socioeconomic program, CSIR-SARI, Nyankpala, Ghana. April 2008 to December 2012. Responsibilities: Coordinate socioeconomic research, and represent socioeconomic team in external deliberations.
- Organizing secretary: Ghana Association of Agricultural Students (GAAS), Legon, Ghana. 2003-2004. Duties: Developed visibility and promotional strategies for the association, participated fund raising activities, and organized the 2004 annual Green Week at the University of Ghana, Legon, Ghana.

Research activities performed in the last 5 years

1. Consultant : Mapping and analysis of value chains and business models in the staple food sectors. May-September 2015. Client : GIZ, Germany.
2. Consultant : Mapping and economic analysis of rice value chains and business models in Nigeria. April-May 2015. Client : GIZ, Germany.
3. Team leader: Market oriented promotion of improved soy bean technology package to sustainably improve productivity and incomes. 2015. Client: CSIR, Accra, Ghana.
4. Team leader: Baseline and end-line surveys for an empirical analysis of expanding rice production in sub-Saharan Africa. 2010 and 2014. Client: JICA, Tokyo, Japan.
5. Resource person: Patterns and determinants of adoption of improved maize and rice technologies in Ghana. 2012-2013. Client: IFPRI, Washington, DC, USA.
6. Principal investigator: Managing yam glut in Brong-Ahafo region. 2009 to 2013. Client: West African Agricultural Productivity Programme (WAAPP), Accra, Ghana.
7. Impact specialist: USAID Africa Rising (Rice) Project. 2012. Client: Africa Rice Center, Cotonou, Benin.
8. Consultant: Survey on indigenous sustainable agricultural practices In Northern Region of Ghana. 2012. Client : ActionAid, Tamale, Ghana.
9. M&E and impact specialist: Rice Sector Support Project. 2011-2012. Client: MoFA, Tamale, Ghana.

10. Facilitator: Developing rice multi-stakeholder platform in Ghana. 2012-2014. Client: AfricaRice, Cotonou, Benin
11. Agricultural economist: Root and Tuber Improvement and Marketing Program (RTIMP), Northern Zone 1. 2008-2012. Client: Ministry of Food and Agriculture, Kumasi, Ghana.
12. Principal investigator: Baseline study of vegetable production systems in Northern Ghana. 2010-2011. Client: International Fertilizer Development Center (IFDC), Accra, Ghana.
13. Agricultural economist: Drought Tolerant Maize for Africa (DTMA), Ghana. 2008-2011. Client: International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.
14. Facilitator: Developing Chili value chain in Northern Ghana. 2008-2011. Client: IFDC, Tamale, Ghana.

List of Publications

Journal articles

1. Appiah, M. K., Feike, T., **Wiredu, A. N**, Mamitimin, Y., 2014. Cotton production, land use change and resource competition in the Aksu-Tarim River Basin, Xinjiang, China. *Quarterly Journal of International Agriculture* 53 (3), 243-261.
2. Martey, E., Etwire, P. M., **Wiredu, A. N.**, Dogbe, W., 2014. Factors influencing willingness to participate in multi-stakeholder platform by smallholder farmers in Northern Ghana: implication for research and development. *Agriculture and Food Economics* 2(11), 1-15.
3. Attoh, C., Martey, E., Kwadzo, G. T. M., Etwire, P. M., **Wiredu, A. N.**, 2014. Can farmers receive their expected seasonal tomato price in Ghana? A Probit Regression Analysis. *Sustainable Agriculture Research* 3 (2), 16-23.
4. **Wiredu, A. N.**, Asante, B. O., Martey, E., Diagne, A., Dogbe, W., 2014. Impact of NERICA adoption on incomes of rice-producing households in northern Ghana. *Journal of Sustainable Development* 7 (1), 167-178.
5. Martey, E., **Wiredu, A. N.**, Etwire, P. M., Fosu, M., Buah, S. S. J., Bidzakin, J., Ahiabor, B. D. K., Kusi, F., 2013. Fertilizer adoption and use intensity among smallholder farmers in northern Ghana: A case study of the AGRA Soil Health Project. *Sustainable Agriculture Research* 3 (1), 24-36.
6. Asante, B. O., **Wiredu, A. N.**, Martey, E., Sarpong, D. B., Mensah-Bonsu, A., 2013.

NERICA adoption and impacts on technical efficiency of rice-producing households in Ghana: Implications for research and development. *American Journal of Experimental Agriculture* 4 (3), 244-262.

7. Asante, B. O., **Wiredu, A. N.**, Dogbe, W., Asuming-Boakye, A., Frimpong, B. N., Haleegoah, J., Nortey. J., Diagne, A., 2013. Factors affecting the adoption and use of NERICA Varieties among rice-producing households in Ghana. *Asian Journal of Agriculture and Rural Development* 3(10), 721-735.
8. Attoh, C., Martey, E., Annin, K., **Wiredu, A. N.**, Quaye, R., 2013. Are farmers surviving the level of seasonal cultivation of tomatoes in Ghana? A Tobit regression analysis. *Journal of Economics and Sustainable Development* 4(6), 53-60.
9. Kusi, F., Asante, S. K., Adjebeng-Danquah, J., Nutsugah, S. K., Buah, S. S. J., Owusu, R. K., **Wiredu, A. N.**, Sugri, I., Zakaria, M., 2013. Participatory integrated pest management strategy for improving shelf-life of yam (Dioscorea spp.). *International Journal of Advance Agricultural Research* 1(10), 124-132.
10. Inusah, B. I. Y., **Wiredu, A. N.**, Yirzagla, J., Mawunya, M., Haruna, M., 2013. Effects of different mulches on the yield and productivity of drip irrigated onions under tropical conditions. *International Journal of Advance Agricultural Research* 1(10), 133-140.
11. Inusah, B. I. Y., Abdulai, M., Haruna, M., **Wiredu, A. N.**, Mawunya, M., 2013. Influence of Stay moist on soil water stress management and productivity of maize in Guinea savannah zone of Ghana. *International Journal of Advance Agricultural Research* 1(7), 74-86.
12. Buah, S. S. J., Kombiok, J. M., Kanton, R. A. L., Denwar, N. N., Haruna, A., **Wiredu, A. N.**, Abdulai, M. S., 2013. Participatory evaluation of drought tolerant maize varieties in the guinea savanna of Ghana using mother and baby trial design. *Journal of Science and Technology* 33 (2), 12-23.
13. Asante, M. D., Asante, B. O., Acheampong, G. K, **Wiredu, A. N.**, Offei, S. K., Gracen, V., Adu-Dapaah, H., Danquah, E. Y., 2013. Grain quality and determinants of farmers' reference for rice varietal traits in three districts of Ghana: Implications for research and policy. *Journal of Development and Agricultural Economics* 5(7), 284-294.
14. Martey, E., **Wiredu, A. N.**, Asante, B. O., Annin, K., Dogbe, W., Attoh, C., Al-Hassan, R. M., 2013. Factors influencing participation in rice development projects: The case of smallholder rice farmers in northern Ghana. *International Journal of Development and Economic Sustainability* 1 (2), 13-27.
15. Martey E., Annin, K., Attoh, C., **Wiredu, A. N.**, Etwire, P. M., Al-Hassan, R. M., 2013.

Performance and constraints of small scale enterprises in the Accra metropolitan area of Ghana. *European Journal of Business and Management* 5 (4), 83-93.

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17. **Wiredu, A. N.**, Gyasi, K. O., Saaka, S. S. J., Asante, B. O., Mensah-Bonsu, A., 2012. Factors affecting proportions of land allocated to the mini-sett technology by yam producers in Northern Ghana. *Africa Journal of Agricultural Research* 7(29), 4158-4166.
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20. Sugri, I., Nutsugah, S. K., **Wiredu, A. N.**, Johnson, P. N. T., Adogoba, D. S., 2012. Kendall's concordance analysis of descriptors influencing consumer preference for sweet potatoes in Ghana. *American Journal of Food Technology* 7(3): 142-150.
21. Awotide, B. A., Diagne, A., **Wiredu, A. N.**, Ojehomon, V. E., 2012. Wealth status and agricultural technology adoption among smallholder rice farmers in Nigeria. *OIDA International Journal of Sustainable Development* 5 (2), 97-108.
22. **Wiredu, A. N.**, Mensah-Bonsu, A., Andah, E. K., Fosu, K. Y., 2011. Hybrid cocoa and land productivity of cocoa farmers in ashanti region of Ghana. *World Journal of Agricultural Sciences* 7(2), 172-178.
23. Asuming-Brempong, S., Gyasi, K. O., Marfo, K. A., Diagne, A., **Wiredu, A. N.**, Boakye, A. A., Haleegoah, J., Frimpong, B. N., 2011. The exposure and adoption of New Rice for Africa (NERICAs) among Ghanaian rice farmers: What is the evidence? *African Journal of Agricutural Research* 6(27), 5911-5917.
24. Fordjour, F., Badu, E. E., **Wiredu, A. N.,** 2011. The challenges of information retrieval by university students: A case study of post graduate students of the University of Ghana, Legon. *International Research Journal of Library, Information and Archival Studies* 1

(5), 135-143.

25. Buah, S. S. J., Nutsugah, S. K., Kanton, R. A. L., Atokple, I. D. K., Dogbe, W., Karikari, A. S., **Wiredu, A. N.**, Amankwah, A., Osei, C., Ajayi, O., Ndiaye, K., 2011. Enhancing farmers' access to technology for increased rice productivity in Ghana. *Africa Journal of Agricultural Research* 6(19), 4455-4466.

Conference papers

1. **Wiredu, A. N.**, Zeller M., Diagne, A., 2015. Impact of fertilizer subsidy on land and labor productivity of rice-producing households in Northern Ghana. Conference of Center for Studies in African Economies, Oxford, United Kingdom. March 22-24, 2015.
2. Martey, E., **Wiredu, A.N.**, Etwire, P.M., 2015. Impact of credit on technical efficiency of maize producing households in northern Ghana. Conference of Center for Studies in African Economies, Oxford, United Kingdom. March 22-24, 2015.
3. **Wiredu, A. N.**, Martey, E., Fosu, M., 2014. Describing adoption of integrated soil fertility management practices in northern Ghana. International Conference on Research on Food Security, Natural Resource Management and Rural Development (Tropentag 2014), Czech Republic, Prague, Czech Republic. September 17-19, 2014.
4. **Wiredu, A. N.**, Gyasi, K. O., Marfo, K. A., Asuming-Brempong, S., Haleegoah, J., Boakye, A. A., Nsiah, B. F., 2010. Impact of improved varieties on the yield of rice-producing households in Ghana. Second Africa Rice Congress, Bamako, Mali, March 22-26, 2010.

Published technical report

1. Ragasa, C., Dankyi, A., Acheampong, P., **Wiredu, A. N.**, Chapoto, A., Asamoah, M., Tripp, R., 2013. Patterns of adoption of improved rice technologies in Ghana. IFPRI working paper 35, July 2013, pp. 11.
2. Ragasa, C., Dankyi, A., Acheampong, P., **Wiredu, A. N.**, Chapoto, A., Asamoah, M., Tripp, R., 2013. Patterns of adoption of improved maize technologies in Ghana. IFPRI working paper 36, July 2013, pp. 11.
3. Abdoulaye, T., Bamire, A. S., **Wiredu, A. N.**, Baco, M. N., Fofana, M., 2011. Drought Tolerant Maize for Africa (DTMA) Project Community Surveys. Characterization of maize producing communities in Benin, Ghana, Mali and Nigeria. West Africa Regional Synthesis Report, pp. 26.
4. **Wiredu, A. N.**, Gyasi, K. O., Abdoulaye, T., Sanogo, D., Langyintuo, A., 2010.

Characterization of maize producing households in the Northern Region of Ghana. Country Report – Ghana: CSRI/SARI – IITA, Ibadan, Nigeria, pp. 33.

Books

1. **Wiredu, A. N.,** 2011. Cocoa technology and productivity: Evidence of smallholder cocoa farmers in Ashanti region of Ghana. Lambert Academic Publishing, Germany.

Conferences attended

- Conference of Centre for Studies of African Economies, Oxford, UK. March 22-24, 2015.
- Conference on Improving Institutions for Growth, Oxford, UK. March 20-21, 2015.
- 4th International Rice Congress, Bangkok, Thailand. October 27-November 1, 2014.
- International Conference on Research on Food Security, Natural Resource Management and Rural Development (Tropentag 2014), Prague, Czech Republic. September 17-19, 2014.
- Global Forum for Food and Agriculture 2014. Berlin, Germany, January 2014.
- 3rd Africa Rice Congress, Yaoundé, Cameroon, October 2013.
- 2nd Africa Rice Congress, Bamako, Mali, March 2010

Awards/Scholarship

- Second best paper and presentation at the 3rd Africa Rice Congress, Yaoundé, Cameroon, 2013
- 2011 Global Rice Science Scholarship
- University of Ghana Graduate Fellowship Award, 2005/2006.

Membership of Professional Bodies

- International Association of Agricultural Economists (IAAE)

- Agricultural Economic Society (AES)
- Agricultural & Applied Economics Association (AAEA)
- African Association of Agricultural Economist (AAAE)
- Ghana Association of Agricultural Economist (GAAE)
- Research Staff Association (RSA), Ghana
- American Evaluation Association (AEA)

Work related travel experience

- Benin, Burkina Faso, Cameroon, Czech Republic, Ethiopia, France, Germany, Ivory Coast, Kenya, Mali, Netherlands, Nigeria, Niger, Sierra Leone, Senegal, South Africa, Tanzania, Thailand, The Gambia, Togo, United Kingdom, and Zimbabwe.

Computer Skills

STATA, DAD, SPSS, E-views, and Microsoft Office Suite.

Language

English (fluent), elementary French, elementary German, Twi (Fluent), Ga (fluent)

Hobbies

Aerobic exercising, cooking, listening to music, watching movies, travelling, admiring nature.

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Alexander Nimo Wiredu

Stuttgart-Hohenheim, 26.08.2015

Author's declaration

I hereby declare that with the exception of references to past and current literature duly cited, I personally conducted the research thesis titled, "Impacts of fertilizer subsidy on farm-level productivity and food security: A case study of rice-producing households in northern Ghana." This work has neither been presented in whole nor in part for any other degree of this university or elsewhere.

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Alexander Nimo Wiredu

Stuttgart-Hohenheim, 26.08.2015