ADOPTION OF NO-TILL AGRICULTURE: THE ROLE OF INFORMATION, TECHNOLOGY PERCEPTION, AND FARMER CHARACTERISTICS IN THE ASHANTI REGION OF GHANA

A Thesis

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ABSTRACT

In recent years, there has been growing concern about soil productivity and environmental implications of conventional agriculture, especially tillage practices. This has led to the promotion of conservation agriculture and more specifically, no-till agriculture. No-till improves the physical and chemical characteristics of the soil, allows land to stay in production for an extended period of time, improves moisture conservation, and is labor saving. This paper uses three theories to discuss factors that influence farmers' decision to adopt or not adopt no-till farming technology. The three theories use different assumptions and hypotheses about technology. The three theories are: 1) economic constraints, distribution of resources; 2) technology characteristics, perceived attributes of the technology; and 3) innovation diffusion, access to information.

The data for the study was collected from farmers in the Ashanti region. A binary probit model is used to empirically test the adoption hypotheses. Four models were estimated to test the three theories, a model for each respective theory and a model that combined all three theories. Three farmer characteristic variables, gender, experience, and education, are included in all four models. Gender and experience are significant in the technology characteristics and combined models. The significant variables for the economic constraint model are labor, tenure, and income. The technology characteristic model has only one variable, the popularity of the technology, to be significant. In-person contact with extension agents and farmers as well as attendance at the no-till

training Center are the significant innovation diffusion variables. Once all three models are combined labor, total land, perception of a problem, in person contact with farmers and extension agents, and attendance at the Center are significant.

The data showed variables from all three theories are significant in the farmer's decision. Looking at only one theory can lead to a skewed picture and over emphasis on one area, leading to ineffective policies and projects with poor adoption rates. All three theories should be considered to create policies and projects to increase adoption rates of no-till.

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NOMENCLATURE

CRI	Crops Research Institute
EPA	Environment Protection Agency
FAO	Food and Agricultural Organization of the United Nations
IITA	International Institute of Tropical Agriculture
MOFA	Crops Research Institute
SRMP	Savannah Research Management Project

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CHAPTER I

INTRODUCTION

Most of the world's poor live in rural areas and are engaged in agriculture. Governments and development agencies promote income generating activities by increasing production and protecting natural resources (Parvan 2011). In recent years, there has been growing concern about soil productivity and environmental implications of conventional agricultural. Conventional agriculture is commonly thought of as intensive tillage but this study defines conventional agriculture as slash and burn, the most common agricultural system in the study area. Intensive tillage is believed to ease planting by loosening and aerating the soil, mixing harvested residue into the soil, destroying weeds, and drying the seed bed. Contrary to intensive tillage, slash and burn systems have little to no soil disturbance. The key problem with slash and burn is the steady decline in soil fertility after farming the land over a long period of time due to the soil being bare and vulnerable in times of rainfall, wind, and heat (Derpsch 2003). This has led to the promotion of conservation agriculture.

Conservation agriculture in itself is not a technology but a system comprised of three principles: 1) minimum or no soil disturbance, 2) continuous soil coverage by growing plants or plant residue, and 3) diversified crop rotation (Boahen et al. 2007; Giller 2009). The three principles are in contrast to the mono crop, heavy soil disturbance, and bare soils that have been promoted in the past (Giller 2009). A 'full conservation agriculture' system can be an individual or several technologies that meet the three principles simultaneously. Full conservation agriculture is rarely seen today and is most common in Brazil and other South American countries (Boahen et al. 2007).

One conservation agriculture technology is minimum or no-till agriculture. The no-till technology is profoundly different than other agricultural technologies for two reasons. First, no-till is a major shift from intensive tillage systems that are based on heavy soil disturbance, leaving less than 15% of crop residue, through the use of plows or hand held hoes. No-till involves little to no disturbance of the soil (Ekboir 2001). The main difference between no-till and conventional systems is the maintaining of a permanent or semi-permanent soil cover, protecting the soil from sun, rain, and wind while also maintaining soil biota that serves as a natural tillage (Knowler and Bradshaw 2007).

Second, no-till technology is a complex social aspect, requiring an unprecedented adoption system. Most agricultural technologies are adopted along a continuum starting with research, testing, and finally large scale adoption by farmers. The new system is based on an 'innovation system.' Under this system the technology is developed under a network of researches, farmers, private sector, etc that coevolves. The no-till network is different in every location creating location specific evolution. In the case of South America, commercial interests of input dealers and commercial farmers' need for sustainable systems drove the no-till network. In the Indo-Gangetic Plains of South Asia, it was driven by local and international researchers (Ekboir 2001).

No-till has had major impact throughout the world by not only creating assets but also reducing risk-aversion. The success of no-till depends on whether farmers adopt the offered technology and for the prescribed length of time to net the full return (Knowler and Bradshaw 2007).

Objectives of Study

The overarching objective of this paper is to identify factors that influence farmers' decision to adopt or not adopt the no-till technology and to assess how no-till training offered to farmers by the Center for No-till Agriculture in Amanchia, Ghana has influenced farmers' decision. To address this broad objective the paper will address the following issues:

1. Identify socioeconomic and biophysical factors that influence farmers' decision to adopt the no-till technology.
2. Asses farmers' perception of the technology and its' effect on the decision to adopt.
3. Analyze the value of information participants receive from the Center and the effect of the training on farmers' decision to adopt.

A better understanding of the reasoning behind the choices made by a subsistence farmer will enable the Center to more efficiently and effectively reach its beneficiaries, increasing the probability of adoption and making the most of aid funding. The results of this paper will be applicable for governments and aid agencies to increase the likelihood of technology adoption, increasing the efficiency and effectiveness of agricultural development projects. Agricultural development projects are crucial to reaching food security, reducing poverty, and increasing economic activity in developing countries.

The paper is organized as follows: Chapter 2 gives a contextual background on Ghana and more specifically the Ashanti region, the study area. The background will include biophysical characteristics of the area, common agricultural practices, and the history and development of no-till in the area. Chapter 3 is a literature review on the three theories of technology adoption: economic constraints, technology characteristics, and innovation diffusion. In addition to introducing the three theories, the Chapter identifies pertinent variables for each. In Chapter 4 the model used to test the three theories, a binary probit, is introduced. The empirical findings of the model are presented in Chapter 5. Finally, the conclusions and implications from the findings are stated in Chapter 6.

CHAPTER II

BACKGROUND INFORMATION

Ghana lies along the Gulf of Guinea of the Atlantic Ocean and shares a border in the east with Togo, on the north with Burkina Faso, and to the west with Côte d'Ivoiré. The country has 10 regions: Upper East, Upper West, Northern, Brong Ahafo, Ashanti, Eastern, Western, Central, Volta, and Greater Accra. The national capital, Accra, is located in the southern part of the country in the Greater Accra region (Boahen et al, 2007).

Ghana is divided into five agro-ecological zones based on climate and vegetation: Guinea Savannah, Sudan Savannah, Forest (Rainforest and Deciduous Forest), Transition Zone, and Coastal Savannah (Mann 2010). The different zones have a variety of soil types but all suffer from poor water infiltration, soil crusting and hardening during dry periods, low water holding capacity, and a high degree of chemical degradation. Soil leaching is also common in areas with heavy rainfall (Steiner 1998) while the savannah zones are most susceptible to desertification (Boahen et al 2007).

According to The Ghana Statistical Service (2012), Ghana's population is 24.7 million with a growth rate of 2.5 percent. The population is spread throughout the 10 regions and eco-zones of the country with 49.1 percent of the population living in rural areas. Fifty-one percent of the population lives in the savannah zones with three percent in Coastal Savannah, thirteen percent in Guinea Savannah, and five percent in Sudan

Savannah. Greater Accra is the district with the largest population density at 1,236 persons per square km followed by the Central region at 224 persons per square km, and the Northern region at 35 persons per square km (GSS 2012).

About 13.6 million hectares (57%) of land is classified as agricultural land area of which only 32%, 7.8 million hectares, is under cultivation. Only 30,269 hectares are irrigated (MOFA 2011). Agricultural land availability per capita has been decreasing putting more pressure on natural resources, in particular on the soil. Agricultural land availability per capita was 1.6 ha in 1970, 1.1 ha in 1984, and most recently was .7 ha in 2000 (Boahen et al. 2007).

The 2007 estimated poverty rate in Ghana was 29%, a significant decrease from the 1999 estimate of 40% of the population. The Upper East, Upper West, and Northern regions have the highest occurrence of poverty. The majority of the poor are subsistence farmers (Boahen et al. 2007).

In 2010, Ghana was re-categorized as a lower middle income country. The agricultural sector plays an important role in Ghana’s economy, comprising 21.4 percent of Ghana’s gross domestic product (GDP) and employing 41.2 percent of the labor force. Approximately 37.7 percent of the farm labor force is women. On the other hand, the service sector accounts for the greatest proportion of GDP, 53.5 percent, but only accounts for 29 percent of the workforce (GSS 2015). Ghana’s agricultural production provides 90 percent of the food needs of the country and accounts for 40 percent of export earnings (Oppong-Anane 2006). Gold and cocoa production and remittances are the major sources of foreign exchange. 21.3 million are aged 5 years and older, 54.2 percent are economically active (have a job or are actively seeking) while the rest are not active (not seeking or not available for work). Of those that are economically active, five percent are unemployed. Students and home makers comprise the majority of the economically not active (GSS 2012).

Ghana's agriculture is predominantly smallholder, traditional, and rain-fed farms. Ninety percent of farms are less than two hectares (Mann, 2010) with about 60 percent of farms consisting of 1.2 hectares or less. Male-headed houses typically have access to larger amounts of land than female-headed households. It is assumed men have a greater need for land to provide for their wife(ves) and children (Boahen et al. 2007). Farming systems differ depending on the ago-ecological zone however there are a few agricultural practices that are seen throughout. Shifting cultivation systems occur whenever there is enough land to permit a plot to rest dormant. Subsistence farmers tend to be diverse, growing more than one type of crop, while cash crop farms are mono-cropped (Oppong-Anane 2006).

Livestock production is seen throughout all of the agro-ecological zones of Ghana. Sheep and goats are widespread throughout Ghana while poultry production is predominately in the south and cattle husbandry is concentrated in the Savannah zones (Oppong-Anane 2006). Animal husbandry is usually not integrated with crop production. Animals are typically grazed on communal lands, farmers' fields and crop residue (Boahen et al. 2007). In addition to meeting food needs, livestock play a socio-cultural role in Ghana. In Northern regions, cattle are a determinant of wealth, payment of dowry, and act as a bank and insurance in times of difficulty. Sheep and goats are often slaughtered for various occasions including births, funeral, and marriages (Oppong-Anane 2006).

Ashanti Region

This paper will focus on the Ashanti region of Ghana where the Center of No-Till is located. The Ashanti region is located in central Ghana. The major occupation in the region is agriculture/animal husbandry/forestry. Sixty-five percent of the population depends on agriculture for their livelihood (MOFA 2011). Shortening fallow times and increasing rates of soil degradation make conservation agriculture necessary in the region. Labor, production, and marketing constraints further highlight the need for alternative systems. The large proportion of self-owned land (437 out of the 631 people interviewed) allows farmers to implement systems with long term returns. All of these reasons along with the heavy vegetation of the deciduous forest zone and low competition for vegetation from livestock (compared to the savannah zones) make the area ideal for no-till agriculture.

The soil type and large amounts of vegetation make conditions for no-till ideal in the Ashanti region. The region falls in the Deciduous Forest and Transitional agro-ecological zones. Villages in this study lie in the Deciduous Forest zone. The soil is generally more fertile than the other agro-ecological zones. The soil consists of well drained forest ochrosols or forest oxysols (Ekboir 2002). The annual rainfall is between 1,100 and 1,800 mm and has a bimodal distribution, defining a major and minor growing season. The major rainy season is from the end of March to July and the minor season is September to November. December to February is the driest, hottest time of year. The mean annual temperature is between 25 and 32 degrees Celsius. The region is rich in naturel resources with lakes, forests, scarps (cliffs), waterfalls, and wildlife. The watershed drains into Lake Bosomtwe, the largest natural lake in Ghana (MOFA 2011).

Conventional Agricultural Systems

The Deciduous Tree Zone is ideal for tree crops such as cocoa, oil palm, citrus and mango. They are typically mono-cropped in plantations and may be intercropped with food crops during establishment (MOFA 2011). Maize and cocoa are the most common and important cash crops in the region. Maize is usually intercropped with cassava or grown solely. Other important crops by quantity and income include: cassava, plantain, cocoyam, vegetables (eggplant, tomato, pepper), and oil palm (Boahen et al. 2007).

Seventy-seven percent of farmers have farm sizes below 1.2 ha (MOFA 2011) and practice shifting cultivation and slash and burn. Under these systems, vegetation is cleared with a cutlass (machete) and is left to dry for a few days. Once dry the residue is burnt, leaving the land clear for planting. Burning is done to reduce the workload, destruct weed seeds, prevent the transmission of plant diseases, facilitate the hunting of small animals, and to make seeding easier (Steiner 1998). Burning is preferred over turning plant residue under. Farmers complain that turning plant residue under makes seed placement difficult, reduces emergence rates, and increases loss to rodents and insects. Planting is conventionally done with a stick or cutlass (Boahen et al 2007).

The land is under cultivation for 2-3 years and is then left to fallow for 5-10 years before the process repeats. Fallowing allows the soil fertility to recuperate from cultivation and weed and pest cycles to be broken. The growing population and urbanization in the region has increased the demand for land, hindering farmers' shifting cultivation system. Ashanti is the most populous region with a population of 4.8 million, 19.4 percent of the country's population (GSS 2015). Fifty percent of the region's population is concentrated in the three districts encompassing the regional capital, Kumasi, the second largest city in Ghana with a population of two million. The remainder of the population is disseminated over the remaining 15 districts and is predominately rural. The growth in the mining industry and commercial activities in Kumasi have attracted people from within the region and outside of the region. Villages near Kumasi have exponentially grown, gaining urban status (population above 5,000). For example, Atimatim grew from 836 in 1970 and 1,123 in 1984 to 14,017 in 2000. The growing population in the area forces farmers to keep land in production for longer periods of time and decrease fallowing periods, deteriorating soil fertility. Compounding the problem, burning the residue off of the land leaves the soil susceptible to wind and water erosion (Ekboir 2002).

Labor

The increased mining and commercial activities have also driven an increase in labor demands, inflating wages. The inflated wages make it difficult for farmers to afford hired labor. Labor is one of the main costs for farmers and it plays an important role into determining what type of agricultural system the farmer implements. The majority of production activities are done manually using hoes, cutlasses, and planting sticks making it labor intensive. Tractors are uncommon in the area. Human labor is employed throughout the production process especially for clearing land, planting, weeding, and harvesting. The recent increase in labor demand and increasing wages have made hiring labor difficult for small holder farmers during critical times. Migrant workers from northern parts of Ghana make up the majority of hired labor during planting. The migrants reach the region in April and are hired to prepare land and plant crops. In May or June they return to the north to begin their own cropping season. This leaves labor scarce during critical weeding and harvesting times (Boahen et al. 2007). Weed control is one of the largest uses of labor in West Africa. Incomplete or untimely weeding can cause great yield loss or complete crop failure in extreme cases (Steiner 1998). Likewise, if crops are not harvested on time they will perish in the field or in route to market.

Usually, men are responsible for clearing and preparing the land and agrochemical application. Threshing and processing maize are women’s responsibilities. Planting, fertilizing, weeding, harvesting, storing, and marketing responsibilities are shared between men and women. Women are also responsible for the household: cleaning, looking after the children, and fetching water. They are also commonly engaged in trading and food processing, accounting for 30% of female household income (Boahen et al. 2007).

Production and Marketing Constraints

Several production and marketing constraints exist in the region including: rainfall, informal marketing systems, and access to credit. Rainfall can be erratic and affect planting times. In severe rain deficit years the cropping system can be reduced from two to one season. Pest infestation can cause significant yield losses; caterpillars, aphids, locusts and termites are the main field pests. Rodents and weevils cause the majority of postharvest loss (Boahen et al. 2007).

Most crops are produced, processed, and marketed in the informal private sector. Produce is sold at farm gate, to middlemen, or at market centers with the exception of cocoa. Cocoa has an organized cocoa board with channels which purchase the produce. Women dominate the market from producer to retailer. Profit margins have been decreasing as input prices (fertilizer, labor, pesticide, seed, etc) have increased and produce prices have decreased. The increase in input prices has been driven by the lowering of subsidies and increasing demand in some cases (labor). Farmers complain about the low prices they receive from marketing agents/middlemen and believe their margin should be lowered by paying higher prices to the producer. Transportation costs along with poor transportation and market infrastructure make it difficult and costly for farmers to bypass intermediaries by selling their products in the local market (Boahen et al. 2007).

Farmers experience a shortage of cash during periods of the year due to the seasonality of crop production. Most farmers lack access to credit. Those with access to credit suffer from inadequate terms for agricultural production: high interest rates, short to no grace periods, and untimely releases (Boahen et al. 2007).

Land Tenure

Legally, all land in Ghana is owned by the state. Land is predominantly regulated by customary laws instead of statutory laws. The state has the power to appropriate land for development purposes but it must pay compensation to the owner. An individual can acquire land from family, spouses, sharecropping, lease, purchase, or by gift (Oppong-Anane 2006). Customary land acquisition differs from region to region, following either a matrilineal or patrilineal system (Mann 2010). Two thirds of the land in Ghana is communally owned with a family head or chief as the custodian on behalf of the group -- referred to as “stools” in the south or “skins” in the north (Mann 2010). Once the land has been harvested all members of the community have the right to graze the communal land. Some individual ownership does exist but it comprises a small share of the total land area (Oppong-Anane 2006).

In the Ashanti region land ownership is generally ruled by the original settlers. The Ashanti regional communal system does not allow individuals to lease or sell the land. The chief is the custodial owner of the land and decides on the allocation of the land to farmers. This system can undermine individual responsibility over long term maintenance of farmland and emphasizes shifting cultivation.

Both men and women have user rights to family land and usually do not rent land. Landowners have user rights to the land and can pass on their rights. Children can inherit land from their parents and is most often matrilineal; this can lead to fragmentation of land holdings. Landowners can also rent their land for money or on a sharecrop basis. Rented land tenure can put extreme emphasis on overuse of land to gain the largest amount of production over a short period of time. In some cases where tenants have practiced conservation agriculture landowners evicted the tenants once they saw the improvement in soil conditions and higher yields (i.e. higher profitability). The landowner may decide it is more profitable for him/her to farm the land themselves versus renting the land. This discourages renters from undertaking conservation systems in favor for conventional systems with short term returns (Boahen et al. 2007).

Sharecropping is common in the region and is usually done *abunu, abusa, or dibimadibi*. Under an *abunu* arrangement the land is already under production. The tenant rehabilitates the land, establishing crops, typically food crops such as yam or cassava. The produce is shared equally between the tenant and landlorderd. Under an *abusa* agreement uses resources to clear and cultivate an uncultivated piece of land. This agreement is common for cash crops including maize. The tenant is entitled to 2/3 of the crop and the landlord to 1/3. *Dibimadibi* is similar but instead of the produce being shared, the land is shared.

Cocoa is commonly grown under sharecrop. The tenant can intercrop maize, cassava, cocoyam, and plantain for subsistence until the cocoa is mature. The plantain serves as shade for the young cocoa seedlings. Once mature the produce is shared abunu. Conservation agriculture may be promoted by the landowner in a sharecropping arrangement if the landowner expects a higher yield and therefore greater share from conservation agriculture. On the other hand some practices of conservation agriculture, such as cover crops, are discouraged. The landowner may see the cover crop as a waste of land area and would rather have it in production; this can lead to occasional conflicts between landowners and tenant (Boahen et al. 2007).

Historical Development of Conservation Agriculture in Ghana[1]

Some aspects of conservation agriculture have been used for several decades in the region. Cocoa farmers have used a method called *proka* (literal translation, leaving to rot or allowing to rot then adding). Under proka farmers clear a piece of land and leave the residue on the soil to decompose before planting instead of burning the residue. In some cases partial burning or cold burning is used to burn off some of the residue but a good amount is left as mulch (Boahen et al. 2007).

In 1983 a nationwide fire burned down the majority of cocoa and oil palm plantations. Many farmers abandoned their land while others shifted to food crops with a shorter planning horizon (cocoa and oil palm take several years before producing a crop), including maize. Slash and burn with shifting cultivation become the most common system to ensure yields remained high. Land was in abundance allowing the farmer to abandon a piece of land after a few cropping cycles and move on to a new, more fertile piece of land. Plots were able to remain fallow for several years before being put back into production. An increasing population has put pressure on land demands and made shifting cultivation difficult. Decreasing fallow periods and slash and burn practices have significantly increased pressure on the soil, depleting soil nutrients, increasing incidences of erosion, and increasing the presence of weeds and pests which have compounded and significantly decreased yields. This has led to a search for new agricultural systems that increase yields and soil vitality (Boahen et al. 2007).

According to the Environmental Protection Agency (EPA 2003), conservation has always been a concern in Ghana. Saharan conditions were realized to be encroaching on the southern regions of West Africa. Burning, erosion, overgrazing, and increased population have caused desertification, especially in the northern regions of Ghana. Conventional agricultural systems increase and intensify the threat of Saharan conditions. This led to the Ghanaian Government calling for a search of alternative systems during the beginning of the 20^{th} Century.

Research institutions such as the Crops Research Institute, the Soils Research Institute, and the Savannah Agricultural Research Institute started testing minimum tillage, mulching, and the use of cover crops. The research began on research stations and later moved to farmers' fields for verification. Several programs came from the research but are not active today (Boahen et al. 2007).

The Savannah Resources Management Project (SRMP) was a national program that promoted sustainable agricultural practices, in particular organic methods to improve land resources. The program did not include all three principles of conservation agriculture but it did promote soil coverage with plant debris (Boahen et al. 2007).

The Land Water Management Project started in 1995 and focused on capacity building of the MOFA to provide agricultural extension services on land management throughout Ghana. The project introduced and promoted soil and water management techniques such as cover crops, minimum tillage, and animal traction (Boahen et al. 2007).

The Sedentary Farming System Project incorporated and promoted management of soil organic matter, rotating crops, using cover crops, and the use of animal manure as fertilizer. In order to support the improvement of agricultural services, reducing postharvest losses, adding value to raw products through processing, and improving marketing opportunities the project's beneficiaries included traders, farmers, and others in the agricultural industry (Boahen et al. 2007).

The Cover Crop Program was a collaborative between the International Institute of Tropical Agriculture (IITA) and the Crops Research Institute (CRI). Mucuna, Pucraria, and Canavalia were tested on station and farms to determine their effectiveness as a cover crop. The Land and Water Management Project and the Sedentary Farming System Project utilized the findings in their extension work (Boahen et al. 2007).

In the 1990s the Crops Research Institute and the Ghana Grain Development Project partnered with Sasakawa Global 2000, Monsanto, and the Ministry of Food and Agriculture (MOFA) to promote and disseminate the on station findings to farmers (Boahen et al. 2007). Together they introduced *no-till with mulch* (henceforth referred to as no-till), as a sustainable agricultural alternative for small holder farmers in the Forest, Guinea Savannah, and Transition Zones of Ghana. No-till improves the physical and chemical characteristics of the soil and facilitates weed and pest control. The maintained soil fertility allows the land to stay in production longer, forgoing the customary fallow period. Additionally, no-till improves moisture conservation, reducing risk of crop failure in dry years (Ekboir 2002).

Although the name only refers to one practice, tillage, no-till includes several practices (Ekboir 2002). The technology adoption focused on the elimination of burning, increase in organic matter on the soil surface, maintenance of soil structure, and reduction in hand labor/time input. Soil cover included growing crops or dead mulch (Garcia-Torres et al. 2003). To obtain the full benefits of no-till, farmers must practice all of the no-till components (Ekboir 2002).

Maize, cassava, vegetables, okra, and plantain were the main crops that were promoted using the no-till system (Boahen et al. 2007). Yams and cassava are harder to grow under no-till because they are grown on mounds that require large amounts of soil disturbance (Steiner 1998). Crops that require heavy soil disruption for harvest (potatoes, groundnuts, etc) cannot be grown under no-till (Ekboir 2001). The project also worked with input suppliers and credit agencies to lessen production constraints that were seen as a hindrance to adoption of the no-till system (Boahen et al. 2007).

All of the above conservation agriculture projects utilized MOFA extension officers to sensitize communities to the new technologies and their potential benefits. Extension officers acted as facilitators with lead farmers. The lead farmers shared issues they were facing with the extension officers and together they worked to find solutions. Once a problem and potential solution was identified an on-farm trial was developed. The farmer set aside a portion of their land to try the new technology while continuing the conventional system on the rest as a control plot. The farmers were trained on various aspects of the trial and on how to manage the trial (Boahen et al. 2007). Extension workers followed up with the farmers by visiting them weekly.

The no-till program also utilized pre-season training, field days, field tours, workshops & seminars, and fact sheets & production guidelines to encourage the program (Ekboir 2002). Training covered the following topics: principles and practices of conservation agriculture, planting maize using lines and pegs, fertilizer and herbicide application, integrated pest management, soil fertility management, HIV/AIDS awareness, organic farming, ruminant nutrition, postharvest management of maize, and farm budget and record keeping (Boahen et al. 2007).

MOFA found that creating community awareness and support could be difficult. If the technologies require inputs or several seasons of investment before realizing a benefit farmers are hesitant to try the technology (Boahen et al. 2007). Farmers attribute a higher value to immediate costs and benefits than to those in the future due to food insecurity. Farmers expect to see visible and immediate returns for an investment in their land when conservation agriculture can take several years before benefits are realized (Giller 2009). To address these constraints the no-till program included an input component to incentivize farmers to participate. Farmers were provided with cover crop seeds, herbicides, and improved maize varieties for on-farm trials. Successful farmers were recommended to rural banks for credit. Short term land tenure was also found to be a hindrance to adoption. Farmers need a minimum of two years of land rights to realize the benefits of cover crops (Boahen et al. 2007).

Although MOFA collaborated in the above projects they relied heavily on funding from donor organizations. Once the projects ended extension agents' visits became less frequent. MOFA estimated a 30% decline in conservation practices with the closure of the projects.

The Center for No-Till Agriculture in Amanchia, Ghana

The Center for No-Till Agriculture, (henceforth referred to as the Center) builds on the Sasakawa Global 2000 and Monsanto program while also incorporating aspects of the other projects including cover crops, organic fertilizer, crop rotation, intercropping, etc. Farmers learn about the no-till system through pre-season training, field days, field tours, workshops & seminars, fact sheets & production guidelines, and 'Sunday School' (Ekboir 2002). Field days allow a group (researchers, extension officers, farmers, etc) to jointly monitor and evaluate a no-till field and discuss benefits and problems with the technology. Field tours allow farmers to see how the no-till system is applied on a larger scale and allows participants of the Center to talk with no-till farmers and learn what their experience with no-till has been (Boahen et al. 2007).

No-till improves the physical and chemical characteristics of the soil and facilitates weed and pest control. The maintained soil fertility allows the land to stay in production for many years, forgoing the customary fallow period. The land staying in production and increased weed control reduces labor constraints. Additionally, no-till improves moisture conservation, reducing risk of crop failure in dry years (Ekboir 2002).

The no-till system promoted by the Center begins the same way as the conventional system by clearing the land of vegetation with a cutlass. Clearing the land is very labor intensive. If the land had previously been fallow it will require more labor time as it will have a secondary forest in addition to grasses and weeds. Since the no-till system allows farmers to cultivate the same plot of land for a long period of time the labor demand will drastically reduce after the initial year. Slashing becomes easier with the number of years a plot remains under no-till (Ekboir, 2002). Once cleared the vegetation is left to dry and turns into mulch (Boahen et al., 2007).

After the initial clearing of the land, the no-till system allows weeds to regrow to 30-40 cm before being treated with a glyphosate based herbicide (Round-Up, Chemosate, or Helosate). The amount of glyphosate needed to control weeds decreases the longer the land has been under no-till cultivation. This system prevents weeds from producing seeds, reducing weed pressure over time. MOFA reported the no-till system reducing weeding sessions by at least one (Boahen et al. 2007). Most farmers do not own a sprayer to apply herbicide due to the high cost. Instead they either rent a sprayer from the owner, spraying their field on their own or the farmer hires a 'sprayer gang' that do the spraying for the farmer. The sprayer gang maintains the equipment and receives training from MOFA and agro-input dealers. The seasonality nature of spraying drives the demand and price for hired sprayers making it expensive for farmers (Boahen et al. 2007). Dead weeds are left on the ground and not incorporated into the soil (Ekboir 2002) for 7-10 days before planting through the residue (Boahen et al. 2007). After planting, weeds are controlled by hand with a cutlass or hand held hoe or with post-emergence herbicide. Despite the success of the no-till system in controlling weeds, it can be one of the main deterrents to no-till adoption (Ekboir 2002). The cost of glyphosate can also be a constraint to farmers. Exboir et al. (2002) found that 70% of farmers use less than the recommended amount in an effort to reduce input costs.

Once the land is cleared, planting is done with a cutlass or dibbling stick through the mulch, disturbing less than 1/3 of the soil surface (Derpsch 2003). Mechanized and non-mechanized planters have been developed but have not fully infiltrated markets in Ghana (Ekboir 2002). A few planting sticks with seed and/or fertilizer metering (matraca krupp) from Brazil can be found (Steiner 1998). The conventional method also uses cutlass or dibbling sticks so the lack of mechanization has not deterred small holder farmers but could have an effect on adaptation for large scale, mechanized farms. Seeding technology can be a deterrent to some for the same reason that burning is preferred over turning the plant residue under. Planting through the mulch left under no-till can be difficult, lowering emergence rates (Steiner 1998). Harvesting techniques are not affected by no-till (Ekboir 2002).

Chemical or organic fertilizer is encouraged and is not incorporated into the soil. Instead, the fertilizer moves naturally through the soil with rain water. Mulch can increase the presence of pests such as leaf borers, millipedes, caterpillars, and grasshoppers especially during the minor season and are managed with the use of pesticides (Boahen et al. 2007). On the other hand, mulch is favorable to beneficial insects that eat the other pests, creating an integrated pest management system (Ekboir 2001). The cover crop canopy also makes a microclimate for frogs, rats, squirrels, and snakes especially during fallowing (Boahen et al. 2007; Giller 2009).

Cover crops, crop rotation, and intercropping are all promoted with no-till. Cover crops can be used in between cropping cycles or with alley crops to reduce weed infestation. The biomass and better soil cover from cover crops suppresses weed pressure from 75-90% after 8-10 weeks. Cover crops provide other advantages including: providing soil cover, reducing water evaporation, increasing water infiltration, and reduce the soil temperature. 2) Protecting soil against erosion. 3) Adding biomass and organic matter to the soil, feeding the soil. 4) Improving soil structure and preventing compaction. 5) Reducing the incidence of diseases and pests (Derpsch 2002).

Cover crops can be grain legumes (groundnut, cowpea, and common beans) or green manure legumes (mucuna, dolichos, or canavalia). Grain legumes have the advantage of providing a yield that can be sold, increasing income dependent on a surplus grain market. Green manure legumes are encouraged because they have a higher nitrogen fixation rate (Giller 2009), 150 kg N/ha, leaving a biomass rich in nitrogen. The recent promotion of cover crops, especially mucuna, has driven seed prices up. Some farmers harvest, store, and sell seed from the cover crops, increasing their farm income. Canavalia has not been as popular due to its less vigorous growth, hampering its ability to suppress weed growth. For that same reason it is a better cover crop option in mixed cropping systems (Boahen et al. 2007).

Cowpea is a common alley crop that can be grown with a green manure cover crop, usually mucuna. Cowpea is a fast growing shrub species. Mucuna is planted between the rows of cowpeas to protect the soil and control weeds until the cowpea matures. Once the cowpea is harvested both the cowpea and mucuna biomass are cleared and left as cover on the soil before the next crop is planted, usually maize, cassava, or cocoyam. Maize is commonly planted in the major season. 6-8 weeks after the maize is planted a cover crop can be replanted, staggering the planting allows the maize to get a head start, minimizing competition between the crops. If mucuna is not planted at the right time it can compete with maize for sunlight, nutrients, and space causing up to a 30% reduction in yields. The mucuna vines can also climb and pull maize stalks down. Once the maize is harvested the cover crop is allowed to continue to grow until the minor season. This is one example of a popular system that uses cover crops, crop rotation, and intercropping in the region (Boahen et al. 2007).

Permanent cover crops are common on plantations such as oil palm. In this case pueraria is the most common cover crop used to conserve soil moisture and control weeds. Ring weeding around the plantation trees is also utilized to prevent vines from climbing the trees. Fields that suffer from a heavy presence of spear grass may be planted solely with mucuna for a full season to break up the weed cycle. This is common in rice production. Rice is grown during the main season and is followed by mucuna for the minor season to suppress weeds and increase soil fertility before the next major season (Boahen et al. 2007).

A maintained biomass on the soil is one of the most important aspects to the no-till system. During the dry season farmers must take precautions to reduce incidences of fire. Some farmers create fire-belts around their fields. Everyone is encouraged to be vigilant and report any incidences. Sanctions are in place to reduce bushfires in many communities during dry seasons, such as:

- No fire-bearing objects such as matches or lighters on farms
- No hunting
- No use of fire for palm wine tapping
- No smoking in bushy areas.

Overgrazing of animals, especially sheep and goats, is another threat to biomass management. Farmers believe sprinkling their fields with manure reduces the incidences of unwanted grazing. There are bylaws to control livestock grazing, imposing a monetary fine on offenders. The owner of the animal is also responsible for any damage incurred to crops. However, the sanctions are not held up in many communities (Boahen et al. 2007).

The Center recently began promoting the use of weed eaters to clear weeds and crop residue after harvest. Weed eaters allow farmers to cover large areas of land quickly and effectively, greatly reducing labor constraints. Decreased labor demands and mechanization also make agriculture more appealing to youth. The high cost of a weed eater will prohibit the majority of smallholder farmers in the area from purchasing one.

In 2013 the Howard G. Buffet Foundation partnered with John Deere and DuPont Pioneer to develop products to support conservation-based agricultural systems. The effort is being piloted at the Center in Ghana before being applied across Africa. DuPont is identifying locally-adapted and tested seed to increase maize and cover crop productivity. The Center is currently testing improved maize seed on demonstration plots. John Deere is developing no-till equipment for smallholder farmers. The first piece of equipment, a no-till planter, arrived earlier this year (2014) and is being tested.

CHAPTER III

THEORIES OF TECHNOLOGY ADOPTION

Three theories of technology adoption have been discussed in the literature. These are: 1) the innovation-diffusion, 2) the economic constraints, and 3) the technology characteristics- user's context. Extensive research has been done on the effects of economic constraints on the decision process. A less extensive amount of research has been done on the technology characteristics and the innovation diffusion theories. All three theories have had mixed results. This paper will analyze each theory separately before combining all three into one model.

1) The economic constraints theory, or Heckscher-Ohlin factor endowment, contends that the distribution of resource endowments dictates the adoption of a technology. Lack of access to credit or land can constrain the adoption of a technology (Adesina 1992). The model assumes that market prices reflect the scarcity of the endowment, highlighting the importance of a performing market and price policies (Negatu and Parikh 1999).
2) The technology characteristics theory, adopter perception, postulates that the perceived attributes of the technology dictate adoption. The model assumes that characteristics of a technology underlying users' agro-ecological, socioeconomic, and institutional context play a key role in the decision process (Negatu and Parikh 1999).

3) The innovation-diffusion theory, also known as the transfer of technology (TOT), is based on Rogers' (1971) work. In this theory the technology is assumed to be appropriate. The technology is passed from its source (research agents) through a medium (extension worker) to final users (farmers). Access to information is the determinant of whether the technology is adopted. Non-adopters can be persuaded to adopt the technology through extension workers, demonstration plots, and media.

Economic Constraints Theory

Giller et al. (2009) found that low adoption rates of conservation agriculture practices by small holder farmers in SSA is not due to the complexity of the technology but due to economic constraints. The decision to invest in a new technology involves a trade-off in allocation of the limited resources that farmers depend on. Land, labor, feed for livestock, manure for fertilizer or fuel, money to invest in inputs, and lack of markets for produce were found to be key limited resources farmers depend on.

Steiner (1998) found land rights and labor constraints to be important factors in the adoption of no-till. They found that a large constraint in the adoption of no-till is due to some land rights only lasting during the growing season. Once the land is harvested it is accessible to the community for grazing and removal of crop residue. Land rights must be secured for at least the medium term in order for farmers to adopt no-till. The supply and demand of labor during the growing season affects the type of agricultural system used. The demand for labor saving techniques is high throughout West Africa. Male members of the family often times seek work in urban centers along with the increasing school enrollment in regions of Ghana has decreased the labor force. At the same time, an increase in commercial farms and gold mines has increased the demand of labor. Many farmers are no longer able to afford hiring laborers for high wages. The promised lower labor demands of no-till make it attractive compared to the conventional system.

Rahm and Huffman (1984) studied Iowa farmers' probability of adopting reduced tillage technology. They found that adoption depends on firm specific characteristics (soil type, cropping system, farm size) as well as human capital variables. The firm specific characteristics show if the technology is economically feasible for the firm. Included firm specific characteristics were income, access to credit, hectares of land, land tenure, crops grown, and the proximity of the nearest market. The human capital variables were expected to increase the probability of farmers making the economically correct adoption decision. Following human capital theory, allocative skills are assumed to be acquired or learned, not innate. Farmers' schooling, experience, information, and health are expected to enhance allocative skills, increasing the efficiency of adoption decisions. Rahm and Huffman (1984) concluded that the predicted probability of adopting differs widely across sample farms. When adoption is not always economically feasible, the results showed that human capital variables such as schooling enhance the efficiency of the adoption decision.

Gould et al. (1989) hypothesized that a farmer must perceive there is a problem before deciding whether or not to adopt conservation tillage. In their study of conservation tillage adoption they found that age is negatively correlated with adoption meaning younger farmers are more likely to adopt the technology. This is in contrast with the positive relationship they found between experience and perception of an erosion problem. While younger farmers are more likely to adopt a new technology, they are less likely to realize there is a problem. Farm size had similar results. A farmer with a smaller plot is more likely to realize a soil erosion problem but a farmer with a large plot is more likely to adopt a new technology. Overall producer perception of the need for soil conservation was significant in the decision to adopt conservation tillage. Knowler and Bradshaw (2007) stated that farmer awareness of, and concern for, soil erosion is the most critical factor affecting adoption.

Technology Characteristics Theory

Negatu and Parikh (1999) and Adesina and Zinnah (1993) expanded the idea of perception to the technology itself. Negatu and Parikh (1999) found that perception about the modern variety has a highly significant effect on adoption. Perception comes from experience of adoption and that earlier introduction and contact with information sources (city visiting, proximity to towns, etc) of modern technology will induce farmers to use or not to use such a technology. Negatu and Parikh (1999) concluded that the adoption of a modern variety depends on the net benefits proxied by an index measure of perception and other variables such as farm size, income, and soil type.

Adesina and Zinnah (1993) investigated the adoption of improved mangrove rice varieties in Sierra Leone. They ran three variations to determine the significance of the technology characteristic theory: 1) using the farm and farmer specific factors on their own; 2) using farmers' perceptions of the technology-specific factors (technology characteristic theory); and 3) using the farm and farmer specific factors as well as the technology characteristic factors. In the first variant none of the variables were significant at the fiver percent level. Participation in on-farm tests and contact with extension agents were significant at the ten percent level. The results for the second variation, the technology characteristic factors, all of the varietal specific traits, except taste, were highly significant at the one percent level and positively related to the probability of adoption. Combining the farm and farmer specific factors with the technology characteristic factors in the third variation showed that none of the farm and farmer specific factors were significant in the adoption decision. Farmer perceptions of the technology specific traits were a major factor in the adoption behavior. The authors concluded that the omission of farmer perceptions of technology specific characteristics may bias the results of the socio economic factors determining adoption decisions of farmers.

Innovation Diffusion Theory

A farmer's knowledge of a possible technology and perception of the technology is dependent on information. Diffusion of innovations refers to the spread of abstract ideas and concepts, technical information, and actual practices within a social system, where the spread denotes flow or movement from a source to an adopter, typically via communication and influence (Rogers, 1971). Such communication and influence alter an adopter's probability of adopting an innovation (Wejnert 2002). Negatu and Parikh (1999) and Adesina (1992) present a model for the farmer's decision to adopt a technology. The decision is based on the assumption of utility maximization which remains unobserved. If the expected utility of no-till is higher than the expected utility of the conventional method the farmer will adopt no-till. The farmer’s expectations depend upon the information they receive about the technology through the diffusion of innovation process.

Spatial effects such as geographic proximity, interpersonal communication, institutional or individual coercion, and the pressure of social networks play key roles in the spread of a technology to a potential adopter and their expected utility of no-till (Wejnert 2002). Contact alone will not promote adoption if the information dissemination process is ineffective, inaccurate, or inappropriate (Knowler and Bradshaw 2007). No-till is a knowledge intensive technology. Farmers need to change crop and soil management practices simultaneously to fully adopt the technology and net the full benefits. The knowledge intensive nature of no-till makes it imperative for farmers to have a reliable information source (Giller 2009).

The source of the information (experimental plots, extension agent, neighboring farmer, etc) may affect the faith the decision maker has in the reliability of the information with the farmer’s own experience outweighing all others (Marra et al. 2001). Some farmers will experiment with no-till on small areas of land until they are convinced of the benefits before fully adopting the technology (Giller 2009). When own farm information is not available farmers appear to more equally weight a variety of information sources, including technology depreciation, cost differences, and popularity of the new technology. The probability of adoption of the new technology increases when the current technology is becoming less effective. As the current technology’s effectiveness decreases farmers will seek out information on new technologies and will be less risk adverse (Marra et al. 2001).

CHAPTER IV

METHODOLOGY

Agricultural systems involve many interacting components. Bio-physical, socio-economic, and cultural constraints must be appropriate for the technology to have wide adoption; a successful technology in one region may not fit the constraints of another, making it imperative to look at regional data (Giller 2009). The data used in the study is based on a survey of farmers in 11 villages in the Ashanti region of Ghana. The villages were selected and categorized by Dr. Boa from the Center[2] into three categories: 1) villages with farmers who most likely would have visited or passed by the Center (Amanchia and Ahwerewa); 2) villages with farmers who most likely would have heard about the Center but may not have attended (Koberg, Seidi, and Wiawso); and 3) villages with farmers who most likely have not heard of the Center (Toase, Nkawie Kuma, Nkawie Panin, Sepaase, Manhyia, and Koforidua).

Table 1 shows the farmer and farm characteristics by village and category. Table 2 shows which crops are grown in the different villages and the average percentage of acres grown under no-till. Maize and cocoa are the most commonly grown crops followed by cassava and plantain. Fruit crops had the highest percentage grown under no-till at 67%. Maize, cocoa, cassava, and plantain followed with 40-49% of acres under no-till. For crops that were not grown under no-till farmers were asked to identify why no-till was not used for that specific crop, the results are reported in table 3. Weeding and difficulty of implementing no-till were the most common reason stated for maize, cocoa, cassava, plantain, and cocoyam followed by a lack of information. Lack of information and weeding were the most common for fruit while difficulty of implementing, lack of information, and weeding were the most common reasons stated for vegetables.

The participants were surveyed in July and August of 2014. The survey included questions on the socioeconomic and biophysical characteristics of the farmer; information sources and their value; the farmer's perception of erosion, fertility, and pests; and the farmer's perception of no-till compared to conventional tillage (slash and burn).

Farmers' adoption decision is based on the assumption of utility maximization (Negatu and Parikh 1999; Adesina and Zinnah 1993; Rahm and Huffman 1984). The decision on whether or not to adopt no-till technology in relation to conventional tillage is based on marginal net benefits. Working from (Adesina and Zinnah's 1993) model, we can define the varietal technologies by j, where $j=1$ for no-till and $j=2$ for the conventional system. The unobservable utility function that ranks the preference of the i^{th} farmer is given by $U(M_{ji}, A_{ji})$.The utility derivable from the technology depends on a vector of M which is composed of farm and farmer-specific attributes and A which is a vector of the attributes associated with the technology. The relation between the utility derivable from a j^{th} technology is postulated to be a function of the vector of observed farm/farmer specific characteristics (e.g. farm size, age, experience, information, perceived problem), the technology specific characteristics (e.g. perceived yield, tolerance, fertility, etc), and a disturbance term having a zero mean:

$$U_{ji} = \alpha_j F_i(M_i, A_i) + \varepsilon_{ji} \qquad j = 1,2; i = 1, \dots, n \qquad (1)$$

Equation (1) does not restrict the function F to be linear. As the utilities U_{ji} are random, the *i*th farmer will select no-till if $U_{1i} > U_{2i}$ or if the non-observable (latent) random variable $Y_i^* = U_{1i} - U_{2i} > 0$. The probability that Y_i equals one (the farmer adopts no-till) is a function of the independent variables:

$$P_i = \Pr(Y_i = 1) = \Pr(U_{ji} > U_{2i})$$

$$= \Pr[\alpha_1 F_i(M_i, A_i) + \varepsilon_{1i} > \alpha_2 F_i(M_i, A_i) + \varepsilon_{2i}]$$

$$= \Pr[\varepsilon_{1i} - \varepsilon_{2i} > F_i(M_i, A_i)(\alpha_2 - \alpha_1)]$$

$$= \Pr(\mu_i > -F_i(M_i, A_i)\beta)$$

$$= F_i(X_i\beta) \qquad (2)$$

where X is the $n \times k$ matrix of the explanatory variables, and β is a $k \times 1$ vector of parameters to be estimated, Pr(.) is a probability function, μ_i is a random error term, and $F(X_i\beta)$ is the cumulative distribution function for μ_i evaluated at $X_i\beta$. The probability that a farmer will adopt no-till is a function of the vector of explanatory variables and of the unknown parameters and error term. Equation (2) cannot be estimated without knowing the form of F, determined by the distribution of μ_i. If μ_i is normal than F will have a cumulative normal distribution (Adesina and Zinnah 1993).

The Probit[3] model is used because the observed variable has possibilities (1,0) where the latent variable is observed through the index function.

$$Y_i = 1 \qquad \text{if } i^* = X_i\beta + \mu_i > 0$$

$$Y_i = 0 \qquad \text{if } i^* = X_i\beta + \mu_i \leq 0 \qquad (3)$$

The dependent variable is whether the land is cultivated using no-till or conventional methods. Thirty-nine potential explanatory variables were identified and are listed with their names, symbols, units of measurement and means and standard deviations of the variables used in the study in table 4. The explanatory variables are grouped into four categories: farmer characteristics, economic constraints, perception of suitability or characteristics of the land or technology, and innovation diffusion.

The farmer characteristic variables include experience, gender, and education level. Experience was measured by the number of years the farmer has been the decision maker. The effect of experience on the adoption decision is unclear. Farmers with more experience may be able to assess the characteristics of the technology and soil degradation issues better than younger farmers. However, older farmers tend to be more risk averse making them less likely to adopt a new technology compared to younger farmers (Adesina and Baidu-Forson 1995). Older farmers also tend to have a shorter planning horizon, reducing the present value for any future long-term returns (Gould et al. 1989).

Literature shows mixed effects of gender on the adoption decision. In some cases females have been more willing to try new technologies to increase profits. In other studies female headed households have been known to be some of the poorest houses making them more risk averse (Knowler and Bradshaw 2007).

Education is hypothesized to have a positive effect on the adoption decision. Farmers with higher education possess higher allocative skills making them better equipped to adjust to farm and market conditions (Parvan 2011) as well as obtain and process information regarding the productivity and benefits of a new technology (Gould et al. 1989). A farmer with more education is also more confident in their ability to find other streams of income in case a new endeavor fails, making them more willing to take on the risk of a new technology (Parvan 2011).

The economic constraint variables include land tenure (land system, that is, owned, leased, sharecropped), farm size, household income, proximity to market, health, access to credit, size of the household, labor, and off-farm income.

Land tenure, farm size, household income, proximity to market, health, and access to credit are hypothesized to have a positive effect on the adoption decision. It is the most vulnerable communities, those that cannot afford a decrease in output, that are the least likely to adopt a new technology. Secure tenure rights reduce risk and uncertainty and increase the planning horizon (Parvan 2011). Table 5 shows land tenure by agricultural system. Owned land is substantially more common in both agricultural systems followed by share-cropped and long-term leases.

A larger farm gives a farmer the advantage of economies of scale, allowing a farmer to spread the cost of adopting a new technology across more land reducing the marginal cost (Adesina and Zinnah 1992; Giller et al. 2009). In addition, soil conservation on small farms is especially costly due to increases in the short-run risk of consumption shortfall with certainty (Parvan 2011).

Household income is the level of income available to the farm household and is composed of net farm income, off-farm wages, non-farm self-employment, returns from investments, remittances, and other passive income and transfers. Farmers with a larger household income have a higher discount rate implying a longer planning period than poorer farmers with a preference for current versus future incomes. Households with a larger income are also less risk averse making them more willing to adopt a new technology (Gould et al. 1989).

A farmer in poor health has a short planning horizon, choosing present returns over future possible returns and is therefore less likely to adopt a new technology (Rahm and Huffman 1984).

Hired labor and the size of the household are hypothesized to negatively impact the adoption of no-till. No-till is believed to be a labor saving technology, incentivizing farmers to adopt in the labor scarce Ashanti region (Boahen et al. 2007; Ekboir 2003). Larger households may be more risk averse due to the higher demand for food to feed their family. In addition, larger households have a larger supply of labor reducing the marginal utility of no-till being a labor saving technology (Ekboir 2003).

Off farm income and the use of technology's effect on the adoption decision is a priori uncertain. Off-farm income was measured as a proportion of the total income that comes from off farm wages. A farmer with a lower amount of time spent on the farm might have a smaller concern for maintaining soil productivity. On the contrary, no-till agriculture requires less labor at critical planting periods, making it attractive to a farmer who is attempting to maintain a farm while working (Gould et al. 1989).

The innovation diffusion variables include participation in the Center's interventions (pre-season training, on farm demos, field days/tours, workshops, seminars, and Sunday school) and contact from extension agents and other no-till farmers. It is hypothesized that interventions at the Center and contact with extension agents and no-till farmers will have a positive effect on adoption. More contact with the Center increases the farmer's knowledge of the technology and exposure to it, increasing the probability the farmer adopts the technology (Adesina and Zinnah 1992; Adesina and Baidu-Forson 1995).

Farmers' subjective assessments of no-till, including: yield performance, water and wind tolerance, the ease of application, soil fertility, and the amounts of fertilizer and pesticide needed were measured by comparing no-till to conventional agriculture (slash and burn). It is hypothesized that yield performance, water and wind tolerance, the ease of application, and soil fertility will be positively related to the adoption decisions. A higher yield performance increases food security and profits. Higher water and wind tolerance as well as soil fertility will lead to higher yields. Ease of application, the ease of implementing the agricultural system, is hypothesized to be greater in no-till, less labor is needed under the no-till system. The amounts of fertilizer and pesticide needed will be negatively linked to the adoption decision. If a farmer perceives there will be a larger requirement of fertilizer and pesticide, a greater cost and greater risk, (s)he will be less likely to adopt no-till (Marra et al 2001).

Farmers that are concerned with soil degradation (fertility, erosion, drought, and pests) and perceive it to be a problem are hypothesized to be more likely to adopt soil conservation practices such as no-till on their farm (Gould et al 1989).

Some of the variables in the model are interrelated and can lead to multicollinearity problems. When collinearity exists among the explanatory variables they can be replaced by a smaller number of variables that account for most or all of the variation. The smaller number of variables are derived using principal components (PC) analysis (Negatu and Parikh 1999).

Two PC variables were derived for the economic constraints model. Income combined the total household and the proportion of income from off-farm wages into a PC variable. Use of fertilizer/herbicide/pesticide and irrigation were combined into a PC input variable. Four PC variables were extracted for the technology characteristic model: one PC variable from the five soil degradation variables and three PC variables from the seven variables assessing the farmer's perception of no-till. Multicollinearity was not present in the innovation diffusion variables so no PCs were extracted. PC variables, eigenvalues, and component weights are listed in table 6.

To account for correlation of errors within a village, standard errors were clustered by village.

CHAPTER V

STATISTICAL ANALYSIS

Four models were estimated to test the three theories of technology adoption. The first three models included explanatory variables addressing one of the three models: 1) Economic Constraints, 2) Technology Characteristics, and 3) Innovation Diffusion. The final model combined the explanatory variables from all three theories.

All four models included three explanatory variables for farmer characteristics: gender, experience, and education. Gender is significant at the five percent level for the technology characteristics and combined models. Gender is measured as a dichotomous variable with 1=male and 0=female and is positively correlated to the adoption decision, males are more likely to adopt no-till. Female headed households tend to be more vulnerable, making them more risk averse and therefore less likely to take the risk of adopting a new technology (Parvan 2011).

Experience is significant at the five percent level in the technology characteristics and combined models. Experience is negatively correlated, farmers with fewer years as the head of the household are more likely to adopt no-till. The farmer’s previous experience with innovations can have a positive or negative influence on their perception of no-till. Older farmers, more experienced farmers, tend to be more risk averse than younger farmers giving them a shorter planning horizon (Ghadim and Pannell 1999). Education was not significant in any of the models.

Economic Constraints Model

Ten exogenous variables, including a principal component variable for income and input, were included in the economic constraints model. The results are reported in table 7. Three variables were significant at the five percent level: labor, tenure, and income.

Labor is negatively correlated with no-till. The relationship between the supply and demand of labor during the peak periods (preparing land, planting, weeding, and harvesting) is one of the main factors determining the type of agricultural system that is used. Labor is one of the largest costs of production. No-till is considered a labor saving agricultural system; no-till farmers are able to produce crops with little to no hired labor after the initial clearing of land. The lower demand for labor allows farmers to decrease cost and therefore increase profits, incentivizing farmers to adopt no-till (Boahen et al. 2007; Ekboir 2003; Steiner 1998). Table 11 reports the uses of hired labor by agricultural systems. 71% of no-till households hired labor while 81% of conventional households did. Weeding is the most common use of hired labor under both agricultural systems followed by planting, harvesting, and preparing land.

Tenure is positively correlated with the adoption decision. The benefits from conservation agriculture are not realized immediately making it imperative that farmers have land rights for a few years to adopt no-till (Steiner 1998).

Income was derived as a principal component with equal component weight (refer to table 6) on total household income and the proportion of income from off-farm wages. Income is positively correlated to the adoption decision. A farmer with a higher income is more likely to adopt no-till because they are less risk averse, making him/her able to endure the uncertainty of adopting a new technology. In addition, higher income farm operators are better able to purchase the recommended no-till inputs, pesticides, herbicides, and fertilizers (Gould et al. 1989). The lower demand for labor also makes no-till attractive to farmers that work off the farm as well.

Technology Characteristics Model

Five exogenous variables were used to test the technology characteristics model. Perception of a problem and three perception of no-till variables were derived using principal components. Only one technology characteristic variable, popularity, was significant at the five percent confidence level in addition to two farmer characteristic variables, gender and experience. The results are reported in table 8.

Popularity of no-till is positively correlated to the adoption decision. If a farmer perceives no-till to be popular they are more likely to adopt no-till. Peer pressure and community norms can greatly affect a farmer's decision to adopt a new technology (Wall 2007).

Innovation Diffusion Model

Five exogenous variables in addition to the three farmer specific characteristics were used to estimate the innovation diffusion model, reported in table 9. Three variables were significant: in person contact with extension agents, in person contact with other farmers, and attendance at the Center.

In-person contact with extension agents was negatively correlated to the adoption decision. Trust determines the role an advisor plays in the decision making process. Farmers tend to trust peers and farmers that demonstrate similar traits as themselves over extension agents or outside parties (Pannell et al 2006).

In-person contact with other no-till farmers was positively correlated. The more contact with other farmers the more likely a farmer is to adopt no-till. Higher contact frequency increases the farmer's knowledge of no-till while decreasing their uncertainty of the new technology (Ghadim and Pannell 1999).

Similarly, if the farmer attended the Center (s)he is more likely to adopt no-till. Attendance at the Center will increase the farmer's knowledge of no-till including the benefits. This will positively affect the farmer's perception of no-till and increase his/her confidence in the new technology (Ghadim and Pannell 1999).

Combined Model

Adesina and Zinnah (1992) demonstrated that only including variables from one theory in an adoption model can bias the results. In order to test Adesina and Zinnah's conclusion, the variables from the three previous models are combined and reported in table 10. Similar to Adesina and Zinnah's (1992) findings, two previously significant variables (tenure and popularity) are not significant in the combined model while land size and perception of a problem became significant.

Eight variables are significant at the 5% level in the combined model: two farmer characteristic, four economic constraints, one technology characteristic, and three innovation diffusion variables. The significant farmer specific characteristics are gender and experience.

Two of the variables from the economic constraint model remained significant and had the same effect as previously stated, labor and income. Tenure is significant in the economic constraint model but is not in the combined model while total land is only significant in the combined model.

Land size is positively correlated to the adoption decision. The larger the farm size the more likely a farmer is to adopt no-till. Farmers with larger parcels of land are better equipped to weather small and medium shocks that may occur when adopting a new technology. The larger amount of land makes them less risk averse. A large plot allows farmers to set aside a small portion of the land to test a new technology while keeping the rest of the land under conventional methods (Parvan 2011). In addition, farming a larger land area requires more labor to prepare the land, plant, weed, and harvest. Therefore, a farmer with a larger parcel of land is more likely to adopt a labor saving technology such as no-till (Fernandez-Cornejo et al 2001).

One technology characteristic variable, perception of a problem, is significant at the 5% level only in the combined model. Popularity of the technology is no longer significant in the combined model.

Perception of a problem is negatively correlated to the adoption decision. A farmer that perceives there to be a problem on his land is less likely to adopt no-till. The variable was derived using principal component analysis. The variables with the highest component weight in the derived principal component variable are perceived problems with pests and drought. Pest infestation can cause significant yield losses. The crop residue, mulch, can increase the presence of pests such as leaf borers, millipedes, caterpillars, and grasshoppers as well as rodents (Boahen et al. 2007), turning farmers that perceive there to be a pest problem away from no-till.

Three innovation diffusion variables, in-person contact with extension agents, in-person contact with other farmers, and attendance at the Center remained significant in the combined model with the same effect.

CHAPTER VI

CONCLUSIONS

A farmer's decision to adopt no-till is a multifaceted decision. The data showed variables from all three models are significant in the farmer's decision. Looking at only one model can lead to a skewed picture and over emphasis on one area, leading to ineffective policies and projects with poor adoption rates. All three models should be considered to create policies and projects to increase adoption rates of no-till.

The economic constraints model identifies areas/people that policy and projects can target to overcome risk and uncertainty in the adoption decision. Technology specific characteristics show possible misconceptions of the technology where education is needed as well as benefits that farmers are interested in that can be highlighted. The innovation diffusion model demonstrates which avenues will reach the most people for widespread adoption. The combined model once again highlights the importance in looking at all three models together to avoid over significance on one model or variable in the adoption decision.

The Government of Ghana supported the development of agricultural systems that conserved natural resources and decreased desertification through several projects in the early 20th century. Although the projects have since commenced, they led to the development of a no-till system for Ghana. If the GoG wishes to continue to promote conservation agriculture and increase adoption rates there are a few policies they can in act.

Income support systems have been used to promote conservation agriculture in countries such as Australia (Pannell et al 2006) and Canada (Stonehouse and Bohl 1993). Under an income support system, no-till farmers receive an annual subsidy from the government. The additional income from a support system would help low income farmers, a group identified in the economic constraint model, overcome the risk of adopting no-till by providing them an immediate return to adoption. Compliance under a support system is by choice, making it more politically feasible and economically efficient versus a tax or penalty system that has been used in some incidents (Knowler and Bradshaw 2007; Stonehouse and Bohl 1993).

Research and development of complementary equipment such as planters is needed to make no-till feasible for larger scale, mechanized, and commercial farmers to adopt. The developed equipment should be locally produced and affordable. Larger farmers face a significant initial investment and transition cost associated with switching agricultural systems. Financial assistance in the form of machine rentals, cost-sharing programs and direct subsidies can be used to help farmers overcome the initial investment.

Less direct policies have been used to enable an environment of adoption through investments in social capital (Isham 2002). Targeted promotions and educational programs can foster discussions on conservation agriculture. A consensus in the community on the benefits of conservation agriculture to the environment can create a farmer pride and interest in “doing the right thing”. Pride, peer pressure from the community, and popularity of a technology can motivate adoption.

Two models showed gender to be significant in the adoption decision. Research is needed to identify what is inhibiting women from adopting no-till whether it is an economic constraint, lack of access to information, or the technology is less suitable for women. Once the inhibiting factor(s) is identified appropriate policies can be put in place to overcome female headed households' limitation in adopting no-till.

The Center has a significant impact on the adoption of no-till. Efforts to scale up the Center's activities to reach more farmers would increase the widespread adoption of no-till. The Center should utilize no-till farmers to diffuse information. In person contact with other no-till farmers is the most significant variable for adoption in both the innovation diffusion and combined model. Trust determines the role an advisor plays in the decision making process. Farmers tend to trust peers and farmers that demonstrate similar traits as themselves over extension agents or outside parties (Pannell et al 2006). A training of trainers program would utilize farmers trust in one another to disseminate no-till. Selected farmers would receive additional training to become a farmer-trainer. Selected farmers should represent a large geographical area to reach farmers in different regions. The farmer-trainer is then expected to hold farmer field schools within their own community.

Factors that influence the decision to adopt no-till are region specific. The factors identified in this paper are specific to the Ashanti region of Ghana. Although the identified factors may not be applicable in different regions of Ghana or other countries the models can be used universally by policymakers to identify factors that influence the adoption decision.

ENDNOTES

1. The account for the Historical Development of Conservation Agriculture in Ghana is based on Boahen et al (2007).
2. Some selection bias may be present.
3. The models were analyzed using both probit and tobit. The dependent variable for tobit is the percentage of land in production under no-till. The models more effectively explained the binary decision to adopt versus the degree at which they adopt, which is why the binary probit model was used for this paper. Further research in this area is needed.
4. Proximity to market was removed due to a bias in the data.

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APPENDIX

Table 1. Farm and Farmer Characteristics by Village

Village	No of farmers	% of Female HH*	Years as head of HH*	Age*	Educ years*	Adults in HH *	Dep'ts in HH*	Access to Credit	Distance to Market*	Hired Labor	Total Income*	% from Off Farm Income*	Remittences	Plot size*	% in No-Till*	Raise Livestock	Irrigate	Used Fert/Pest /Herb	Attended the Center
Ahwerewa	99	36%	18	47	7	3	4	7	13	76	2912.71	29%	25	3	47%	56	37	94	37
Amanchia	104	46%	21	47	8	2	3	5	11	72	1898.04	24%	24	2.49	57%	49	17	96	63
Category 1	**203**	**41%**	**20**	**47**	**8**	**3**	**4**	**6**	**12**	**148**	**2405.37**	**27%**	**49**	**2.745**	**52%**	**105**	**54**	**190**	**100**
Koberg	120	56%	13	43	6	3	3	2	10	86	1380.59	3%	8	8	56%	66	31	98	41
Waiso	33	30%	13	46	6	3	4	1	4	23	1029.85	1%	2	5	57%	15	5	32	12
Seidi	83	51%	13	43	7	3	2	3	8	56	429.43	1%	3	7.8	44%	42	41	75	37
Category 2	**236**	**46%**	**13**	**44**	**6**	**3**	**3**	**6**	**7**	**165**	**946.62**	**2%**	**13**	**6.9**	**52%**	**123**	**77**	**205**	**90**
Koforidua	28	21%	12	44	9	3	1	4	15	28	1629.69	33%	1	2	7%	11	10	25	0
Manhyia	20	25%	16	45	6	2	2	3	14	15	988.66	39%	4	1.1	30%	2	10	18	0
Nkawie	87	47%	20	49	7	2	4	1	0.3	72	1167.72	10%	10	2.4	49%	29	4	79	13
Sepasse	16	56%	16	46	7	4	3	0	4.5	8	5938.48	77%	1	3.9	41%	9	3	13	1
Toase	40	65%	23	50	8	3	3	0	1	33	1654.18	31%	9	2.75	30%	20	3	35	1
Category 3	**191**	**43%**	**17**	**47**	**7**	**3**	**3**	**8**	**7.0**	**156**	**2275.75**	**38%**	**25**	**2.43**	**31%**	**71**	**30**	**170**	**15**

*are reported as averages; all others are totals

Table 2. Total Acreage and Percentage in No-Till by Crop

	Maize		Cocoa		Cassava		Plantain		Cocoyam		Fruit		Vegetables		Other	
Village	Acres	% No-Till*	Acres	% No-Till*	Acres	% No-Till*	Acres	% No-Till*	Acres	% No-Till*	Acres	% No-Till*	Acres	% No-Till*	Acres	% No-Till*
Ahwerewa	103.8	56%	111.7	43%	52.8	46%	72.0	46%	38.5	47%	0	-	19.6	86%	2.1	0%
Amanchia	83.5	64%	62.4	43%	42	57%	61.6	56%	18.2	50%	0.2	100%	10.1	55%	1.9	67%
Category 1	187.3	60%	174.0	43%	94.8	52%	133.6	51%	56.7	49%	0.2	100%	29.7	70%	4.0	33%
Koberg	352	61%	403.5	67%	294.0	51%	289.8	56%	264.5	52%	99	66%	633.7	49%	156.5	48%
Waiso	56	56%	18	53%	34.7	52%	16.5	86%	6	33%	16	100%	12.8	34%	12.0	20%
Seidi	255.9	51%	136.5	44%	208.2	37%	140.2	42%	179.1	30%	48	1%	467.7	26%	36.0	40%
Category 2	663.8	56%	558.0	55%	536.8	47%	446.5	61%	449.6	39%	163.0	56%	1114.1	37%	204.5	36%
Koforidua	3.9	6%	5.6	75%	2.4	13%	0.5	33%	0.1	0%	0	-	14.5	0%	7.4	0%
Manhyia	7.7	35%	7.6	0%	7.2	43%	1.6	74%	1.5	50%	1	100%	1.8	0%	0.8	0%
Nkawie	51.3	55%	93.5	50%	32.5	35%	14.3	50%	5.2	40%	9.6	50%	0.4	0%	9.5	41%
Sepasse	15	35%	38.8	40%	15.5	30%	5.6	25%	6.5	20%	0	-	2.0	13%	2.3	50%
Toase	34.4	29%	29.1	19%	39.5	33%	17.6	24%	15.2	19%	5.1	50%	0.8	100%	0.0	0%
Category 3	112.3	32%	174.6	37%	97.1	31%	39.6	41%	28.5	26%	15.7	67%	19.5	23%	20.0	18%
Total	**963.4**	**45%**	**906.6**	**43%**	**728.7**	**40%**	**619.7**	**49%**	**534.7**	**34%**	**178.9**	**67%**	**1163.3**	**36%**	**228.4**	**26%**

*are reported as averages; all others are totals

Table 3. Reasons Given for Not Using No-Till by Crop

Crop	Weeding	Difficulty	Cost	Lack of Information	Pest	Lack of Mechanization	Other
Maize	94	95	24	63	18	2	11
Cocoa	47	49	9	48	5	5	8
Cassava	99	90	24	65	17	3	7
plantain	70	58	18	56	13	1	1
Cocoyam	57	52	20	33	12	1	5
Fruit	7	4	3	8	1	2	0
Vegetables	83	110	47	90	62	4	4
Other	18	27	8	15	11	5	2
Total	**475**	**485**	**153**	**378**	**139**	**23**	**38**

Table 4. Names, Symbols, and Descriptive Statistics of Variables in the Study

Name of Variable	Unit	Symbol	Expected Sign	Mean	Standard Deviation
Farmer Characteristics					
Experience	Years	Experience	?	16.788	12.794
Gender	(0,1)	Gender	?	0.542	0.499
Education completed	Years	Education	+	6.964	4.354
Economic Constraint					
Health	0(poor), 1, 2, 3, 4(excellent)	Health	+	2.590	1.221
Size of household	Number of people	Household	-	5.981	3.276
Hired labor	(0,1)	Labor	-	0.754	0.431
Total land	Acres	Land	+	4.443	6.278
Irrigate*	(0,1)	Irrigate	?	0.254	0.435
Fertilizer/Herbicide/ Pesticide*	(0,1)	Fert/Herb/Pest	?	0.905	0.294
Household Income*	Cedis	HHIncome	+	1572.049	3203.931
Proportion of income from Off-farm wages*	Proportion	OffFarmInc	?	0.166	0.289
Tenure	(0,1,2,3,4)	Tenure	+	3.460	0.932
Innovation Diffusion					
In person contact w/ extension agent	Times per month	Ext. Agent in person	+	1.209	2.769
Contact w/ extension agent by phone	Times per month	Ext. Agent by phone	+	0.187	1.432
In person contact w/ no-till farmer	Times per month	Farmer in person	+	1.310	3.177
Contact with no-till farmer by phone	Times per month	Farmer by phone	+	0.120	1.726
Center Intervention	(0,1)	Center	+	0.323	0.468
Technology Characteristics					
Soil fertility problem*	0(none), 1, 2, 3 (large problem) (P)	Fertility Problem	+	0.614	0.878
Erosion problem*	0(none), 1, 2, 3 (large problem) (P)	Erosion Problem	+	0.586	0.851
Drought problem*	0(none), 1, 2, 3	Drought Problem	+	0.887	0.994

	(large problem) (P)				
Pest problem*	0(none), 1, 2, 3 (large problem) (P)	Pest Problem	+	1.233	1.124
Other problem*	0(none), 1, 2, 3 (large problem) (P)	Other Problem	+	0.252	0.603
Yield performance*	0(less), 1, 2, 3, 4(more) (P)***	Yield	+	3.754	0.612
Drought tolerance*	0(less), 1, 2, 3, 4(more) (P)***	Drought	+	3.065	1.221
Erosion tolerance*	0(less), 1, 2, 3, 4(more) (P)***	Erosion	+	1.166	1.252
Soil fertility*	0(less), 1, 2, 3, 4(more) (P)***	Soil fertility	+	3.747	0.656
Fertilizer demand*	0(less), 1, 2, 3, 4(more) (P)***	Fertilizer	-	0.563	0.840
Pesticide demand*	0(less), 1, 2, 3, 4(more) (P)***	Pesticide	-	1.312	1.010
Ease of application*	0(less), 1, 2, 3, 4(more) (P)***	Application	+	2.149	1.465
Popularity of no-till	0(unpopular), 1, 2, 3, 4(popular) (P)	Popularity	+	1.769	1.124

(P) Refers to a perception variable; *Variable used in Principal Component Analysis; **Farmer’s own use of technology compared to other farmers; ***farmer’s perception of no-till compared to conventional agriculture.

Table 5. Land Tenure by Agricultural System

Agricultural System	Total	Owned		Share-cropped		ST Lease		LT Lease		Other		Land Title	Lease Contract	Land Dispute
	HH	Acres	HH	Acres	HH	Acres	HH	Acres	HH	Acres	HH	HH	HH	HH
No-Till	363	1077.4	273	281.5	51	31.5	17	151.8	47	23.6	19	74	15	54
Conventional	268	812.35	177	213.2	45	74.2	13	68.2	31	69.5	15	72	10	37
Total	**631**	**1889.75**	**450**	**494.7**	**96**	**105.7**	**30**	**220**	**78**	**93.1**	**34**	**146**	**25**	**91**

Table 6. Principal Components Analysis

Component	Eigenvalues IncPC	InputPC	ProbPC	PercTechPC
Comp1	1.214*	1.114*	1.974*	1.570*
Comp2	0.786	0.886	0.989	1.236*
Comp3	.	.	0.725	1.029*
Comp4	.	.	0.687	0.912
Comp5	.	.	0.624	0.635
Comp6	.	.	.	0.619

Principal Component Weights (eigenvectors)

PC Variable	Components	Comp1	Comp2	Comp3	Comp4	Comp5	Comp6
IncPC	HHInc	0.707	0.707	.	.	.	.
	OffFarmInc	0.707	-0.707	.	.	.	.
InputPC	Irrigate	0.707	0.707	.	.	.	.
	Fert/Herb/Pest	0.707	-0.707	.	.	.	.
ProbPC	Fertility prob	0.489	-0.067	-0.474	0.670	-0.287	.
	Erosion prob	0.465	-0.176	0.836	0.161	-0.168	.
	Drought prob	0.522	-0.117	-0.124	-0.127	0.826	.
	Pest prob	0.501	0.069	-0.218	-0.705	-0.448	.
	Other prob	0.145	0.973	0.119	0.110	0.081	.
PercTechPC	Drought	0.405	0.454	0.414	-0.298	-0.375	-0.479
	Erosion	0.502	0.097	-0.162	0.646	-0.440	0.319
	Soil fertility	-0.162	0.750	0.102	-0.125	0.189	0.591
	Fertilizer	0.321	-0.467	0.532	-0.336	-0.042	0.531
	Pesticide	0.619	0.066	-0.080	0.074	0.764	-0.128
	Application	-0.269	0.007	0.709	0.600	0.209	-0.145

*Denotes significant eigenvalues, >1, that were used in the analysis.

Table 7: Estimated Probit Coefficients for the Economic Constraints Model

No-Till	Coefficient	Standard Error	Z	P > Z	[95% Confidence Interval]	
Gender	0.228	0.161	1.410	0.158	-0.089	0.544
Experience	-0.009	0.005	-1.770	0.077	-0.019	0.001
Education	0.010	0.011	0.900	0.366	-0.012	0.031
Health	0.007	0.053	0.130	0.898	-0.096	0.110
Input**	-0.036	0.067	-0.530	0.595	-0.167	0.096
HH	-0.003	0.018	-0.150	0.885	-0.038	0.033
Labor	-0.351	0.162	-2.170*	0.030	-0.669	-0.034
Land	0.015	0.013	1.180	0.240	-0.010	0.041
Tenure	0.102	0.047	2.180*	0.029	0.010	0.193
Income**	0.101	0.043	2.330*	0.020	0.016	0.186
Intercept	-0.090	0.232	-0.390	0.698	-0.544	0.364

*Critical value at 5% level.

**Denotes Principle Component Analysis variables.

Number of observations = 630

Log Pseudolikelihood = -414.157

Pseudo R2 = .036

Table 8: Estimated Probit Coefficients for the Technology Characteristics Model

No-Till	Coefficient	Standard Error	Z	P > Z	[95% Confidence Interval]	
Gender	0.294	0.121	2.440*	0.015	0.058	0.530
Experience	-0.015	0.006	-2.680*	0.007	-0.026	-0.004
Education	0.002	0.009	0.260	0.799	-0.015	0.020
Problem**	-0.089	0.055	-1.600	0.109	-0.198	0.020
Pertech1**	0.000	0.090	0.000	0.998	-0.177	0.177
Pertech2**	0.006	0.052	0.120	0.903	-0.096	0.109
Pertech3**	-0.073	0.064	-1.140	0.252	-0.198	0.052
Popularity	0.156	0.060	2.590*	0.010	0.038	0.274
Intercept	0.119	0.253	0.470	0.637	-0.376	0.614

*Critical value at 5% level.

**Denotes Principle Component Analysis variable.

Number of observations = 519

Log pseudolikelihood= -326.728

Pseudo R2 = .046

Table 9: Estimated Probit Coefficients for the Innovation Diffusion Model

No-Till	Coefficient	Standard Error	Z	P > Z	[95% Confidence Interval]	
Gender	0.241	0.154	1.560	0.118	-0.061	0.542
Experience	-0.005	0.006	-0.860	0.390	-0.017	0.007
Education	0.004	0.009	0.480	0.634	-0.014	0.023
Ext. agent by phone	-0.075	0.070	-1.060	0.290	-0.213	0.064
Ext. agent in person	-0.044	0.017	-2.500*	0.012	-0.078	-0.009
Farmer by phone	0.106	0.376	0.280	0.777	-0.630	0.843
Farmer in person	0.154	0.053	2.910*	0.004	0.050	0.257
Center	0.428	0.166	2.570*	0.010	0.102	0.754
Intercept	-0.134	0.159	-0.840	0.398	-0.445	0.177

*Critical value at 5% level.

Number of observations= 564

Log pseudolikelihood= -346.648

Pseudo R2=.104

Table 10: Estimated Probit Coefficients for the Combined Model

No-Till	Coefficient	Standard Error	Z	P > Z	[95% Confidence Interval]	
Gender	0.231	0.094	2.460*	0.014	0.047	0.415
Experience	-0.014	0.008	-1.730*	0.083	-0.030	0.002
Education	0.005	0.019	0.280	0.782	-0.031	0.042
Health	-0.002	0.045	-0.050	0.957	-0.090	0.085
Input**	0.055	0.072	0.760	0.444	-0.086	0.195
HH	-0.003	0.016	-0.180	0.860	-0.033	0.028
Labor	-0.477	0.198	-2.410*	0.016	-0.866	-0.088
Land	0.057	0.027	2.100*	0.036	0.004	0.111
Tenure	0.054	0.064	0.830	0.406	-0.073	0.180
Income**	0.080	0.042	1.920	0.055	-0.002	0.162
Problem	-0.126	0.042	-3.020*	0.003	-0.208	-0.044
Pertech1	-0.024	0.084	-0.280	0.779	-0.189	0.142
Pertech2	0.062	0.046	1.330	0.182	-0.029	0.152
Pertech3	-0.096	0.049	-1.950	0.051	-0.193	0.000
Popularity	0.070	0.047	1.470	0.142	-0.023	0.163
Ext. agent by phone	-0.047	0.050	-0.940	0.347	-0.146	0.051
Ext. agent in person	-0.070	0.011	-6.240*	0.000	-0.092	-0.048
Farmer by phone	0.139	0.353	0.390	0.693	-0.552	0.831
Farmer in person	0.149	0.060	2.460*	0.014	0.030	0.267
Center	0.377	0.191	1.980*	0.048	0.003	0.751
Intercept	0.006	0.369	0.020	0.988	-0.717	0.728

*Critical value at 5% level.

**Denotes Principle Component Analysis variable.

Number of observations = 462

Log pseudolikelihood= -255.133

Pseudo R2 = .170

Table 11. Hired Labor by Agricultural System

Agricultural System	Total HH	HH that Hired Labor	% of HH that Hired Labor	Uses of Hired Labor				
				Weeding	Preparing Land	Planting	Harvesting	Other
No-Till	363	259	71%	249	90	110	103	52
Conventional	268	217	81%	199	28	50	42	5
Overall	**631**	**476**	**75%**	**448**	**118**	**160**	**145**	**57**

Survey Instrument

INVESTIGATOR'S AFFIDAVIT:

☐ The investigator certifies that to the best of his/her knowledge the participant was informed of the nature, demands, benefits, and risks involved in his/her participation.

Date: _______________
Interview Start Time: _________ End Time:_________
Region Name: _______________
Village Name:________________
Interviewee Name:____________
Age:_______
Gender: F M
Interviewer Name:_____________

Are you the decision maker for the farm? Yes / No

If yes, how many years have you been the decision maker? _______years

Did you receive any formal education? Yes/No

If yes, how many years? ________years

Would you say your health is Excellent/ Very Good /Good/ Fair/ Poor?

Do you have access to credit? Yes / No

If yes, have you received credit in the last 12 months? Yes / No

If yes, how much did you receive? _______cedis

What are the sources of the credit you received? Circle all that apply.

Bank/Government/NGO/Cooperative/Susu/ Trader/Relative/Friend/ Other______

How far is the nearest market? ________km

How do you get there? Walk/ Bike/ Bus/ Taxi/ Own Car/ Other_________

How long does it take you to get there? ______hr   _____min

How many people are in your household? ____total ____male

____female

How many people are capable of working (15-60)? ____total ______male

______female

How did the capable individuals in your household allocate their labor during the last 12 months?

	Person 1	Person 2	Person 3	Person 4	Person 5
Days working on the farm					
Days working off the farm					
Off farm income from the last 12 months (cedis)					

How many people are younger than 15 or older than 60 in your household?

_____total _____male _____female

Did you hire laborers for farming in the last 12 months? Yes / No

If Yes, How many laborers? ___________laborers

How many days were laborers hired? ______________ days

What was the total cost of labor for the last growing season? ______________cedis

Which activities did you hire labor for?

Weeding/ Preparing the land/ Planting/ Harvesting/ Other_______

Do you have family members/friends that live elsewhere and send money to help support the household? Yes / No

If yes, How much did they send in the last year? ____________ cedis

Do you have access to land for agricultural production? Yes / No

How many hectares do you have access to?

	Owned by Household	Share cropped	Seasonal Lease	Long Term Lease	Permission from Chief	Other _______
Hectares						

If the land is owned by the household, Do you have a title to the land? Yes / No

If the land is leased, Do you have a formal contract? Yes / No

How many hectares are in fallow? _________hectares

Have you ever had a disagreement over your land? Yes / No

Which crops do you grow?

*Mark an M for Mixed Crop

	Unit	Maize	Millet	Sorghum	Rice	Cassava	Yam	Cocoyam	Groundnut	Pepper
How many hectares?	Ha									
Percentage using No-Till?	%									
How much did you harvest?	kg									
How much did you sell?	kg									
Price per unit?	cedis/kg									

	Unit	Okra	Tomato	Leafy Green	cowpeas	Legumes	Oil Crops	Fruit	Other ______
How many hectares?	Ha								
Percentage using No-Till?	%								
How much did you harvest?	kg								
How much did you sell?	kg								
Price per unit?	cedis/kg								

For each crop that is planted but 0% under No-till, why was No-till not used? Mark all that apply.

Check all that apply							
	Weeding Problem	Too difficult/more labor to seed	Too Costly	Lack of Information	Pest Problem	Lack of Mechanization	Other ________
crop ____________							
crop ____________							
crop ____________							
crop ____________							

Do you own livestock? Yes / No

If yes, which do you own?

	Cattle	Sheep	Goats	Swine	Chicken	Fish	Other ________
Number of Head							

Did you sell any livestock or products from livestock (dairy) in the last 12 months? Yes / No

If yes, how much did you profit? _________ cedis

Compared to other farmers in your area, how do you rate your level of use of machinery to plant, irrigate, harvest, etc? **Much more/Somewhat more/About the same/Somewhat less/Much less**

Do you irrigate your crops? Yes/ No

Did you use fertilizer, herbicide, and/or pesticide? Yes/ No

If yes, Fill out the chart.

	Unit	Organic fertilizer	Inorganic Fertilizer	Herbicide	Pesticide
How much did you use?	weight				
How much did you pay?	cedis				

Are any of the following an issue on your land? If yes, to what degree?

Check the appropriate box.

	Not A Problem	Small Problem	Some What of a Problem	Large Problem
Soil fertility				
Soil Erosion				
Drought				
Pests				
Other___________				

Compare No-till to traditional tillage practices, check the appropriate box.

	Significantly Greater	Somewhat Greater	Same	Somewhat Less	Significantly Less
Yield					
Drought tolerance					
Soil erosion					
Soil fertility					
Amount of fertilizer needed					
Amount of pesticide Needed					
Ease of application					

How did you first hear about No-till?

Family/ Friend/ Neighbor/Media/ Extension Agent/ Other__________

Did you receive any training/information from the Center for No-till Agriculture? Yes/ No

***If no, go to 13.2**

If yes, in which interactions did you participate?

Intervention	Yes (mark X)	Distance from home (km)	Date(s) MM/YEAR
Pre-season Training			
On Farm Demos			
Hosted a Farm Demo			
Field Days			
Field Tours			
Hosted a Field Tour			
Workshops			
Seminars			
Sunday School			
Other ___________			

Did you use No-till before attending the above intervention(s)? Yes/ No

After attending the above intervention(s) do you use No-till on more/ the same/ or less land?

How did you hear about the Center for No-till Agriculture?

Family/ Friend/ Neighbor/ Media/ Extension Agent/ Other________

How many farmers in your community use No-till?

All/ Almost all/ About half/ Several/ A few/ None

How often do you have contact with the following?

Person	Type of Contact	Times Per Month During Growing Season
Extension Agent	Phone	
Extension Agent	In Person	
No-Till Farmer	Phone	
No-Till Farmer	In Person	