The Graduate Programs in Sustainable International Development
The Heller School for Social Policy and Management
Brandeis University

Factors affecting technology adoption among small maize farmers in Tanzania

Submitted by
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A paper submitted in partial fulfillment of the requirements for the

Master of Arts Degree
in
Sustainable International Development

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Academic Advisor Date

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Director, Program in Sustainable International Development Date

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Abstract

Farmers in sub-Saharan African countries use little agricultural technology such as improved seed and mineral fertilizer along with modern cultivation practices. As a result, agricultural productivity has decreased in sub-Saharan Africa over the last few decades. In countries such as Tanzania, yields have dropped by 3% in the last decade. However, the total agricultural production has increased due to an increase of area, but this is not an indication of a sustainable solution. The investment in the agricultural sector is around 5% of the national budget in Tanzania, which is much lower than the committed investment which is 10%. BRAC has been promoting improved agricultural technology to raise productivity among small farmers (i.e. cultivated area does not exceed two hectare) in Tanzania through a project called Livelihood Enhancement through Agricultural Development (LEAD). In this paper I examine the factors associated with the adoption of fertilizer among small farmers in Tanzania. For this I have four hypotheses to test: (1) increased supply of arable land decreases technology adoption among farmers, (2) receiving a fair prices increases technology adoption among maize farmers, (3) favorable geographical conditions, such as medium to high altitude, as a proxy for high rainfall, helps technology adoption, and (4) having a female head of household helps technology adoption. I use primary data from 2145 small maize farmers to test these hypotheses using probability models. Results confirm the first three hypotheses.

Executive Summary

Lower agricultural productivity in sub-Saharan Africa (SSA): The growth of cereal productivity has been stagnant or decreasing in SSA compared to other developing countries. The cereal yield in SSA is 34% lower than low income countries (LIC), 51% lower than South Asian countries, and 61% lower than the world as a whole.

Causes of lower productivity in SSA: The key reason for lower agricultural productivity is the lack of usage of yield-enhancing technologies such as improved seed, mineral fertilizer, pesticides, and recommended spacing for planting. The cost of production is too high for small farmers who depend on rain-fed irrigation to grow crops. During the drought season small farmers cannot even recover their production costs.

Causes of lower productivity in Tanzania: The country has been suffering from lower and stagnant productivity growth due to the lower use of improved technology. For instance, only 7.2% of all farmers use inorganic fertilizer. The quantity of usage of fertilizer is low (i.e. 7kg/ha) in Tanzania. In addition to the lower use of fertilizer, only 17.6% of the total planted area use improved seeds and only 9% of the total area planted use insecticides in Tanzania. Only 2.4% of agricultural households have access to credit. As a result, the average food crop productivity in Tanzania is 1.7 tons per hectare, while the yield of maize varies from 1.2 ton/ha to 1.4 ton/ha by season. Since farmers have little knowledge of agricultural markets, around 67% of agricultural households receive lower prices for their produce than the current market price. Also, government investment in agriculture is still less than 6% of national budget while this figure is over 20% in Ethiopia.

BRAC's project in Tanzania: BRAC is currently promoting enhanced technology adoption through a DFID funded project called LEAD. The major components of the project are extension training, input support limited to demonstration farmer, market linkage between farmer and agricultural inputs dealers, traders, and agricultural loans for farmers. The small farmers (where the cultivated area does not exceed two hectare) are supposed to accumulate maize right after harvest to benefit from economies of scale and get a fair price (that covers at least their production costs) for their produce. Bulk volume of maize might attract the potential buyer thereby reducing transaction costs. Thus, both farmers and traders will benefit through collective selling and price negotiation. Thus, market linkage is critical component of the project.

Main idea of this masters paper: As we know that technology adoption is the primary condition of increasing agricultural productivity, I want to explore the factors associated with the use of improved farm technology in Tanzania. I have four hypotheses to test: (a) increased supply of arable land is inversely associated with technology adoption among farmers, (b) receiving a fair price is positively associated with technology adoption among maize farmers, (c) favorable geographical conditions, such as medium to high altitude as a proxy of high rainfall helps technology adoption, and (d) having a female head of household helps technology adoption.

Lessons learned: I found that the amount of agricultural land owned is critical for technology adoption though BRAC currently does not take this factor into consideration in targeting farmers for the LEAD project. Farmers who have more land are less likely to adopt technology. The study also finds that the land use right on agricultural land matters in that it helps increase technology adoption among small maize farmers. In other words, lack of land entitlement might hinder them to invest on land for a longer time. I also found that receiving a fair price encourages farmers to adopt modern technology which eventually enhances farm productivity and income. Having a female head of household does not necessarily help adoption of modern technology though most of the BRAC beneficiaries are women. My findings show that access to credit is associated with increased technology adoption. I find that technology adoption is greater among those farmers who sell their product in the in the marketplace.

Dedicated to

Sabita Barua

and

Kanchan Barua

Acknowledgements

I am indebted to BRAC for their generous financial support throughout my two years master program at Brandeis University. I am also thankful to my colleagues at BRAC whose support helped me to pursue my study at Brandeis University.

I must express my heart-felt sense of gratitude and profound gratefulness to my beloved teacher and academic advisor, Professor Ricardo Godoy, at the Heller School for Social Policy and Management at Brandeis University for his ingenious guidance, invaluable suggestions, and thought-provoking comments from proposal development to the final paper. I benefited from his quick feedback in each and every stage of my paper. Without his untiring effort, this paper would not have come into its present shape. I am thankful to my field supervisor Dr. Md. A. Saleque at BRAC International for guiding me during my practicum. I am indebted to the Heller faculty who taught me during fall 2013 to spring 2014 at Brandeis University.

I want to express lifelong gratitude to my wife Gayatri Talukdar and my son Protul Barua for their continuous inspiration, blessings, and moral support from the very beginning to the end of my study at Brandeis. I am also thankful to my BOLLI family, Elaine and Joel Shwimer, who have been my family in the U.S., miles away from my home. They supported me, my wife and son at our critical time in the U.S. I also acknowledge their support for editing my masters paper. Last but not least, I am indebted to my cousin and childhood friend Prajoy Barua and his wife Mahua Barua who sheltered me, my wife and son upon our arrival in the U.S.

Acronyms and Abbreviations

AGITF	Agricultural Inputs Trust Fund
AGRA	Alliance for a Green Revolution in Africa
ASDP	Agricultural Sector Development Program
ASHA	Alliance for Sustainable Holistic Agriculture
ASTI	Agricultural Science and Technology Indicators
ATAI	Agricultural Technology Adoption Initiative
BRAC	It is a proper name of an organization formerly known as Bangladesh Rural Advancement Committee
BRRI	Bangladesh Rice Research Institute
CAADP	Comprehensive African Agricultural Development Program
DFID	Department for International Development
FAO	Food and Agricultural Organization
FGD	Focus Group Discussion
GDP	Gross Domestic Product
GoT	Government of Tanzania
GR	Green Revolution
IFPRI	International Food Policy Research Institute
LEAD	Livelihood Enhancement through Agricultural Development
LIC	Low-income countries
MAFAP	Monitoring African Food and Agricultural Policies
Masika	Kiswahili word; long rainy season in Tanzania
MASL	Meters above sea level
MDGs	Millennium Development Goals
NAIVS	National Inputs Voucher Scheme
NAP	National Agricultural Policy
NEPAD	New Partnership for Africa's Development
NFRA	National Food Reserve Agency
NGOs	Non-Governmental Organizations
NMRP	National Maize Research Program
OPV	Open Pollinated Variety
PSM	Propensity Score Matching
R&D	Research and Development
SSA	Sub-Saharan Africa
TASAF	Tanzania Social Action Fund
UNHS	Uganda National Household Survey
VAT	Value Added Tax
Vuri	The short rainy season in Tanzania. It is a Kiswahili word See above
WRS	Warehouse Receipt System

1. Introduction

1.1 Development problem in SSA

Food insecurity: According to the Food and Agriculture Organization (FAO) report, global hunger has been reduced over the twenty years. The prevalence of undernourishment in the world has decreased from 18.7% in 1992 to 11.3% in 2014. In other words, about 805 million people are estimated to be chronically undernourished in 2012–14, while this figure was 905 million in 2002-04 and 1,014 million in 1990-1992(FAO, IFAD, & WFP, 2014; FAOSTAT, 2015a). In the same period, the prevalence of undernourishment has fallen from 23.4 to 13.5 percent for the developing countries. Despite overall progress, sub-Saharan African (SSA) countries have the highest prevalence of undernourishment (23.8%). Around one in four people in the region remain undernourished. It has been projected that by 2022 there will be 839 in the world who will consume less than the nutritional target of 2,100 calories per day. Of these people, 411 million (49%) are from SSA(Rosen, Meade, Shapouri, D'Souza, & Rada, 2012). The estimated difference between projected food availability and the food needed to be consumed is the highest (61%) in SSA followed by Asia (37%) and Latin American and Caribbean (LAC) regions (7%). There will be 38% undernourished people in SSA assuming a projected 28% rise in population between 2012 and 2022.

Lower agricultural productivity: To this end, increasing domestic food production and more robust agricultural productivity are critical to the long-term food security in SSA by improving low yields and lagging labor productivity in agriculture. Global spending on agricultural research and development increased from US$26.1 billion in 2000 to US$31.7 billion in 2008 (as measured in constant 2011 US$). Despite these large investments, agricultural productivity remains relatively stagnant (Heyman, Fillipo, & Michael, 2012). In 2010, the cereal yield in SSA was 34% lower than in low-income countries (LIC), 51% lower than in South Asia and 61% lower than the world as a whole. These gaps were slightly more in 2000 (Figure 1). According to FAO statistics, the share of maize production is the highest for the USA (53.1%) followed by Asia (28.2%), Europe (11.4%), Africa (7.2%) and Oceania (0.1%). Maize is one of the staple foods in African countries and seven out of ten people in SSA are farmers where as this figure is two out of hundred in the U.S. However, African farmers get five times lower yield (i.e. 30 bushels/acre) of maize from their land than US farmers do (i.e. 160 bushels/acre). So, SSA has to depend on imports (US$50 billion/year) and food aid to feed its people (Gates, 2015).

Reasons for lower agricultural productivity: The reason for the low productivity is that farmers in sub-Saharan Africa are not using technologies proven to increase yields (Gollin, Morris, & Byerlee, 2005). For instance, in 2010, the fertilizer consumption in SSA was 93% lower than LIC,37% lower than South Asia and 90% lower than the world(Figure 2). In addition, lack of access to the agricultural input market for improved seed, fertilizer, and pesticides discourages small farmers to adopt those technologies. Furthermore, lack of access to output market where they could sell their produce and absence of collective bargaining power for selling their produce, poor infrastructure (i.e. road for transport, warehouse for store) discourage small farmers to increase their yield by adopting modern agricultural technology. As a result, small farm productivity in Africa remains low. Many experts argue that these new technologies generate high returns and that dramatic growth in agricultural yields in Asia and the stagnation of yields in Africa can largely be explained by increased use of these agricultural technologies in Asia and continued low use of them in Africa (Michael Morris, Valerie A. Kelly, Ron J. Kopicki, & Derek Byerlee, 2007).The good news is that by 2030 farmers in SSA could increase their yield by 50% through innovations in farming. Thus Africans can achieve food security by 2030 (Gates, 2015).

Importance of technology adoption: The Green Revolution (GR) that occurred in the 1960s has had a massive effect in the development of the agriculture sector through food production. For instance, the world food price would be 35–65% higher without the Green Revolution. The caloric availability would be 11–13% lower and the number of malnourished children would be six to eight percent higher if the Green Revolution had not occurred (Pingali, 2012). While Asian, Latin American and Caribbean countries take advantage of GR through technology adoption, African countries do not since technology adoption is very low. African farmers use 10kg of nutrients per hectare on an average while the global average is 130kg per hectare (Allafrica, 2014).As a result, production of cereals is extremely low in African countries compared to the rest of the world. For instance, African farmers typically harvest just one ton of maize per hectare while this figure is up to five tons per hectare in many parts of the world. Research revealed no evidence of increased food production reflecting the Asian Green Revolution in SSA. The results also showed that the cost of labor in Ghana still limits the development of labor-intensive technologies like the Asian Green Revolution (Nin-Pratt & McBride, 2014).

1.2 Development problem in Tanzania (case country)

Lower agricultural productivity in Tanzania: The food supply increased in Tanzania due to the increase of arable land and not necessarily because of an increase in the cereal yield during last couple of decades. The food supply increased from 2035 kcal/capita/day in 2001 to 2167 Kcal/capita/day in 2011 meaning that the food supply increased by 6.48% during last decade. On the other hand, arable land increased from 8.60 million hectares in 2002 to 14.50 million hectares in 2012, implying that agricultural land area increased by 68.6% during the same time. The cereal yield decreased from 3332.5 Kg/ha in 2000 to 1441.3 Kg/ha in 2010 which implies that cereal production decreased by 7.54% during the last decade (FAOSTAT, 2015b). Other statistics shows that cultivated area increased by 7.36% in Tanzania between 2000 and 2010 which was the highest followed by Uganda (3.23%) and Kenya (2.02%). This increased area led to production growth of overall crops by 3.53% in Tanzania during the same period, by 2.88% in Uganda and by 0.99% in Kenya. The consequence is that yield actually dropped by 3.57% in Tanzania, by 0.33% in Uganda and by 1.02% in Kenya. So, the supply of food in Tanzania appears to be closely associated with area increase and does not reflect the use of modern technology (improved seed and fertilizer) or other productivity improvements in agriculture (USDA, 2015). The annual growth of cereal yield in Tanzania is -0.82% during 2000 to 2013 while this figure is 2.76% for Uganda,0.33% for Kenya, and 5.31% for Ethiopia (FAOSTAT, 2015c). Figure 3 shows that the cereal yield in Tanzania (i.e. 1647kg/ha) is much lower compared to Asian countries (i.e. 3364 kg/ha on average). The yield of cereal in Tanzania is also lower compared to other neighboring countries, i.e. Kenya, Uganda and Ethiopia (Figure 4).

Causes of lower agricultural productivity: *First*, low usage of fertilizer. Only 7.2% of all farmers use inorganic fertilizer. In addition, the quantity of usage of fertilizer is incredibly low in Tanzania (7kg/ha) compared to Bangladesh (184kg/ha), India (179kg/ha), Pakistan (217kg/ha) and China (548kg/ha) as shown in Figure 5. Tanzania is also less likely to use fertilizer compared to neighboring countries such as Kenya and Ethiopia, and Zambia (Figure 6). There is less increase in yield (14%) in Tanzania between 2002 and 2010 as compared with the corresponding 51% increase for Ethiopia during the same time. Therefore, technology adoption is critical for increasing the agricultural productivity to reduce poverty and hunger in Tanzania.

Second, in addition to the lower usage of fertilizer, only 17.6% of the total area planted used improved seeds. Farmers usually use retained seed for maize cultivation. There are two hybrid varieties and six open pollinated varieties (OPVs) in Tanzania. The Kilima OPV variety is the most preferred maize variety in Tanzania since 75% of farmers like it.

Third, insecticides are used on only 9% of the total area planted is in Tanzania.

Fourth, 2.4% of agricultural households have access to credit.

Fifth, since farmers have little knowledge about the agricultural market, around 67% of agricultural households receive a lower price for their produce than the market price.

Sixth, loss of soil nutrition is another factor for decreasing agricultural productivity. Soil nutrient mining, as measured in the application and removal of the major nutrients nitrogen (N), phosphorus (P), and potassium (K), appears to be widespread in Africa. In general 85% of African farmland has nutrient mining rates of more than 30 kilograms per hectare per year. This nutrition loss is worst in east African countries. 40% of farmland in Africa losses soil nutrients at a rate greater than 60 kilograms per hectare per year. This figure is 61kg/ha/year for Tanzania (61), 66kg/ha/year for Uganda, 68kg/ha/year for Kenya, and 77kg/ha/year for Rwanda. This rate is much lower in Ethiopia i.e. 49 kg/ha/year (Michael Morris, Valerie A. Kelly, Ron J. Kopicki, & Derek Byerlee, 2007).

Importance of technology adopting in Tanzania: Tanzania's agriculture is representative of most of rural Africa. It is a key sector of the economy and is primarily dependent on subsistence farming in the country. Around 28% of the country’s GDP comes from agriculture (Statistics, 2013). In addition, around 90% and 78% of rural women and men are employed in the agriculture sector. Small farmers (cultivated area does not exceed two hectares dominate the sector. For instance, most of the 4.4 million farm families are engaged in subsistence farming and the main subsistence crops are maize, sorghum, millet, cassava, and rice. The growth of this sector is insufficient to feed the growing population (i.e. growth rate 3%) and pull them out of poverty. The total population increased from 33.18 million in 1999 to 50.76 million in 2011 implying a 52.98% increase of population during the reference period. So, Tanzania has to increase its food production to feed additional people and technology adoption is the best alternative to do so.

Best practices: Investment in agricultural research and development: According to the Comprehensive Africa Agriculture Development Programme (CAADP) and the Maputo Declaration in 2003, African heads of state and governments pledged to allocate at least 10 percent of their national budgets to the agricultural sector for its development (Benin & Yu, 2013). 13 countries, including Ethiopia, surpassed the CAADP 10% target since 2003. It is interesting to note here that agricultural investment in Ethiopia increased from less than 5% of the national budget in 2003 to over 20% in 2010. On the other hand, investment in agriculture was only 5-6% of national budget in Tanzania during the same time period. According Agricultural Science and Technology Indicators (ASTI, 2015), the annual level of agricultural research intensity measured by full time researchers per 100 thousand farmers is the highest for Kenya followed by Tanzania, Ethiopia and Uganda (Table 1). However, agricultural research intensity increased the most for Ethiopia (87%) between 2000 and 2011followed by Tanzania (15%), Kenya (3.6%) and Uganda (3.3%). So, Ethiopia has drastically increased the investment in agricultural research and as a consequence the cereal yield is the highest there as compared to other east African countries.

The total agricultural Research and Development (R&D) spending in Tanzania increased from US$14.2m in 2000 to US$28.6m in 2011(as measured in constant 2011 US$). In terms of total agricultural R&D spending in 2011, Kenya is the highest followed by Uganda, Tanzania and Ethiopia. The annual growth of total spending on research and development (R&D) is also the highest for Kenya followed by Ethiopia, Uganda and Tanzania (Table 2).

Empirical evidence shows that agricultural research contributes significantly to productivity growth in SSA which leads to an increased per capita income. Agronomic research results in higher yielding varieties that eventually increase the supply of foods in the market. As we know increased supply lowers real food prices. Alternatively, this increases real disposable income, particularly for all consumers owing to lower food prices, but particularly for the poor who spend a higher share of their income on food than do the rich. Thus agricultural research helps to reduce poverty. More precisely, agricultural research currently reduces the number of poor by 2.3 million or 0.8% annually(Alene & Coulibaly, 2009).So, there is huge potential to reduce poverty in SSA by investing in agricultural research. Alene & Coulibaly also find that SSA could reduce poverty by 9% per annum by doubling investments in agricultural research with more efficient use of agricultural extension, credit, and agricultural input supplies. The return on investment in agricultural research is 55% in SSA while this figure is 82% for Ethiopia which could be the main reason why Ethiopia has been increasing agricultural investment over the years.

Investment in agricultural research also contributes to the creation of new crop varieties for the farmer. Since the Green Revolution in the 1960s, the National Maize Research Program (NMRP) has released 15 improved maize varieties (hybrid and open pollinated) while the private seed companies have released 12 varieties in Tanzania between 1974 and 2010 (Lyimo, Mduruma, & Groote, 2014). On the other hand, the Bangladesh Rice Research Institute (BRRI) has released 57 high-yielding rice varieties during the same period(BRRI, 2015). Clearly there are more limited options of staple crop varieties in Tanzania as compared to Bangladesh. It implies that farmers have more limited crop varietal options to choose from in a geographically diverse country like Tanzania. It also implies the investment in agricultural research is much higher in Bangladesh as compared to Tanzania.

Host organization and second year responsibility: As part of partial fulfillment of the requirements for the Master of Arts degree in Sustainable International Development at the Heller School for Social Policy and Management, I did a practicum with BRAC (formerly Bangladesh Rural Advancement Committee) where I had been working before coming to Brandeis. I actually rejoined my previous organization as a Research Fellow meaning my practicum was paid. I wrote my masters paper during a six month practicum with BRAC which is located in Dhaka, Bangladesh. BRAC was started in a remote village of Bangladesh and has turned into the largest development organization in the world. BRAC is now working in 11 countries in Asia (Afghanistan, Sri Lanka, Pakistan, the Philippines, and Myanmar), Africa (Uganda, Tanzania, South Sudan, Liberia, Sierra Leone) and the Caribbean (Haiti). BRAC is also working in the USA, UK and the Netherlands, especially to raise funds for changing the lives of poor people in Asia and Africa. BRAC does its activities with a holistic development approach geared toward inclusion, using tools like microfinance, education, healthcare, legal services, community empowerment, social enterprises and BRAC University. I have been privileged to work with BRAC and be an agent of change for poor people through my research and innovation. Apart from writing my masters paper, I had to do multiple tasks during my practicum with BRAC. My academic interest is agricultural technology adoption in sub-Saharan Africa. So, I focused on technology adoption in agriculture that matched well with BRAC's Livelihood Enhancement through Agricultural Development (LEAD) project located in Tanzania. I discuss the project later in the substantive discussion section. My key responsibilities with BRAC included quality checking of real-time data collection, data analysis, baseline report writing. I also collected qualitative data from two districts in Tanzania. I had to coordinate with the Research and Evaluation Unit (REU) in Uganda, Tanzania, South Sudan, Sierra Leone and Liberia. I also took part in skill development training on data analysis for my young colleagues It should be mentioned here that I organized a research agenda conference in Kampala, Uganda with approximately 30 participants attending from five African counties including Uganda. I participated in a randomized control trial (RCT) study to promote agricultural technology among small farmers in Tanzania. In my masters paper I focus on the baseline study and estimate the influencing factors of technology adoption.

2. Background and Country Context

In this section I discuss the contribution of the agricultural sector to the economy of Tanzania, the government policies and strategies for small farmers to increase food production in Tanzania, BRAC's intervention in Tanzania along with project components and project theory of change.

Contribution of agriculture to the economy of Tanzania: Tanzania's agriculture is representative of most of rural SSA. Agriculture is a key sector of the economy which is primarily dependent on subsistence farming. Small farmers, who have one to two hectares of land, dominate the sector. Around 28% of country's GDP comes from agriculture (W. Bank, 2015; NBS, 2013). In addition, around 90% of females living in the rural areas and 78% of males in these areas are employed in the agriculture sector. Most of the 4.4 million farm families are engaged in subsistence farming and the main subsistence crops are maize, sorghum, millet, cassava, and rice. The growth of this sector is insufficient to feed the growing population (i.e. 3% growth rate) and pull them out of poverty.

Technology use by seasons in Tanzania: There are two planting seasons in Tanzania: (a) Short Rainy season or *vuri* (November to December) and (b) Long Rainy Season or *masika* (March to May). 80% of the total planted area is allocated to the long rainy season and 20% of the total planted area is allocated to the Short Rainy Season. 60.4% of the total crop growing households grow maize in the Long Rainy Season while 28% grow it in the Short Rainy Season. The cultivated maize area is 94% of the total cereal cultivated area (115,167 ha) in the Long Rainy Season. 7.2 % of total planted area use chemical fertilizer in Long Rainy Season while this figure is 4 % in Short Rainy Season. 16.20 % of total planted area use improved seed in *masika* while this figure is 16.95 % in *vuri*. It seems that the Long Rainy Season is favorable to small farmers. The use of improved seed is more or less same in the two seasons. However, the yield of maize is higher in *masika* (1.4 ton/ha) compared to *vuri* (1.2 ton/ha). So, seasonal variation is critical to implement any agricultural intervention for technology adoption in Tanzania.

Government policies and strategies for agricultural development in Tanzania: Government of Tanzania (GoT) undertook several policy initiatives for agriculture development since 2000. These strategies and policies target three broad categories of stakeholders (i.e. producers, consumers, and trade and market participants) to address food security and nutrition in Tanzania.

The producer oriented policies were agricultural credits at a reduced interest rate (i.e. 8%) through the Agricultural Inputs Trust Fund (AGITF), Savings and Credit Cooperatives (SACCOs), the Tanzania Investment Bank and the Tanzania Agricultural Development Bank. A total of US$529.7m in loans was disbursed during 2009 to 2012 to finance the agricultural sector (FADPA, 2014). Under the Agricultural Sector Development Program (ASDP), Subsidies for fertilizer and seed were provided through the National Inputs Voucher Scheme (NAIVS) during 2008 to 2014.

The consumer oriented policy decisions taken by the ToG during 2007 to 2013 included the restructuring of reserves and the distribution of grain at affordable prices. For instance, the National Food Reserve Agency (NFRA) purchased food crops from farmers and warehouses in surplus area, especially in the Southern Highlands at 10% higher than market price.

The trade and market oriented policy decisions included reducing import tariffs and import quotas progressively, implementing cereal export bans intermittently between 2007 and 2014 and expanding the warehouse receipt system (WRS) for helping small farmers.

BRAC's initiative to address the lower agricultural productivity in Tanzania: To address the productivity problem among the maize farmers, different donors have been implementing development projects through local not-for-profit organizations (NGOs). The Department for International Development (DFID) is one of the larger donors in Tanzania and is implementing its LEAD project through BRAC. The project currently operates in 40 branches nationwide spread across 15 regions in Tanzania. LEAD's approach integrates both demand and supply side interventions that it expects to help improve agricultural productivity and incomes among the small farmers. The supply side constraints are lack of market access for agricultural loans and quality inputs such as improved seed and fertilizer. These constraints lower the agricultural productivity among the poor farmers in Tanzania. The LEAD project tries to address these constraints through integrated interventions. The project is designed to build a network of trained extension workers, lead farmers and market participants who are responsible for promoting modern agronomic techniques and yield enhancing inputs. The individual farmers are linked with agricultural dealers for procuring inputs while the lead farmers are equipped with skills required to impart knowledge and skills to a group of about 10-12 general farmers. This farmers group participates in the regular training sessions and refreshers sessions which serves as a forum through which they can talk about their experiences. In addition to this, farmers are also able to access agricultural credit through these groups in the form of an agricultural loan, thus addressing the credit constraints that they face. Collective marketing and improved access to markets is another goal of the groups as farmers are encouraged to take advantage of the economies of scale by bulk purchase of inputs and selling their products.

The second set of constraints to be addressed are the demand side constraints relating to challenges that prohibit agriculturally- based companies like agricultural input dealers/suppliers, produce buyers and other stakeholders from meaningfully participating in the market place. The LEAD project views these as important factors in ensuring that the benefits of agriculture are tangible. Just like small farmers, these players also experience numerous bottlenecks that render them unable to ensure efficient markets. Credit is one of the major constraints that companies face in that they cannot scale up their production to serve new markets. LEAD hopes to empower these players by tailoring enhanced financial situations for them. By empowering these input supplier companies, the project expects there to be a trickledown effect to the lower levels.

Project theory of change: The key desired outcome of the LEAD project is to increase productivity of maize among small farmers through the adoption of enhanced technology. Increased yield would lead to increased income and would reduce poverty and hunger in the long run. The theory of change for this project is presented in Figure 7. To achieve this objective, the project first selects the small farmers from respective communities through a census. The project staff selects three types of farmers: demonstration farmers, lead farmers, and general farmers in each project operation areas (Figure 8). There is one lead farmer for every 10-12 general farmers. This lead farmer is supposed to organize the general farmers into a producer group. It should be mentioned here that BRAC uses a community level network for organizing farmers. After selection of the beneficiaries BRAC's field staff provides them with two to five days of training on modern cultivation practices. The project also provides some input support to lead farmers and demonstration farmers (Table 3).

The present project is slightly different from BRAC's mainstream agricultural programs. The current project focuses on facilitation rather than implementation which is a key distinction. For instance, BRAC is not supposed to sell improved seed to farmers, but rather connect them to marketers such as agro dealers or input suppliers. Similarly, BRAC is not supposed to sell their outputs, but rather introduce them to market participants and traders. These linkages or networking connections are established during the training sessions when the small farmers are introduced to agricultural inputs dealers, maize processors

3. Literature Review

This section focuses on empirical evidence concerning technology adoption in the agricultural sector, especially in East African countries, that were published in last five to ten years. I have explored the factors of adoption of technology in the literature along with key barriers to its technology. I have also reviewed the impact of adoption of agricultural technology in developing countries. The agricultural technologies include chemical fertilizer, improved seed, and modern cultivation methods like spacing, weeding, and timely planting.

Factors affecting technology adoption: Kasirye's study (Kasirye, 2013) in Uganda based on the 2005/6 - 2009/10 Uganda National Household Survey (UNHS) panel data of 1600 farm household finds that farmers with smaller land holdings are less likely to use improved seed and fertilizer in Uganda. The author used the standard definition of adoption which is the proportion of land cultivated with improved seed or chemical fertilizer. This is different from the definition used in this paper. Kasirye's study also shows that peer effect plays a big role in influencing farmers to use improved seed or fertilizer. This is similar to the findings in Ghana (Conley & Udry, 2010). Khonje, Manda, Alene, & Kassie examine the determinants of technology adoption among 800 farm households in Zambia. They find that the education of the head of household, access to extension service measured in distance to the extension office, market information and group membership are the key determinants for the use of improved maize seed in Zambia (Khonje, Manda, Alene, & Kassie, 2014). Using a double hurdle (DH) econometric model, IFPRI researchers found that access to improved seed and fertilizer through extension services helped to increase technology adoption among small farmers in Ethiopia (Yu, Nin-Pratt, Funes, & Gemessa, 2011). They also found that accessibility is greater among male heads of households than with female heads of households. Early adopters of improved seed and fertilizer influence the neighbor farmers to use those yield enhancing inputs. Price volatility of agricultural produce is very common in Tanzania and this typically has a bad affect on small farmers. It is interesting to note that farmers are net buyers of cereals and they have to buy maize when the price is high and sell when the price is low (Campenhouta, Lecoutereb, & D'Exellec, 2015).

The researchers found that institutional engagement helps increase the adoption of agricultural technologies among small farmers based on a study of 1120 farm households in Ethiopia (Abebaw & Haile, 2013). More precisely, membership of a farmer in a cooperative increases the adoption of fertilizer by 9-10 percent as compared to those who do not have membership. Exchange of reliable information through experience sharing in a cooperative forum could be the reason behind this. However, it is not that easy for small farmers to adopt costly technologies whereas subsidies could encourage small farmers to do so. Subsidy is a government policy-level initiative to increase the usage of yield enhancing inputs among small farmers. Subsidies for fertilizer are very common in some Asian countries like Bangladesh, India and Sri Lanka (i.e. 10-20% of government's budget on such subsidies). This is not the case in east African countries like Kenya, Tanzania, and Uganda (i.e. only 1-2% of government budget is spent on such subsidies). In addition, the high price of fertilizer due to transportation cost discourages the small farmers to use fertilizer in Tanzania. The UNDP estimates that it costs more to transport fertilizer from an African port to a farm 100 kilometers inland than it does to ship the same fertilizer from North America to the port (Acquaye & Frimpong-Manso, 2012). The researchers found that a little subsidy (e.g. free delivery of fertilizer) is quite effective for sustainable use of fertilizer in Kenya (Duflo, Kremer, & Robinson, 2011). They found that farmers get used to using fertilizer in the long run with a small initial subsidy rather than a larger subsidy which is not sustainable.

A systematic review report of five top papers out of the over 20 thousand papers on technology adoption in low and lower middle income countries shows that the adoption of agricultural technologies like improved seed and managing spacing, planting time increases yield by 18-20% (Loevinsohn, Sumberg, Diagne, & Whitfield, 2013). However, they identify that the agricultural technology adoption depends on several conditions and circumstances. These are institutional (i.e. farmer-led research, group governance, limited seed and insecticide regulations), social (i.e. land scarcity, local information networks, village ethnic/cast composition), personal (i.e. market orientation, access to information, age of household head), economic (i.e. relative crop prices, unstable prices), and agro-ecological (i.e. slope of land, access to irrigation, good water control, soil quality, farm proximity to homestead, altitude and Temperature of topography). I use some variables in my model from social (amount of agricultural land), personal (age, education, market orientation) and agro-ecological (altitude) categories as explanatory variables.

Barriers to the adoption of agriculture technology: Farmers might not adopt proven technology if they do not get profit from doing so. So it is worthwhile to understand the underlying causes or constraints which work against the adoption of technology in agriculture. The existing agricultural markets do not function well which is a major reason for the small farmers not to adopt agricultural technologies. According to an Agricultural Technology Adoption Initiative (ATAI) white paper, there are seven types of market inefficiencies preventing or limiting agricultural technology adoption (Jack, 2013). Only the three that are closely related to this paper will be discussed:

- *Input and output market* – problems with infrastructure and with supply chains, especially in geographically diverse country like Tanzania, make it more costly for farmers to access agricultural input markets and to enjoy the benefits of modern technology. They also don't have access to output markets for selling their produce due to unfavorable road conditions. Good road conditions do increase the adoption of high yielding rice varieties in developing countries like Bangladesh (R. Ali, 2011). Researchers have also found that crop prices are closely related to access to good road conditions in Sierra Leone (Casaburi, Glennerster, & Suri, 2012).
- *Credit market*–small farmers have to put up collateral in order to obtain loans. This deters the usage of modern technology while contracts for standing crops, as well as farmers' reputation, are useful in obtaining loans (Janvry, A., & Sadoulet, 2010).
- I*nformational*– lack of proper information or misleading information may deter the adoption of modern agricultural technology by small farmers, especially when they do not know about its benefits and/or do not know how to use it effectively. Researchers also have found that asymmetric information misleads the maize farmers in Kenya who traded maize rather keeping it for home consumption (Hoffmann, Mutiga, Harvey, Milgroom, & Nelson, 2012).

Impact of the adoption of technology on income and poverty: The impact of technology adoption is to increase household income and improve livelihood through using modern yield enhancing techniques. Researchers used the instrumental variable (IV) method to see the impact of using hybrid maize on income in Kenya (Mathenge, Smale, & Olwande, 2014). They used 1997-2010 panel data for 1578 maize farmers. Their findings suggest that the adoption of hybrid seed increases annual income by 7% among maize-growing households. They also show that maize farmers not only increased income, but also increased assets by over 9 % in the longer-term. It should also be mentioned that using 10kg of hybrid maize seed reduces the poverty gap by 2.9% as compared to those not using the hybrid seed. So, adoption of technology has a multidimensional impact on such things as household income, asset accumulation and the reduction of inequality among farmers.

Researchers assessed the impact of using maize seed on income using the propensity score matching (PSM) method (Khonje, Manda, Alene, & Kassie, 2014). They found the results for the adoption of technology to be impressive. For instance, the adoption of improved maize seed has led to significant gains in crop income - namely US$425/ha more than a corresponding control group. Per capita consumption expenditure also increased by US$55.5 per year among those who used improved maize seed. They also find that poverty has been reduced by 21percentage points when compared to a matched control group. .This evidence implies that technology adoption has a multidimensional impact on the livelihood of the small farmers. The adoption of improved varieties of wheat on household food security was found to have a positive impact in Ethiopia. More precisely, the adoption of improved wheat varieties increased the probability of food security for adopters by about 4.5 percentage points and by 2.7 percentage points for non-adopters (Shiferaw, Kassie, Jaleta, & Yirga, 2014).

Negative impact of the adoption of technology: As we have learned, there are many advantages resulting from the adoption of technology in the agricultural sector in developing countries. However, the technology adoption also has some limitations or negative impacts, especially on human health and the environment. According to the Alliance for Sustainable Holistic Agriculture (ASHA), these consequences are due to the lack of a intelligent policy on the part of the government. For instance, 67 types of pesticides are banned in other countries while India is still using those harmful pesticides. The critical point here is that only 1% of the pesticides used actually reaches its intended target and the other 99% remains in the environment and causes the negative effects. This can result in uterine and breast cancer in women and diseases of the esophagus, lymphoma and leukemi in men. Pesticides also affect pregnant women and infants, i.e. stunted growth and mental disorders (The-Health-Site, 2015a). In addition, women's workload has been increased which cuts their time for child care and feeding. The environmental effects caused by expanding agricultural land include water scarcity, climate change, and biodiversity loss. An example is from Panjab, India where farmers suffer from a disease called zoonotic. Farmers in Punjab have been using pesticides for a long time to increase the rice yield which is the highest rice exporter state of India. 2.5% of the agricultural land of the country uses 18% of pesticides used in India, a very high number by any standard. It implies that the intensity of chemical use is too high. As a result, Panjab has 90 cancer patients per thousand people while the national average is only 80 per thousand people. More precisely, in the cancer belt region of Malwa in Panjab, this figure is 135 per thousand people. Evidence also shows that 18 people die of cancer every day on average in Panjab which is the consequence of using toxic chemicals for agriculture (The-Health-Site, 2015b).

Previous studies have found that land size, year of education, access to inputs, head of household, credit, and extension services are related to technology adoption. Clearly fair price for agricultural produce, favorable geographical condition, and female head of household are almost important yet none of the studies reviewed examines these additional factors. My empirical analysis tries to overcome this gap with a relatively larger sample of small maize farmers in Tanzania.

4. Methods

Technological adoption is measured by the degree to which a new technology is used by farmers or adopters in long-run when they have complete information about the technology and its potential. Adoption at the small farm level indicates a farmers' decision to use a new technology in the production process. In this paper I use a simple definition of the adoption of technology as the number of small maize farmers who used fertilizer and/or pesticides in the last cropping season for cultivating maize in Tanzania. It is hard to collect an accurate proportion of farm land where subsistence farmers used modern inputs. I selected maize farmers for two reasons: first, maize is a staple food of Tanzania and around 80% of agricultural land is allocated for maize by the small farmers in a given season. Thus, maize is the dominant crop of Tanzania. Maize and maize products are the first of the top ten commodities available for consumption in Tanzania providing 511 Kcal/capita/day(FAO, 2015). Second, BRAC works with small maize farmers in Tanzania and I have access to their latest baseline dataset that includes relevant information on maize farmers.

Hypotheses: The question is: "What are incentives for small maize farmers to use agricultural technology (i.e. improved seed and fertilizer)?" Alternatively, what are the reasons for the small farmers to not use the advanced technology? Evidence shows that small farmers currently increase their production by increasing land size and not by increasing yield or productivity. On the other hand, a good price for maize could encourage farmers to adopt technology. In addition, small farmers totally depend on rain for cultivating crops in Tanzania. Elevation is going to be used as a proxy for rainfall to see the association between technology adoption and altitude. Evidence shows that the altitude and the average rainfall have positive correlation (i.e. 89%). High rainfall could encourage farmers to use improved seed or fertilizer to enhance farm productivity. The following four hypotheses will be studied in this paper.

Hypothesis one: Access to a greater amount of land might discourage farmers from invest in agriculture. They could increase their total production by simply increasing their acreage of land under cultivation rather increasing the productivity of the land being used. It is hypothesized that the adoption of fertilizer and amount of agricultural land are inversely related.

Hypotheses two: Empirical evidence shows that a low price for their product (i.e., the lack of an efficient market) is the main barrier to the adoption of technology by small farmers. Alternatively, assurance of obtaining a fair price could increase the adoption of technology to increase their production. Farmers could earn a better margin by receiving a fair price which more than covers the production cost of maize. It is hypothesized that obtaining a fair price for their output helps small farmers to adopt farm technology.

Hypothesis three: Tanzania is a vast and geographically diverse country. The weather varies across the regions while small farmers exclusively depend on rain-fed irrigation for cultivating major crops like maize. The empirical evidence shows that rainfall is positively correlated with altitude (Subarna, Purwanto, Murtilaksono, & Wiweka, 2014). However, since I do not have rainfall statistics from the primary survey, but do have access to the elevation of each farm location of respondent farmers, the altitude will be used as a substitute for rainfall. It is hypothesized that the adoption of technology increases among farmers who reside in a higher altitude area since they are expected to receive more rainfall.

Hypothesis four: The contribution of women in agriculture is recognized in developing countries. In subsistence farming, the women supply critical labor inputs, especially during planting and harvesting. The current LEAD project targets mostly women farmers as over 60% of small farmers are women. It is assumed that the women are more likely to adopt technology and apply the training lessons that might increase agricultural productivity. In addition, the women farmers who are the heads of household might have decision-making power to invest in agriculture though purchasing modern inputs such as improved seed and fertilizer. Therefore, it is hypothesized that female heads of households increase technology adoption. It will also confirm BRAC whether they are in right track in targeting beneficiaries by gender.

Model: The following probability model (equation 1) will be used to determine the factors of influence over the likelihood of using agricultural technology. The **dependent variable** is *adoption* which is a binary variable being1=if the small farmer uses fertilizer, and 0=otherwise. The **primary explanatory** variables are amount of cultivable land in acre (*Arland*), whether the farmers are getting a fair price for their maize (*FrPrice*; 1=yes, 0=otherwise), the elevation of the location of the farm in meters above the sea level (*MASL*), and female head of household (*FeHead*; 1= yes, 0=otherwise). The control variables are farmer's experience in maize farming in years (*Exp*), market access (i.e. distance of nearest market from village in kilometer for agricultural inputs) (*MktAcess*), years of education of farmers (*Edu*), age of the farmers in years (*Age*) and e which is a normally distributed random variable with mean zero and variance one.

$$\Pr(\boldsymbol{Adoption}_i = 1|X) = \alpha + \beta_1 \boldsymbol{Arland}_i + \beta_2 \boldsymbol{FrPrice}_i + \beta_3 \boldsymbol{MASL}_i + \beta_4 \boldsymbol{FeHead}_i + \beta_5 Exp_i + \beta_6 MktAccess_i + \beta_7 Edu_i + \beta_8 Age_i + e_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

***Expected sign, size and significant level of coefficient**:* If the first hypothesis (adoption vs. land size) is correct, then the $\beta_1$coefficient in the above equation should be negative, large and meaningful. Similarly, if the hypothesis (adoption vs. fair price) is correct, then the β_2 coefficient should be positive, large and meaningful. If the third hypothesis (adoption vs. altitude) is correct, then the β_3 coefficient should be positive, large and meaningful. Finally, if the fourth hypothesis (adoption vs. female head of household) is correct, then the β_4 coefficient should be positive, large and meaningful.

Data: A sub-sample of 2145 maize farmers is used while the full sample consists of 4200 farmers. The data was collected during October-November 2014 for evaluating the impact of LEAD project in Tanzania. The study area represents five agro-ecological zones[1]. In order to take advantage of recent baseline data to be used as an observational study to explore why some farmers use improved technology (i.e. fertilizer, pesticides), I also used qualitative data that I

[1] Northern Zone (Arusha, Kilimanjaro, Manyara), Southern highlands (Mbeya), Central Zone (Dodoma), Lake Zone (Mwanza), Eastern Zone (Dar es Salam, Morogoro)

collected in mid-February 2015 from Dodoma and Manyaoni. In addition, I used a focus group discussion (FGD) to collect qualitative data. I interviewed a total of 35 persons consists of general farmer, lead farmer, demo farmer, agricultural trader, and BRAC's field staff. This supplementary data is useful to understand the field situation and interpret the results.

Limitations of the study: The impact of the adoption of technology is beyond the scope of this paper. The adoption of technology may be influenced by many other unobserved endogenous variables. However, this study does not check endogeneity. A simple definition of adoption, which is a two-valued (or binomial) variable is used. However, most of the previous studies I reviewed defined adoption as the proportion of land covered by improved seed and/or fertilizer.

5. Results and Discussion

Descriptive information on the variables used in the analysis: Both probit and logit models were used for testing the hypotheses. The results are reported in a range where variability in results of those probability models were observed. In this section the descriptive information of the variables used in the econometric models is discussed. The information in Table 4 suggests that 42% of 2145 sample farmers use fertilizer and/or pesticides. It also implies that 42% of the maize farmers adopt modern technology. The farm households are mostly headed by males in the study area which is consistent with national statistics. Only 21% of the farm households are headed by females. The average age of the farmers is around 42 years with a standard deviation 13 years implying the presence of farmers with various ages in the sample. Farmers have experience with maize cultivation for an average of 13 years with a high standard deviation of 11 years. The average years of education of the respondent farmers is 7.39 with a standard deviation of 2.77 years. This suggests that the farmers have only a primary level education on average.

The land is an important and essential asset for farmers and the amount of land is one of the BRAC's farmer selection criteria. Farmers own an average of 1.71 acres of agricultural land with a standard deviation of 1.76 acres. The higher standard deviation indicates the presence of heterogeneous farmers in the sample regarding land ownership. Therefore, the farmers were categorized by land ownership: small farmers who own less than one acre of land (27%), medium farmers who own one to less than three acre of land (56%) and large farmers who own three and more acres of land (17%). Medium farmers dominate the sample due to the selection criterion. The implication of this categorization is to see the variation of technology adoption by farmers in the categories being incorporated in the probability model. The small farmers might be interested in increasing production by using technology since they did not have the option of increasing the allocation of cultivatable land. Alternatively, large farmers might increase agricultural production by simply increasing their arable land. It has been hypothesized that technology adoption is negative correlated with the amount of agricultural land being cultivated. It is interesting to note here that most of farmers who own land have an exclusive land use right. Only 20% of farmers do not have this land use right.

As we know from the literature review, getting a fair price encourages small farmers to use yield enhancing technology. However, only 19% of maize farmers in the sample received a fair price for selling maize in the market. This variable has been included as one of the important determinants of technology adoption. As mentioned earlier, Tanzania is a huge and geographically diverse country. Therefore, the geographical location of the farmers could be a crucial factor of adopting technology. For instance, the altitude varies from less than zero to more than 1500 meter above the sea level (MASL) and there is close positive relationship between rainfall and altitude. The empirical evidence shows a positive correlation of 0.89 between rainfall and altitude. Altitude is used as a proxy for rainfall in the probability model. Rainfall is one of the crucial natural factors for small farmers in Tanzania since farmers totally depend on rain-fed irrigation. The average altitude of the farms is 971 MASL with a high standard deviation of 546meters. Farmers were categorized into three groups based on the altitude of their location: high altitude, medium altitude and low altitude. 13% of the sample maize farmers are located in high altitude which is more than 1500 MASL. The majority of farmers (56%) are in the medium altitude area which is between 900 and 1500 MASL. The remaining just over 30% of farmers are from the low altitude area which is below 900 MASL. Since it is more likely that farmers from the high altitude group get more rainfall as compared to farmers located in the medium and low altitude areas, the positive correlation between altitude and the adoption of technology is an hypothesis to be tested. Market orientation, access to credit and proximity of input market are also important indicators of technology adoption and these variables have been incorporated into the model. It is encouraging that 46% of the sample farmers sell maize in the market while 44% of farmers are quite confident of obtaining agricultural loans for maize cultivation. The proximity to urban center where farmers could purchase inputs is around five kilometers with a standard deviation of approximately seven kilometers.

Results of the probability model: To test the hypotheses both a probit and a logit model were used; since the results of the analysis did not vary by the type of model used, only the results of the probit model are reported in this paper. In Tables 5-8 the results of the probit model used to test the proposed hypotheses are presented. Table 5 contains the results of the sample with a robust standard error clustered by village. Table 6 contains the results of the sample with the village fixed effect (FE). Table 7 is simply an extension of Table 5 with the inclusion of quadratic terms of significant variables. Table 8 contains the results of the sample with all explanatory variables, control variables, and interaction terms. The Pseudo R-square improves from 0.15 in Table 5 to 0.29 in Table 8 meaning that the explanatory power of the probit model improves sharply as quadratic and interaction terms are included. To make the reading of the results easier, the coefficient, robust standard error (clustering by village), and the probability of adoption at mean value of the explanatory variables are reported. For instance, in Table 5, the probability of adoption fertilizer in a model increases by 33% if the farmer has land use right. In discussing results the focus is on variables that are significant at the 5% level and below. The results are presented below in order of the hypotheses.

Hypothesis one: The hypothesis regarding the relationship of land size and technology adoption is confirmed; that is, access to increased supply of land deters technology adoption. Probit results show that an extra one acre of land reduces the probability of technology adoption by 6% (Table 5). A more reliable and larger estimate (13%) is obtained as more variables are included in the model (Table 8). However, a positive relationship between land size and adoption is found when the quadratic term of land size is included in the probit model (Table 7). This implies that commercial farmers with large amounts of land adopt technology as they may want to take the benefit of economies of scale. Table 8 also shows that the probability of adoption increases by 7% if farmers have three or more acres of agricultural land.

Hypothesis two: The probit results confirm that farmers are more likely to use technology when they get a fair price for maize from last season. For instance, the probability of adopting fertilizer increases by 12.7% if farmers get a fair price (Table 5&6). The probability of adoption increases by 24.7% when the interaction terms are included in the model (Table 8). It is matter of fact that farmers do not receive a good price for maize in Tanzania. In talks with farmers and traders about the price of maize cereal during field visits in Tanzania, it became clear that farmers do not get a fair price for their produce. For instance, maize farmers in Dodoma and Manyoni get only TZS288/kg (US$0.16) during harvesting season while traders and millers get around 19% and 178% higher price than the farmers respectively.

Hypothesis three: A positive relationship between adoption and altitude as a proxy of rain fall was found (Table 7) meaning that farmers are more likely to adopt technology in higher elevations where the chance of rain fall is higher. For instance, the probability of adopting fertilizer increases by 30% if farmers are from above 900 MASL (Table 8). This implies that farmers in high altitude area may be more able to utilize rain-fed irrigation which encourages them to use modern inputs to help increase productivity.

Hypothesis four: Having a female head of household deters technology adoption in the study area meaning that the hypothesis presented earlier is not supported by the results. The probability of adoption reduces by 16% if the farmer is a female head of household (Table 5). The probability of adoption drops at an even faster rate (18%) when more variables are included in the model (Table 8). Alternatively having a male head of household helps technology adoption which is consistent with existing evidence. The women might not have the major decision-making powers at a household level.

Key lessons learned: (1) this paper finds that amount of agricultural land under cultivation is positively associated with technological adoption. For instance, large farmers may have the option to increase maize production by increasing allocation of land area and by using technology to take the benefit of economies of scale. On the other hand, small farmers who have less than one acre of land (BRAC's target group) have no option to increase production through increasing land, but can only do so by using modern technology. However, improved seed, fertilizer, and pesticides are expensive for them to adopt. So, technology is critical for small farmers in Tanzania. The study also finds that the use right to agricultural land matters in helping technological adoption among small maize farmers. Farmers may feel more secure in investing in agriculture when they have an exclusive land title. For example, farmers can grow cover crops which add nitrogen to the soil thereby enhancing soil productivity in the long run. In addition, perennial crops need at least two to five years to harvest produce which requires secured land.

(2) Receiving a fair price encourages farmers to adopt modern technology that eventually enhances farm productivity. However, it is very challenging for farmers to get a fair price for maize since there is great price volatility in Tanzania. For instance, the price of maize varies from TZS185/kg (US$0.11) to TZS675/kg (US$0.39) depending on supply of maize in the market in Dodoma and Manyoni. In the drought season, farmers could not recover the production cost of maize due to poor harvest. From focus group discussions it was found that farmers spend TZS100000-120000 per acre (US$57-69) in Dodoma and Manyoni which includes land preparation and seed cost. In the ideal condition, farmers could earn TZS200000/acre (US$114) but often they earn much less than that amount for cultivating one acre of land.

(3) As Tanzania is a geographically diverse country, BRAC could proportionately target its beneficiary population by considering weather conditions such as rainfall statistics which is essential for agriculture. However, accurate rainfall data might not readily be available to the program. In addition, data collection might take time that could delay the implementation of the project. In this situation, BRAC could use altitude as a proxy of rainfall since the altitude and rainfall are positively correlated . Altitude is also positively related with technological adoption as found inthe analysis reported above. In addition, once collected, elevation data remains unchanged for long periods unlike rainfall data. Farmers in the high and medium land groups are more likely to adopt technology as compared with those farmers who are in the low land group.

(4) Female head of household does not necessarily help adoption of modern technology though most of the BRAC beneficiaries are women (over 60% of total beneficiary farmers). Women might not have the decision-making power for investing in agriculture in spite of their being the head of household. In addition, they might not know about the new technology due to lack of wider network and physical mobility.

6. Conclusion and Recommendations

There is substantial undernourishment (i.e., people who get fewer than 2100 calories per day) in the world – 11.3% in the whole world and 13.5% in developing countries. This implies that 805 million people remain chronically hungry in the world. This problem seems more severe in sub-Saharan Africa (SSA) where the 23.8% of the population are undernourished. This is more than twice as much as the world as a whole and a little less than twice as much as in the developing world. In other words, around one in four people in SSA remain undernourished. It has been projected that around half of the hungry people in the world will be in the SSA by 2022. The food deficit will be the highest in SSA (61%) followed by Asia (37%) and Latin American and Caribbean regions (7%).The critical reason for this problem is the lower agricultural productivity in SSA. For instance cereal yield is 51% lower in SSA than that in south Asia. The lower use of yield enhancing technology such as improved seed, mineral fertilizer, pesticides is the main reason for the lower productivity in SSA as compared with the Asian countries. For instance, fertilizer consumption in SSA is around 90% lower as compared with low income countries and as well as the global average.

Tanzania which is one of the east African countries that has been suffering from agricultural productivity problem is the country studied in this paper. For instance, during 2001-2011 food supply increased by around 7%, but this was largely due to an increase of about 69% in the cultivated area in Tanzania. As a result, the cereal yield decreased by 7.54% during 2000-2010 in Tanzania and the growth of cereal during2000-2013 was negative. This is because only 7.2% of the farmers in Tanzania use chemical fertilizer and the quantity used (7kg/ha) is extremely low when compared to South Asian countries i.e. 184kg/ha in Bangladesh. In addition to fertilizer, usage of improved seed (around 18%), pesticides (9%), and access to credit (2.4%) and lack of market information for updated prices are also barriers to increased cereal yield in Tanzania.

To address this problem BRAC has implemented an extension project in Tanzania which is called Livelihood Enhancement through Agricultural Development (LEAD). However, there is no active participation from BRAC during harvest (i.e. weighing yield) or post harvest (i.e. connecting farmers with traders) which is a critical time for farmers. The critical period is post-harvest when farmers sell their produce at cheaper prices. On the other hand farmers buy same amount of food during January-March at higher prices. This implies that farmers are net losers and they have no incentives to use yield enhancing inputs like mineral fertilizer, improved seed and pesticides. So, BRAC could pay special attention during the critical period of farmers.

I find positive and significant relationship between fair price and technology adoption. So, BRAC could actively engage in organizing farmers group for selling their maize at a fair price by providing them with current price information. BRAC could also actively participate in storing maize using government's storage facility where available. Alternatively, farmers might be offered cheaper technology for storing their maize. For instance farmers can store seed and/grain in a container that is painted on the inside to contain moisture. BRAC could also promote cheaper technology to small farmers that would add greater value to their product. Thus, farmers could enjoy a higher price thus adding value by storing and controlling seasonal supply.

Currently, BRAC targets female farmers for using agricultural technology which contradicts the results from the probability models described above. The probability models show that being the female head of household does not help to use technology. Female heads of household is not very common in Tanzania and it is often due to the absence of any adult male members of the households. So, female headed households are more likely to be poor and cannot afford costly and labor intensive technology such as land preparation, weeding and cleaning.

The other important determinants of technology adoption in Tanzania have been found to be access to finance and market orientation of small farmers (selling maize in the market place). It is known that technological adoption is a sustainable way of enhancing agricultural productivity which will impact on the well-being of farmers. It is also important to consider the factors which lead to greater adoption of technology when setting the target population for projects designed to improve technological adoption.

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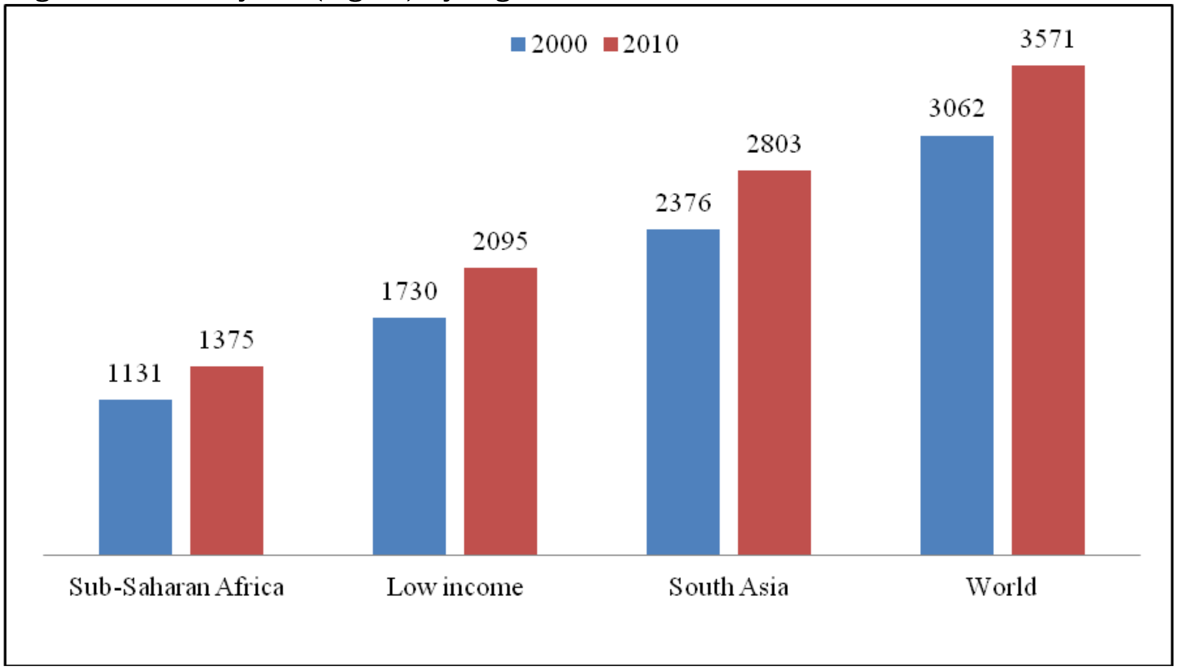
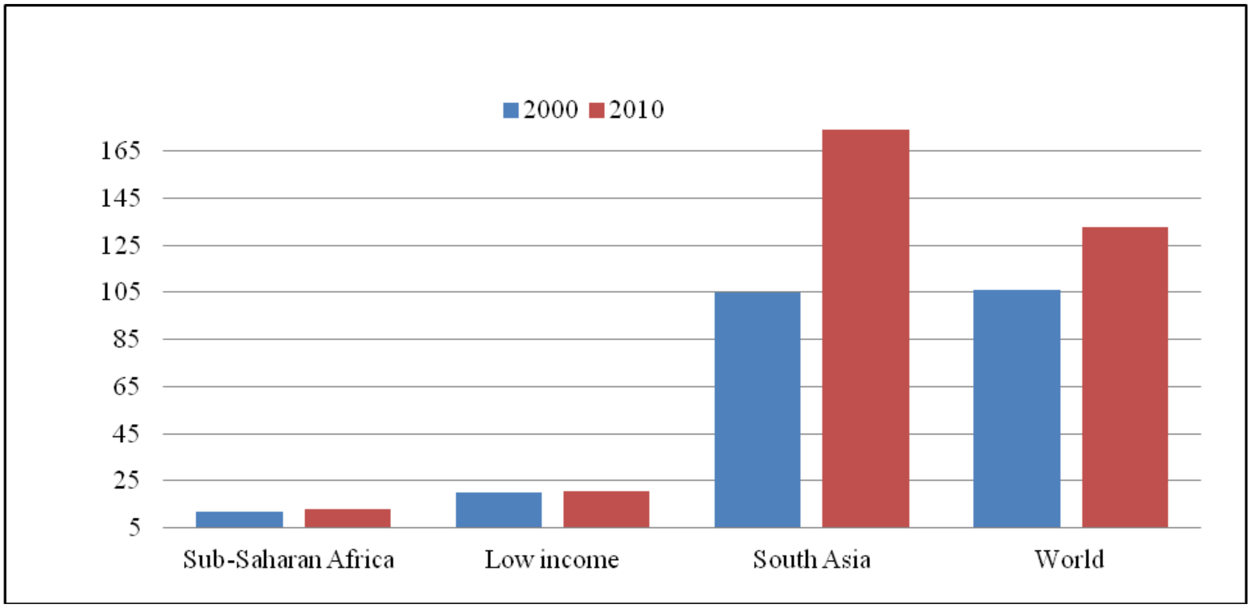
8. Annexes (Tables, Figures and Maps)

Figure 1: Cereal yield (Kg/ha) by region in 2000 and 2010



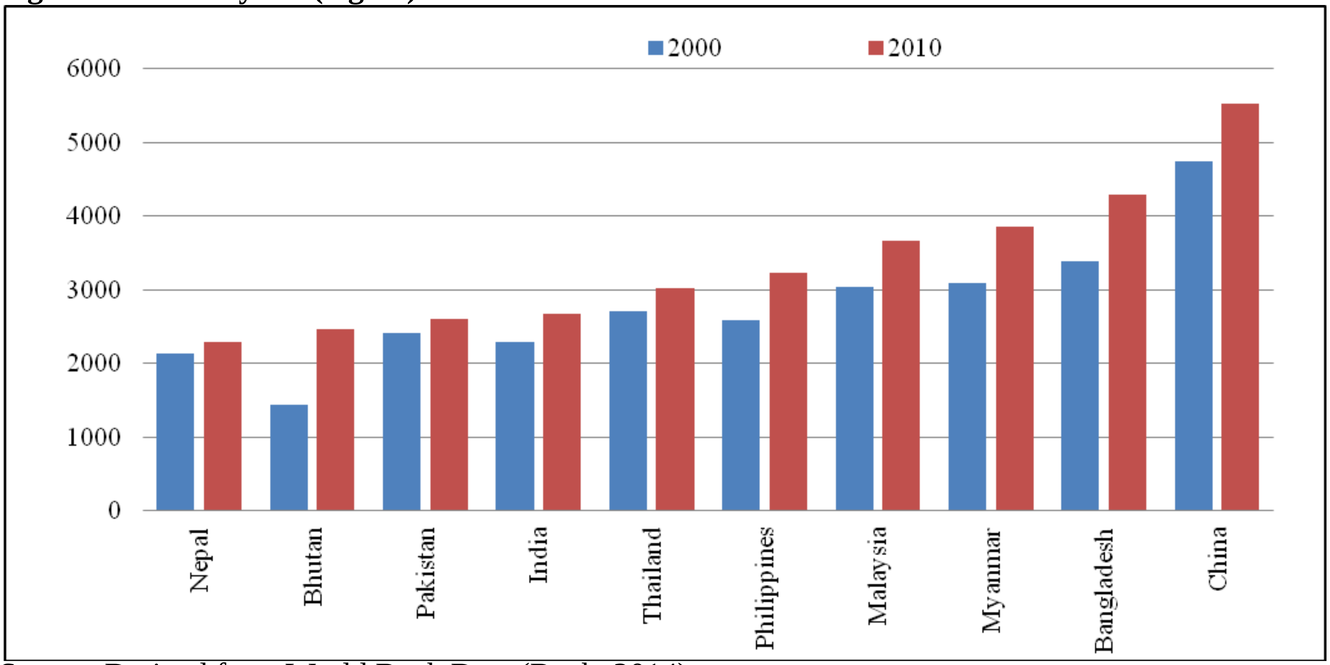
Source: Derived from World Bank Data (Bank, 2014)

Figure 2: Fertilizer use (Kg/ha of arable land) by region



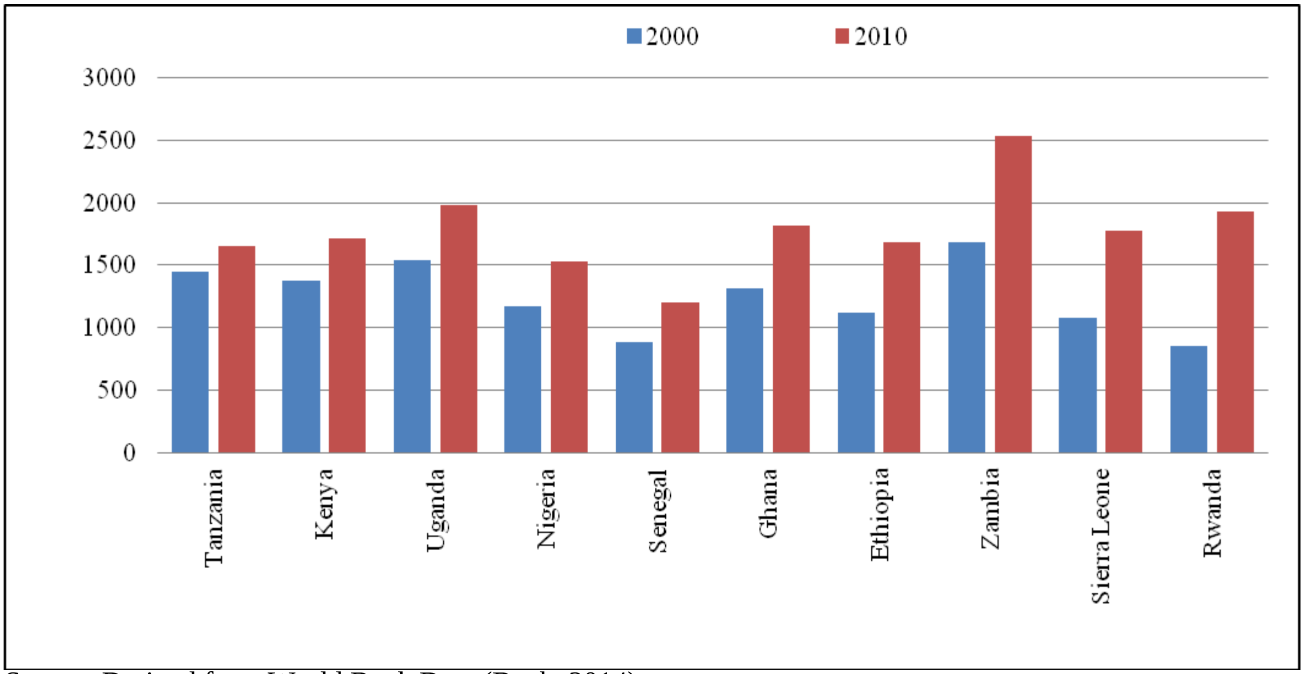
Source: Derived from World Bank Data (Bank, 2014)

Figure 3: Cereal yield (Kg/ha) in some Asian countries



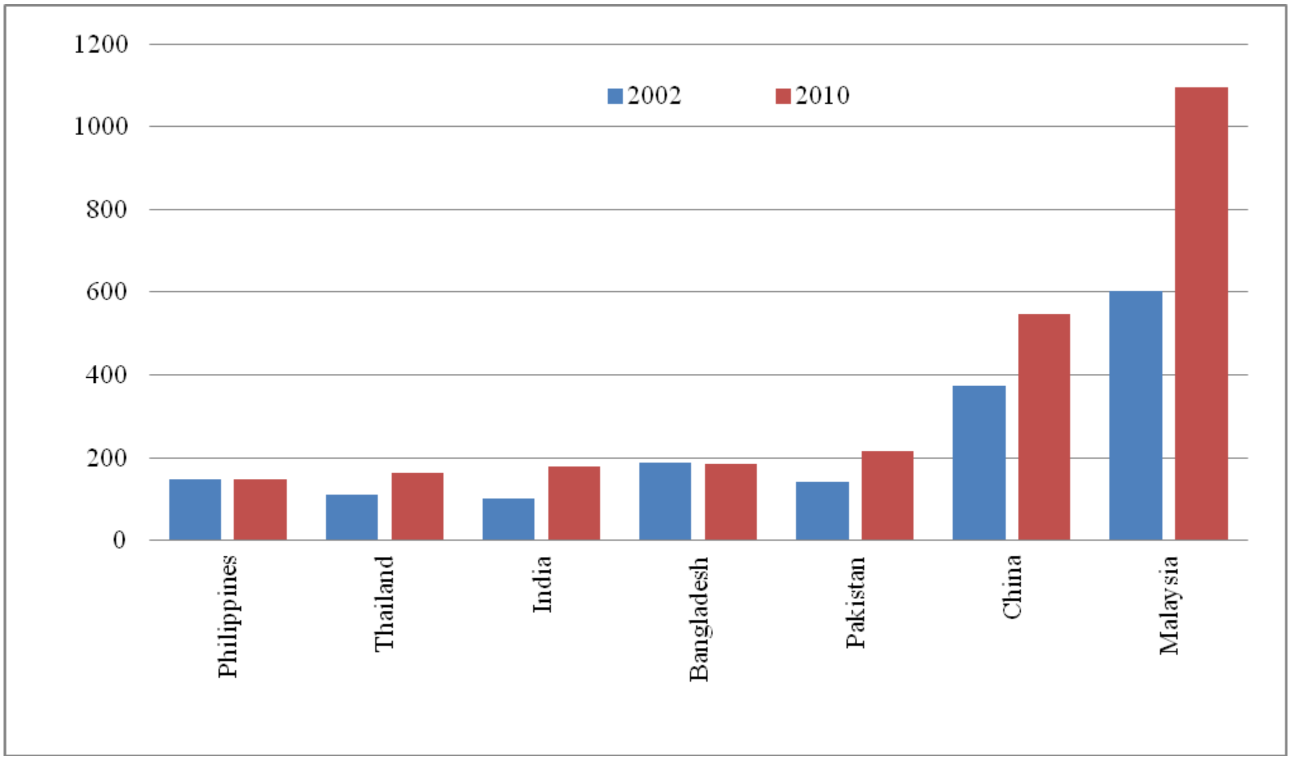
Source: Derived from World Bank Data (Bank, 2014)

Figure 4: Cereal yield (kg/ha) in some African countries



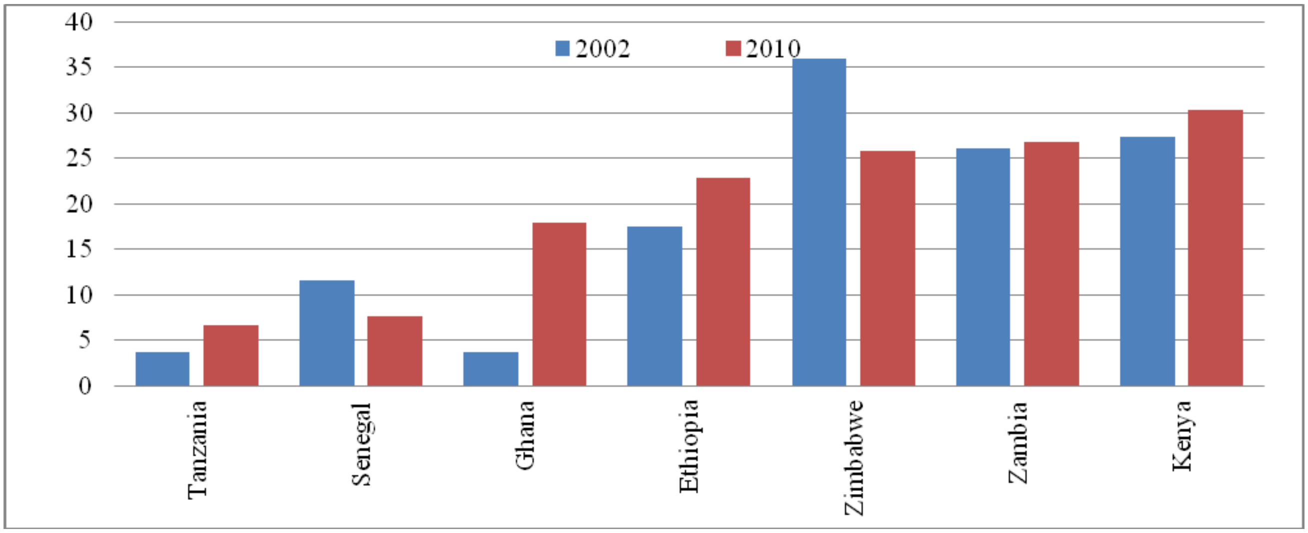
Source: Derived from World Bank Data (Bank, 2014)

Figure 5: Fertilizer use (Kg/ha) in some Asian countries



Source: Derived from World Bank Data (Bank, 2014)

Figure 6: Fertilizer use (Kg/ha) in some African countries



Source: Derived from World Bank Data (Bank, 2014)

Figure 7: The theory of change of BRAC's LEAD project in Tanzania

Inputs	Activities	Outputs	Outcomes	Impact
• Human resources • Financial resources • Time • Seed, fertilizers	• Census • Lead, demo farmer selection • Group formation with general farmers • Selecting of local agricultural inputs dealers • Training • Procuring inputs/linking farmers with agro dealers/traders • Distribution of seeds and fertilizers • Disbursing loans to farmers for agriculture	• General, lead and demo farmers selected and Farmer's group formed • General, lead and demo farmers received training • Lead and demo farmers received seed and fertilizer • Eligible maize farmers received agricultural loans	• Farmers using improved seed • Farmers using fertilizers • Farmers applied line sowing • Increased maize yield • Farmers selling their products collectively • Farmers getting better price for maize	• <u>Broad</u>: enhanced economic wellbeing among small farmers • <u>Specific</u>: Self- reported poverty reduced; reduced borrowing for food; and increased access to sufficiency in basic food items

Figure 8: LEAD project's beneficiaries in each BRAC operating area or branch

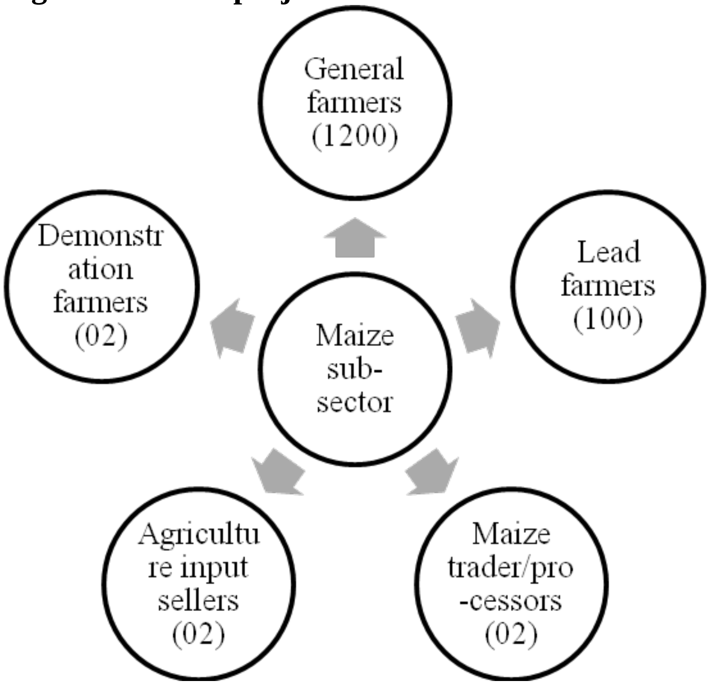


Table 1 : Agricultural Research Intensity (Full time equivalent researchers per 100000 farmer)

Year	Uganda	Tanzania	Kenya	Ethiopia
2000	3.0	4.1	8.2	3.1
2001	2.9	4.5	8.2	3.6
2002	2.7	4.5	8.4	4.0
2003	2.7	4.6	8.1	4.3
2004	2.5	4.6	8.0	4.3
2005	2.5	4.6	8.0	4.3
2006	2.8	4.6	7.9	4.4
2007	3.0	4.4	7.8	4.8
2008	3.0	4.3	8.0	4.7
2009	3.1	4.2	8.2	4.7
2010	2.9	4.1	8.3	5.2
2011	3.1	4.7	8.5	5.8
Average	2.9	4.4	8.1	4.4
Annual Growth rate (%)	2.71	4.45	8.10	3.47

Source: ASTI (2015)

Table 2: Total Agricultural R&D spending (million in constant 2011 US$) excluding private for-profit sector

Year	Uganda	Tanzania	Kenya	Ethiopia
2000	13.6	14.2	59.3	12.4
2001	13.8	9.6	63.7	22.2
2002	18.1	12.6	52.4	23.3
2003	25.4	17.1	49.3	21.5
2004	25.3	17.0	47.3	20.9
2005	25.2	10.4	52.9	19.3
2006	24.1	16.8	66.8	19.1
2007	29.0	23.2	66.3	19.4
2008	32.4	27.3	66.3	16.8
2009	31.7	28.8	70.2	16.0
2010	36.2	34.2	70.3	19.9
2011	37.2	28.6	73.5	18.1
Average	26.0	20.0	61.5	19.1
Annual Growth rate (%)	15.24	10.63	52.19	19.17

Source: ASTI (2015)

Table 3: LEAD project's intervention at the village and market level

Intervention	General farmer	Lead farmer	Demo farmer	Agro dealer and trader
Training (days)	2	3	5	3
Refresher training (day)	-	1 (every three month)	1 (every six months)	-
Improved maize seed (kg)	-	5	10	-
Fertilizer (Kg)	-	16 (basal dose only)	100 per acre (50 kg for basal dose and 50kg for top dressing)	-
Producer group formation	Yes	Yes	Yes	-
Market linkage	Yes	Yes	Yes	Yes
Food and transportation for training and refresher	Yes	Yes	Yes	Yes
Receive certification	-	-	-	Yes

Source: Compiled from LEAD project documents

Table 4: Summary statistics of variables used in the logit regression analysis of the relationship of access to land, fair price, altitude, female head of household with technology adoption (dependent variable), based on cross-sectional data November 2014 (n=2145 maize farmers in Tanzania) Divide them by the four main explanatory variable and the controls

Variables	Observation	Mean	Standard Deviation
Dependent variable			
Adoption is 1 if farmer uses chemical fertilizers, pesticides and zero otherwise	2145	0.42	0.49
Explanatory variables			
Amount of owned land (acre)	2145	1.71	1.76
Farmers getting a fair price for maize (%)	2145	0.19	0.40
Altitude (meters above sea level)	2145	970.79	546.28
Female head of household (yes=1, otherwise=0)	2145	0.21	0.41
Control variables			
Farmers from high altitude land (%)	2145	0.13	0.34
Farmers from medium altitude land (%)	2145	0.56	0.50
Farmers sell maize in the market (%)	2145	0.46	0.50
Farmers have access to credit (%)	2145	0.44	0.50
Experience in maize cultivation (years)	2145	12.50	10.74
Farmers with exclusive land use right (Yes=1, otherwise=0)	2145	0.80	0.40
Distance to nearest market from village (km)	2145	5.12	6.65
Age of farmers (in years)	1686	41.76	13.25
Years of education of farmers	1686	7.39	2.77
% of small farmers (who have <1 acre of arable land)	2145	0.27	0.44
% of medium farmer (who have 1 to less than 3 acre of arable land	2145	0.56	0.50
% of large farmers (who have 3 and above acre of arable land	2145	0.17	0.37

Source: LEAD baseline survey 2014

Table 5: Multivariate probit regression of individual farmer's technology adoption rate as a function of the amount of ownership of land holdings, getting a fair market price, altitude, and a female being the head of household, based on cross-sectional data November 2014 (n=2145 maize farmers in Tanzania): Clustered by village

Explanatory variables	**Coefficient**	**Marginal effect**
Hypothesis-1: Amount of arable land owned (care)	-0.161*** (0.037)	-0.062*** (0.014)
Hypothesis-2: Farmers getting a fair price (1=yes, 0=otherwise)	0.325* (0.142)	0.127* (0.056)
Hypothesis-3: Altitude in MASL	0.000 (0.000)	0.000 (0.000)
Hypothesis-4: Female head of household (1=yes, 0=otherwise)	-0.438*** (0.084)	-0.162*** (0.030)
Control Variables		
Farmers having land use right (1=yes, 0=otherwise)	1.019*** (0.148)	0.334*** (0.044)
Experience in maize cultivation (years)	0.019** (0.006)	0.007** (0.002)
Distance to nearest agricultural inputs markets(Km)	0.015 (0.010)	0.006 (0.004)
Farmers selling maize in the market (1=yes, 0=otherwise)	0.322* (0.127)	0.124* (0.049)
Farmers have access to credit (1=yes. 0=otherwise)	0.226 (0.131)	0.087 (0.051)
Age of farmers (years)	0.001 (0.004)	0.000 (0.002)
Year of education of farmers	0.012 (0.016)	0.005 (0.006)
Constant	-1.596*** (0.317)	
Pseudo R square	0.156	0.156
Observations	1,552	1,552

Robust standard errors in parentheses adjusted by 86 clusters; *** p<0.001, ** p<0.01, * p<0.05

Source: LEAD baseline survey 2014

Table 6: Multivariate probit regression of individual farmer's technology adoption rate as a function of the amount of ownership of land holdings, getting a fair market price, altitude, and a female being the head of household, based on cross-sectional data November 2014 (n=2145 maize farmers in Tanzania) using Village Fixed Effect

Explanatory variables	**Coefficient**	**Marginal effect**
Hypothesis-1: Amount of arable land owned (care)	-0.161*** (0.025)	-0.062*** (0.010)
Hypothesis-2: Farmers getting fair price (1=yes, 0=otherwise)	0.323*** (0.093)	0.127*** (0.037)
Hypothesis-3: Altitude in MASL	0.000 (0.000)	0.000 (0.000)
Hypothesis-4: Female head of household (1=yes, 0=otherwise)	-0.440*** (0.080)	-0.163*** (0.028)
Control Variables		
Farmers having land use right (1=yes, 0=otherwise)	1.015*** (0.113)	0.333*** (0.028)
Experience in maize cultivation (years)	0.019*** (0.004)	0.007*** (0.002)
Distance to nearest agricultural inputs markets(Km)	0.015* (0.006)	0.006* (0.002)
Farmers selling maize in the market (1=yes, 0=otherwise)	0.323*** (0.079)	0.124*** (0.030)
Farmers have access to credit (1=yes. 0=otherwise)	0.225** (0.072)	0.086** (0.028)
Age of farmers (years)	0.001 (0.003)	0.001 (0.001)
Year of education of farmers	0.013 (0.013)	0.005 (0.005)
Village Fixed Effect	0.000 (0.001)	0.000 (0.000)
Constant	-1.612*** (0.214)	
Pseudo R square	0.156	0.156
Observations	1,552	1,552

Standard errors in parentheses; *** p<0.001, ** p<0.01, * p<0.05

Source: LEAD baseline survey 2014

Table 7: Multivariate probit regression of individual farmer's technology adoption rate as a function of the amount of ownership of land holdings, getting a fair market price, altitude, and a female being the head of household, based on cross-sectional data November 2014 (n=2145 maize farmers in Tanzania): Using quadratic variables

Explanatory variables	**Coefficient**	**Marginal effect**
Hypothesis-1: Amount of arable land owned (care)	-0.287*** (0.066)	-0.111*** (0.026)
Amount of arable land owned squared (care)	0.019** (0.007)	0.007** (0.003)
Hypothesis-2: Farmers getting fair price (1=ye, 0=otherwise)	0.278* (0.140)	0.109 (0.056)
Hypothesis-3: Altitude in MASL	-0.004*** (0.001)	-0.001*** (0.000)
Hypothesis-3: Altitude squared in MASL	0.000*** (0.000)	0.000*** (0.000)
Hypothesis-4: Female head of household (1=yes, 0=otherwise)	-0.504*** (0.075)	-0.187*** (0.027)
Control Variables		
Farmers having land use right (1=yes, 0=otherwise)	0.998*** (0.183)	0.330*** (0.050)
Experience in maize cultivation (years)	0.019*** (0.006)	0.007*** (0.002)
Distance to nearest agricultural inputs markets(Km)	0.024* (0.011)	0.009* (0.004)
Farmers selling maize in the market (1=yes, 0=otherwise)	0.440** (0.140)	0.170** (0.055)
Farmers have access to credit (1=yes. 0=otherwise)	0.335** (0.125)	0.130** (0.048)
Age of farmers (years)	0.000 (0.004)	0.000 (0.002)
Year of education of farmers	0.006 (0.016)	0.002 (0.006)
Constant	-0.868** (0.304)	
Pseudo R square	0.228	0.228
Observations	1,491	1,491

Robust standard errors in parentheses adjusted by 86 clusters; *** p<0.001, ** p<0.01, * p<0.05

Source: LEAD baseline survey 2014

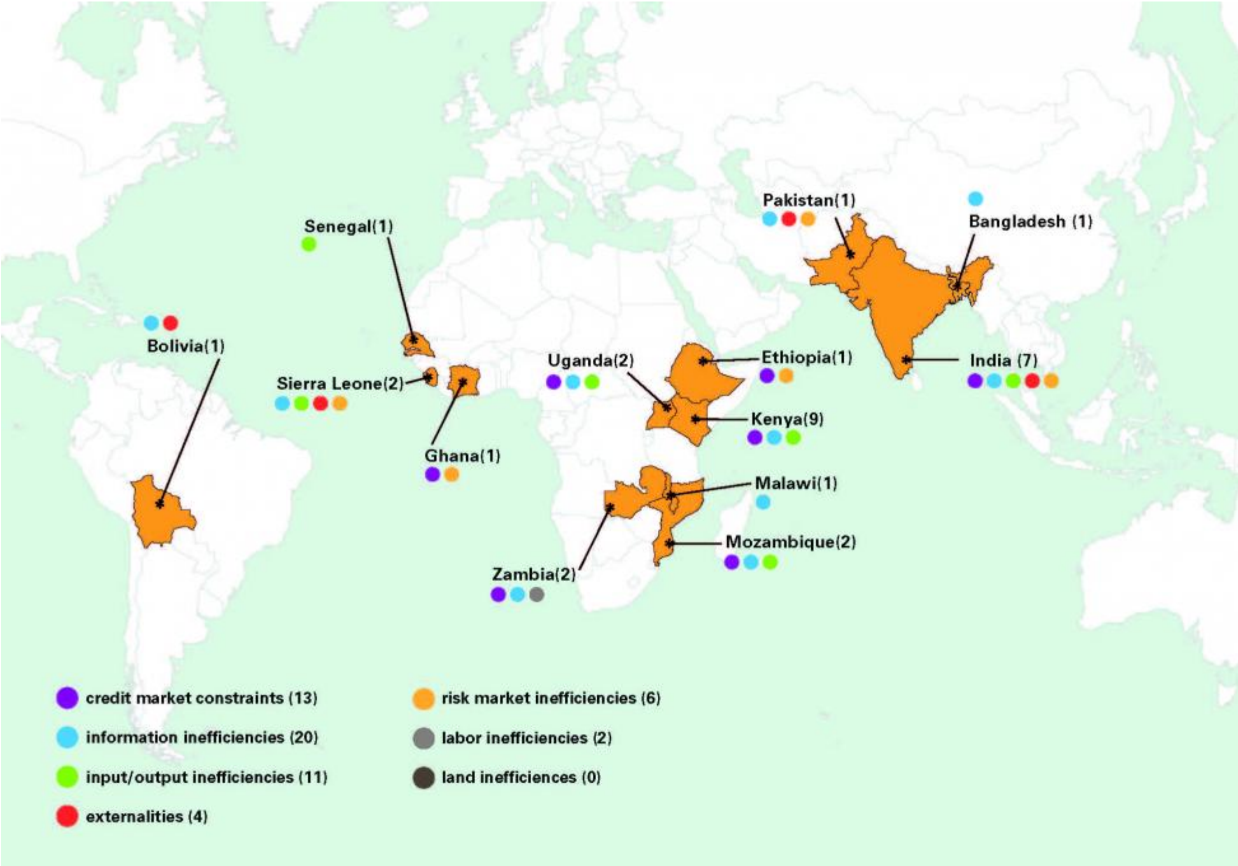
Table 8: Multivariate probit regression of individual farmer's technology adoption rate as a function of amount of the ownership of land holdings, getting a fair market price, altitude, and a female being the head of household, based on cross-sectional data November 2014 (n=2145 maize farmers in Tanzania): Using interaction variables

Explanatory variables	**Coefficient**	**Marginal effect**
Hypothesis-1: Amount of arable land owned (acre)	-0.341***(0.097)	-0.130***(0.037)
Amount of arable land owned squared (acre)	0.006(0.010)	0.002(0.004)
Hypothesis-2: Farmers getting fair price (1=yes, 0=otherwise)	0.633**(0.240)	0.247**(0.093)
Hypothesis-3: Altitude in MASL	-0.008***(0.001)	-0.003***(0.000)
Altitude squared in MASL	0.000(0.000)	0.000(0.000)
Hypothesis-4: Female head of household (1=yes, 0=otherwise)	-0.455(0.276)	-0.165(0.094)
Control Variables		
Farmers having land use right (1=yes, 0=otherwise)	0.963***(0.180)	0.307***(0.049)
Experience in maize cultivation (years)	0.023***(0.005)	0.009***(0.002)
Distance to nearest agricultural inputs markets(Km)	0.028*(0.011)	0.011**(0.004)
Farmers selling maize in the market (1=yes, 0=otherwise)	0.572***(0.135)	0.215***(0.051)
Farmers have access to credit (1=yes. 0=otherwise)	0.091(0.116)	0.034(0.044)
Age of farmers (years)	0.001(0.004)	0.000(0.002)
Year of education of farmers	0.004(0.017)	0.002(0.007)
Interaction variables		
Farmers sell maize* Farmers get fair price	-0.424(0.256)	-0.152(0.085)
Female head of household*land use right	0.035(0.280)	0.013(0.107)
Amount of land holdings *small farmers	-0.315(0.199)	-0.119(0.076)
Amount of land holdings * large farmers	0.178***(0.053)	0.067***(0.020)
Altitude (MASL)*high altitude	0.007***(0.001)	0.003***(0.000)
Altitude (MASL)*medium altitude	0.006***(0.001)	0.002***(0.000)
Constant	-0.936**(0.298)	
Observations	1,491	1,491
Pseudo R square	0.292	0.292

Robust standard errors in parentheses adjusted by 86 clusters; *** p<0.001, ** p<0.01, * p<0.05

Source: LEAD baseline survey 2014

Map 1: Map of studies on agricultural technology adoption in the world



Source: http://www.ideasforafrica.net/articles/why-dont-farmers-invest-addressing-major-barriers-technology-adoption