UNIVERSITY FOR DEVELOPMENT STUDIES

EFFECTS OF ADOPTION OF SOIL AND WATER CONSERVATION TECHNIQUES ON TECHNICAL EFFICIENCY OF MAIZE FARMERS IN GHANA

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DECEMBER, 2015

DECLARATION

Student

I hereby certify that except the references to other studies, which have been duly acknowledged, the work herein submitted as a dissertation under the supervision of my supervisors is the outcome of my own research and that no part of it has been presented for another degree in this university or elsewhere:

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I hereby declare that the preparation and presentation of the dissertation/thesis was supervised in accordance with the guidelines on supervision of dissertation/thesis laid down by the University for Development Studies.

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ABSTRACT

The rapid population growth coupled with the effects of climate change in sub-Saharan Africa has made adoption of soil and water conservation (SWC) techniques even more crucial for increased farm productivity. A study on the socioeconomic analysis of SWC techniques to improve agricultural production therefore becomes imperative. This study sought to examine the farmer, farm and socioeconomic/institutional characteristics that influence the adoption of SWC techniques and adoption effects on farmers' output and technical efficiency in Ghana. The data is obtained from the Ghana Agriculture Production Survey (GAPS), a national level survey conducted by Ghana's Ministry of Food and Agriculture with technical and financial support from the International Food Policy Research Institute (IFPRI). A total sample size of 1,530 farm households selected from 20 districts across Ghana was used. The Poisson model was employed to estimate the determinants of adoption of SWC technique while the Stochastic Frontier Production function was used to analyze the effects of SWC technique adoption on output and efficiency. The study found that adoption of SWC techniques significantly affected output in maize production. Significant policy variables that were found to positively influence the adoption of SWC techniques include credit, farm size, group membership and proximity to input sale points. Also, credit, education and distance to input store significantly and positively influenced farmers' technical efficiency. In general, access to education, extension services and credit for smallholder farmers should be improved since these are strongly linked with high adoption of SWC techniques. Farmers should also be supported to form farm groups as a viable source of farm labour.

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DEDICATION

I dedicate this work to my late father, Afa Alidu Abdallah and my mother, Madam Hussainatu, who provided the strong foundation for the realisation of this dream. The entire work is also dedicated to anybody in pursuit of higher knowledge.

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LIST OF ABBREVIATIONS

CSOs.....................................Civil Society Organizations

FARA.....................................Forum for Agricultural Research in Africa

FASDEP.................................Food and Agriculture Sector Development Policy

FBOs.....................................Farmer Base Organizations

FAO.......................................Food and Agriculture Organization

GAPS.....................................Ghana Agriculture Production Survey

GPRS.....................................Ghana Poverty Reduction Strategy

GSGDA..................................Ghana Shared Growth and Development Agenda

GSSP.....................................Ghana Strategy Support Program

GSS.......................................Ghana Statistical Survey

IAR4D...................................Integrated Agriculture Research for Development

IFPRI.....................................International Food Policy Research Institute

ISA..International Society of Arboriculture

LATE.....................................Local Average Treatment Effect

MDGs....................................Millennium Development Goals

METASIP..............................Medium Term Agricultural Sector Investment Program

MiDA.....................................Millennium Development Authority

MoFA.....................................Ministry of Food and Agriculture

NDPC.....................................National Development Planning Committee

SPSS......................................Statistical Package for Social Scientist

SRID......................................Statistical Research and Information Directorate

SWC......................................Soil and Water Conservation

SSA..Sub-Sahara Africa

WH..Water Harvesting

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

The second Ghana Poverty Reduction Strategy (GPRS II) noted that, significant progress in raising the average real incomes of Ghanaians would not be achieved without massive improvements in the productivity of the agriculture sector (NDPC, 2005). Under the Ghana Shared Growth and Development Agenda (GSGDA), government expects agriculture to spur industrial growth with the non-oil sector expected to grow at 8.2% by 2013. Also, the minimum 6% annual agricultural sector growth set under the Comprehensive Africa Agricultural Development Program (CAADP) can only be attained and maintained with high performance in the agricultural sector. Unfortunately, these expectations are not realised as the sector records growth rates (ranging from 1.3% to 4.5%) which are far below the attainable levels (MoFA, 2012).

Cereal production is a major component of small-scale farming in Africa. Among the cereals, maize is perhaps the most important; as it forms the major staple for most communities(Djokoto, 2011).Maize comes after wheat and rice in terms of world importance. In West Africa sub-regional trade, maize is an important commodity particularly among Ghana, Burkina Faso, Mali, Togo and Niger through informal trading.Maize is one of the most important crops for Ghana's agricultural sector and for food security (MiDA, 2012).In Ghana, maize has been cultivated for several hundred years after its introduction in the late 16th century (Morris *et al.*, 1999).It is the largest staple crop and is a significant component of many diets. Maize is the number one crop in terms of area planted, accounting between 50 – 60% of total cereal production (MiDA, 2012). Additionally, maize represents the second largest crop in the country after cocoa. It is also an important component of poultry and livestockfeed and has been used as a substitute in the brewing industry. Maize is grown in all parts of Ghana though the major producing areas are located in the transitional and forest zones.

Maize is widely regarded as a crop that can be developed to improve food security in Ghana. This development entails enhancing the productivity (as advocated in significant documents such as GPRS II, GSGDAand CAADP) of smallholder farmers through technology.According to Slaymaker (2002) and Essilfie*etal.* (2011), sustainable increases in food production, especially maize are critical for achieving food security for growing populations in many developing countries.

In Ghana, Agriculture Production Survey in 2012 cropping season by the Ministry of Food and Agriculture showedthat maize was produced in all parts of the country and that maize farmers adopted and changedfarm techniquesmore frequently.Farmers adopt technology because the technology has the potential to improve their productivity (Akudugu*et al.*, 2012). The potential impact of adoption of SWC techniques on maize yields has been documented. Several reports including Mwangi*etal.* (2001)suggest significant yield improvements associated with adoption of improved technology. Using the counterfactual outcomes framework to estimate the Local Average Treatment Effect (LATE) of SWC technique adoption on households' output, results of Olarinde*etal.* (2012) found that the adoption of soil and water management technology increased the value of total crop production by 17-24% per household.

Kato *etal.* (2009)also applied the Just and Pope Framework using a Cobb-Douglas production function to investigate the impact of various SWC techniques on average crop yields and the variance of crop yields, while controlling for several household- and plot-level factors. Results show that soil and water conservation investments like soil bunds, stone bunds, grass strips, waterways, and contours have significant positive impacts on average crop yields in low-rainfall areas.Morris *etal.* (1999) also reported that significant farm-level productivity gains (measured in terms of maize yields) and noticeable increases in the income earned from sales of maizehas been associated with adoption of Improved Maize varieties, fertilizer use and row planting.The evidence however suggests thatimprovements arerealized by well-to-do farmers who invest in using improved production practices(MiDA, 2012).But farming is dominated bysmallholder production, estimated to contribute over 90 % of national food production with the majority of thesesmall-holder producers ranked among the poorest households in Ghana(Morris *etal.*, 1999). Smallholder farmers face severalconstraints including limited access to production inputs and efficient produce markets. Hence, adoption of technologies is low among smallholders and so are the yields andincomes. It is generally believed that thesefarmers lack knowledge of the factors that affect the adoption of technology. This therefore serves as an obstaclethat prevents thereadjustingof their production strategies to obtain better yields.

1.2 PROBLEM STATEMENT

Maizeis Ghana's number one staple crop and domestic demand for it is growing. Intensifying maize production would improve the food security for millions of households and help eradicate hunger and poverty in the long-run. Increasing the productivity of maize farmers is key to the attainment of food self-sufficiency in Ghana, and by extension the attainment of Millennium Development Goal one which seeks to eradicate extreme poverty and hunger. This recognition is evident in Ghana's Medium and Long Term Agricultural Development Program and Food and Agriculture Sector Development Program (METASIP; FASDEP I and II). The Government of Ghana therefore developed astrategyto increase production of key staple food crops in order to meet the country's growing demand for food.Despite these efforts,Ghana is still not self-sufficient in food production and maize in particular as it hasexperienced average shortfalls in domestic supplies of about 12 percent in recent years(MiDA, 2012). The goal of eradicating extreme poverty and hunger is therefore threatened. This is because maize production is currently dominated by smallholder farmers who are poor and rely solely on rain fed conditions,with limited technology especially SWC techniques. Averageyields in Ghana are therefore below attainable levels and post-harvest losses are high. The knowledge of how to get farmers to use SWC techniques would go a long way to improve productivity.

Sustainable land management is the first pillar of the Comprehensive Africa agriculture program (CAADP), yet as reported by Marenya*etal.* (2012); adoption of improved land management practices remains low. For example, average application of fertilizer in sub-Saharan Africa (SSA) is only about 10 kg of nutrients/ha, which is the lowest level in the world (FAOSTAT, 2012). In Ghana, both governmental and non-governmental organizations have introduced a number of soil and water conservation (SWC) techniques, but the adoption rates are not better than what prevails elsewhere in the continent. Mindful of the fact that most agricultural growth in the country has been attributed to land area expansion as opposed to yield increases (Diao *etal.,* 2008); improving factor productivity through dissemination of yields-enhancing technology has become a focus for Ghana's Ministry of Food and Agriculture. Productivity with emphasis on the long-term ecological sustainability of soil and water conservation technologies is a key determinant of food security especially in resource poor areas. This recognition is the driving force behind SWC efforts in many developing countries. Efforts to generate new productivity enhancing SWC techniques in developing countries have been intensified in recent years (Ellis-Jones and Wattenberg, 2000).However, the contribution of new technology to poverty reduction and economic growth can only be realized if the new technology is widely diffused, adopted and used. Until many users adopt a new technology; it may contribute little to our well-being (Hall and Khan, 2002).

The findings of the Ghana Agriculture Production Survey (GAPS) during the 2011/2012 survey across the 20 selected districts in Ghana, showed that mulching, composting, crop rotation, zero tillage, fertilizer use, water harvesting, row planting and intercropping were identified as the main conservation techniques that are being promoted among maize farmers in Ghana. However, average shortfalls (as experienced in domestic maize supplies)resulting from low average yields and high post-harvest loss as reported by MiDA (2012), contrasts with the findings of Akudugu*etal.* (2012) in which it is argued that low adoption of modern agricultural production technologies amongst farmers in Ghana has been identified as one of the main reasons for the low agricultural productivity while high adoption is identified as the main reason for high productivity.This makes the resulting effects of adoption on output questionable.

Faced with such challenges, one may be tempted to conclude that soil and water conservation practices are not profitable. Such doubts would be in direct conflict with the emerging evidences that demonstrate the benefits of soil water conservation. Few of these evidences includethe study by Keyser and Mwanza (1996) which observedthat there is differential income to the user of conservation farming techniques in the order of 45-60% over and above the users of conventional farming and the findings of Olarinde*etal.* (2012) which also indicates that there is scope for improving farmers' income from crop production through increased use of the soil and water management technologies.

Considering the level of adoption of these technologies and the low yields resultingfrom the practiceby farmersit becomes imperative to unravel the factors that influence adoption of these technologies by farmers inGhana. This will contribute to the technology adoption literature with the examination of the factors influencing farmers' decision to adopt SWC techniques and the effects on output, from the perspective of a developing country.

Also, insufficient knowledge of the socio-economic factors influencing adoption of soil water conservation technologies and maize output in Ghana constitutes a problem for production leading to low yields in maize. A study to unravel the factors influencing the adoption of SWC techniques as well as the relationship between adoption and output/technical efficiency is therefore worthwhile. .

1.3 MAIN RESEARCH QUESTION

The main research question therefore is: Whatfactors influence the adoption of SWC techniques in Ghana and what is theadoption effect onmaize output/technical efficiency?

1.3.1 Specific Research Questions

The specific questions are:

1. What are the levels of SWC techniques adopted in Ghana?
2. What factors determine the adoption of SWC techniques by maize farmers in Ghana?
3. What is the effect of adoption of SWC techniques onoutput/technical efficiency of maizein Ghana?
4. What level of technical efficiency can be associated with adopters and non-adopters of SWC techniques in Ghana?
5. What factors affect technical efficiency of maize farmers in Ghana?

1.4 MAIN OBJECTIVE

The main objective of the study was to determine the factors that influence the adoption of SWC techniques and the effect of adoption on maize output/technical efficiency in Ghana.

1.4.1 Specific Objectives

The specific objectives of the study are to:

1. Identify the levels of adoption of SWC techniques in Ghana.
2. Investigate the factors that influence the adoption of SWC techniques in Ghana.
3. Analyse the effect of adoption of SWCtechniques on output/technical efficiencyof maizein Ghana.
4. Estimate the level of technical efficiency of maize farmers in Ghana.
5. Determine the factors that influence the technical efficiency of maize farmers in Ghana.

1.5 JUSTIFICATION/RATIONALE OF THE STUDY

A better understanding of the factors that will condition adoption and possibly restrict the adoption of soil and water conservation practices would allow the formulation of well-tailored interventions that could result in rationalizing the scarce physical, financial and human resources that the nation most requires for use in other sectors of the economy. A better understanding could further facilitate close monitoring of conservation activities. Moreover, future related efforts in other areas with similar characteristics may be targeted with less difficulty and it would allow for prediction of the speed at which adoption of the practice to be introduced would likely take place.

Soil and Water Conservation (SWC) is widely believed to have the potential of improving maize yields by significantly increasing returns per unit input. This study explains the effects of adoption of SWCtechniques on maize yields.

As the population of Ghana continues to grow rapidly, the carrying capacity of its agricultural land is becoming lower, bringing closer the land frontier. Consequently, agricultural productivity and food security in Ghana are threatened by the steady decline in soil fertility. Soil and Water Conservation technique is key for reversing agriculture productivityloss. Equally important is the realization that farmers are always trying technologies. This being the case, it is important to understand potential changes in farmer use of SWC practices.

This study augments existing empirical literature on smallholder agricultural production in Ghana by focusing on the technical efficiency and factors that influence the technical efficiency of maize production on smallholder farms or plots. With respect to public policy, the government of Ghana has pursued several strategies to improve agricultural production and this study will provide an indication of the level of technical efficiency that these efforts have achieved and by identifying sources of technical efficiency which government further needed to address in order to maximize food production among the many land-constrained smallholder farmers.

It would also lend empirical support to assertions that conservation techniques improve smallholder productivity since this view is the drive behind government's effort to promote SWC techniques.

1.6 ORGANIZATION OF THE STUDY

The dissertation is presented in five chapters.Chapter two reviews literature on maize production in africa, global maize production trend, maize production and policy, maize supply, maize demand, conceptual and theoretical frameworks for adoption of SWC techniques, the economic effects of adoption of SWC techniques, adoption of innovations, adoption/diffusion theories, inter-personal technology transfer, soil and water conservation practices promoted, empirical studies on adoption decisions, technical efficiency, the stochastic frontier production function and technical efficiency, review of empirical studies on technical efficiency.Chapter three presents the methodology on the study. The chapter provides an overview of the study area,research design and data, data cleaning and analysis as well as the theoretical model to explain technology adoption and its effects on output/technical efficiency.Chapter four presents the results and discussions of the study which are inline with the study's objectives. This includes levels of adoption of SWC techniques, factors influencing the adoption of SWC techniques, effects of adoption of SWC techniques on output/technical efficiency and the level of technical efficiency as well as factors influencing the technical efficiency of maize farmers in Ghana.A general summary, conclusions and policy recommendations are presented in chapter five.

CHAPTER TWO

LITERATURE REVIEW

INTRODUCTION

This chapter reviews literature related to the area of study.It reviews studies conducted in other parts of the world and type of statistical and econometric analysis employed and challenges encountered in using these analyses. The chapter also provides an overview onmaize production in Africa and Ghana, maize market and policy, trends in demand and supply of maize. Additionally, the chapter also looked at the conceptual and theoritical frameworks of adoption, economic effects of adoption, SWC techniques practised in Ghana, technical efficiency and adoption studies.Theories of innovation diffusion and adoption are also explored.Particularly, the individual innovativeness theory, innovation decision process theory,technology transfer, rate of adoption theory and the perceived attributes theory. These theories have a direct bearing on the study.

2.1 MAIZE PRODUCTION IN AFRICA

Although Africa accounts for only 7% of the global maize production, it is still an important player in terms of potential. Average annual production was estimated at 49 million tons during the period 2005-2007; increasing from 17 million tonnes over the 1985-1987 period(see Table 2.1). Maize yields in Africa are low relative to the global average. While the global average is about 5 tonnes per hector, yields in Africa average at 1.7 tonnes per hector making Africa one of the lowest in terms of productivity and a net importer of maize (FARA, 2009). Africa accounts for 12% of total global maize imports and 2.2% global exports.

Yields have increased only marginally over the last two decades. Most of the increase in production has come from expansion in areas cultivated rather than from increases in yield as seen in Table 2.1. The areas cultivated increased from 131 million hectares in 1986 to 152 million hectares in 2006. This represents about one fifth of the global area harvested.Most of the maize produced and consumed in Africa comes from smallholder rural farmswhereproduction takes place under difficult conditions characterized inter alia, by poor soils; low-yielding varieties; inadequate access to yield-enhancing inputs such as fertilizers and improved seeds; inadequate access to finance by producers, suppliers and buyers; and variable climatic environmental conditions and finally inadequate/lack of knowledge in the use of a particular technology (FOA, 2009). There are also heavy post-harvest losses due to poor storage and processing facilities and technologies. The entire maize value chain, from input supply through production to marketing and consumption also suffers from constraints that could be removed if known techniques and marketing innovations could be harnessed effectively and efficiently.

Table 2.1: Maize Production, Yield and Area Harvested in Africa and the World (1986 – 2006)

Production (Mt)	**1986**	**1996**	**2006**
World	472.3	564.1	736.1
Africa	31.7	40.3	48.9
Africa as % of the World	6.7	7.1	6.6
Yield (ton/ha)	**1986**	**1996**	**2006**
World	3.6	4.1	4.9
Africa	1.4	1.6	1.7
Africa as % of the World	39.6	38.8	35.7
Area Harvested (ha)	**1986**	**1996**	**2006**
World	130.8	139.1	156.6
Africa	22.2	25.6	28.2
Africa as % of the World	17.0	18.4	18.6

Source: FOA, 2009.

2.2 GLOBAL MAIZE PRODUCTION TRENDS

According to FAOSTAT (2012), Africa remains one of the least contributors to global maize production while North America records the largest production of maize, contributing 39% of the global output. Asia, South America and Europe complete the topwith contributions of 29%, 11% and 11% respectively. Table 2.2presents maize production over the last two decades. The data shows that maize production in Africa rose from approximately 31.7 million tonnes in 1986 to 48.9 million tonnes in 2006, representing a 3% annual growth rate within the period. Annual growth averaged 3.4% between 1986 and 1996, but declined marginally to 3% per annum between 1996 and

2006.Table 2.2 also reveals thatSouthern Africa, Central Africa and West Africa are the major producing areasin the African continent.

Table 2.2: Average Annual Maize Production in Africa between 1986 and 2006, Categorized by Sub-region

Region	Maize Production (1000 tons)			Grow Rate (%) Per Annum		
	1986	1996	2006	1986– 1996	1996 – 2006	1986 - 2006
Africa	31,683	40,286	48,908	3.44	3.02	3
Eastern Africa	3,955	5248	5,047	4.48	0.45	2
Central Africa	7,170	8,070	7,840	2.52	4.16	3
Southern Africa	753	758	969	6.53	3.98	6
West Africa	13,509	15,900	14,633	18.96	- 0.05	9

Source: FARA, 2009.

2.3 MAIZE PRODUCTION AND POLICY

Even though maize is grown in all agro-ecological zones of Ghana,the transitional and northern guinea savannah belts are the major producing areas. Over 90 percent of maize in Ghana is produced by smallholders on scattered plots ranging from less than 1acre to about 3 acres. Small holder maize production is labour intensive with little or no purchased inputs (MiDA, 2012). Large, capital intensive maize farms are virtually non-existent in Ghana. The one known capital intensive maize farm is Ejura Farms in the northern part of the Ashanti Region. Even though yields vary from across region and producing areas, they are generally low as shown in Table 2.3. Yields hardly exceed 1.5 metric tonnes per hectare even in high potential yield areas in the transitional zone.

Increases in maize production have largely been achieved by expansion of area under cultivation rather than increase in land productivity (Yawson*etal.*,2010). As part of

Ghana's trade liberalization programme, the guaranteed minimum prices for maize and rice programs were abolished in 1990 and the free market policyhassince been used to determine their prices. Yield instability from year to year has caused fluctuations which in turn affected production and investment decisions (Seini, 2002).

Table 2.3: Ghana Corn Production by Year

Market Year	Production	Unit of Measure	Growth Rate
1990	553	(1000 MT)	-22.66 %
1991	930	(1000 MT)	68.17 %
1992	730	(1000 MT)	-21.51 %
1993	960	(1000 MT)	31.51 %
1994	940	(1000 MT)	-2.08 %
1995	1035	(1000 MT)	10.11 %
1996	1000	(1000 MT)	-3.38 %
1997	1000	(1000 MT)	0.00 %
1998	1000	(1000 MT)	0.00 %
1999	1015	(1000 MT)	1.50 %
2000	1015	(1000 MT)	0.00 %
2001	940	(1000 MT)	-7.39 %
2002	1400	(1000 MT)	48.94 %
2003	1290	(1000 MT)	-7.86 %
2004	1160	(1000 MT)	-10.08 %
2005	1658	(1000 MT)	42.93 %
2006	1189	(1000 MT)	-28.29 %
2007	1220	(1000 MT)	2.61 %
2008	1470	(1000 MT)	20.49 %
2009	1620	(1000 MT)	10.20 %
2010	1676	(1000 MT)	3.46 %
2011	1500	(1000 MT)	-10.50 %
2012	1700	(1000 MT)	13.33%

Source: United States Department of Agriculture, 2012.

2.4 MAIZE SUPPLY

Overall maize production in the country has remained relatively stable both in terms of area harvested and volume because of reliance on traditional farming methods.Under traditional production methods and rain fed conditions, yields are well below their attainable levels – maize yields in Ghana average approximately 1.5 metric tons per hectare. However, yields as high as 5.0-5.5 metric tons per hectare have been realized by farmers using improved seeds, fertilizer, mechanization and irrigation (Ayamga and Dzanku, 2013).

Commercial farming can help to fill the increasing gap between domestic supply and demand for maize. The Ministry of Food and Agriculture estimates the annual domestic production deficit between 84,000 and 145,000 metric tons over the last four years. This represents a shortfall in domestic production of between 9 and 15 percent of total consumption in these years (MiDA, 2012).

2.5 MAIZE DEMAND

In addition to the current shortfall indomestic supplies relative to demand, maizeconsumption is projected to grow at acompound annual rate of 2.6%based on population growth and per capita income. Based on the mostrecent domestic production data, the gapbetween domestic production anddomestic consumption would reach 267,000 metric tons by 2015. Further,beyond these householdconsumption projections, there is considerabledemand for processed maizefor use in the growing animal feedsector within Ghana (FAOSTAT, 2012).

2.6 CONCEPTUAL FRAMEWORK FOR ADOPTION OF SWC TECHNIQUES AND OUTPUT

The relationship between smallholder adoption of SWC techniques and economic benefits is conceptualised in the model presented in Figure 2.1. The conceptual model presents the various relationships that exist between output and incomes of smallholder farmers, adoption of SWC and some variables that are hypothesised to influence adoption of SWC techniques.

From Figure 2.1, the adoption of SWC technique has immediate effects on farmers' field as follows: increase aeration and moisture content; reduce erosion; and improve soil fertility. These help to increase farm output.

Farm output is also influenced by other internal factors such as land, labour, fertilizer and weedicides. External factors are basically climatic factors including rainfall, temperature, humidity, precipitation over which farmers have little or no control.

Increased farm output also has the effects of improving farmers' income, food security and the quality of the environment. The end result is that there is economic growth and development and hence, reduction in vulnerability.

However the adoption of SWC technique is influenced by a number of factors, including farm and farmer characteristics as well as some policy variables. The farmer characteristics include gender, age, education, household size while some farm characteristics are farm size, distance to market/input store, soil fertility and land tenure. Among the policy variables are extension staff, group membership, and access to credit.

Government policies are macro inclined and they include taxes or subsidies as well as liberalization or price control. Taxes on agricultural products raise their prices and are generally disincentive to production, while subsidies go a long way to boost production. In a liberalized framework, prices of agricultural inputs and products are determined by the forces of demand and supply, while under price control regime, governments can institute minimum and maximum price legislations for agricultural products and inputs respectively in the interest of the small scale farmer. The economic history of Ghana shows that both the capitalist (characterised by liberalization) and the socialist economic system (where price control is common) have been practised since independence (Nyanteng and Seini, 2000). Currently, the former is what is being practised in Ghana, like in most economies globally.

It is however worthy to note that the conceptual model in Figure 2.1 does not deal with the theoretical issues of the adoption of SWC techniques. It simply depicts the relationship between the adoption and effects of SWC techniques. In the section that follows attempts are made to establish the theoretical link between the adoption of SWC and some economic benefits.

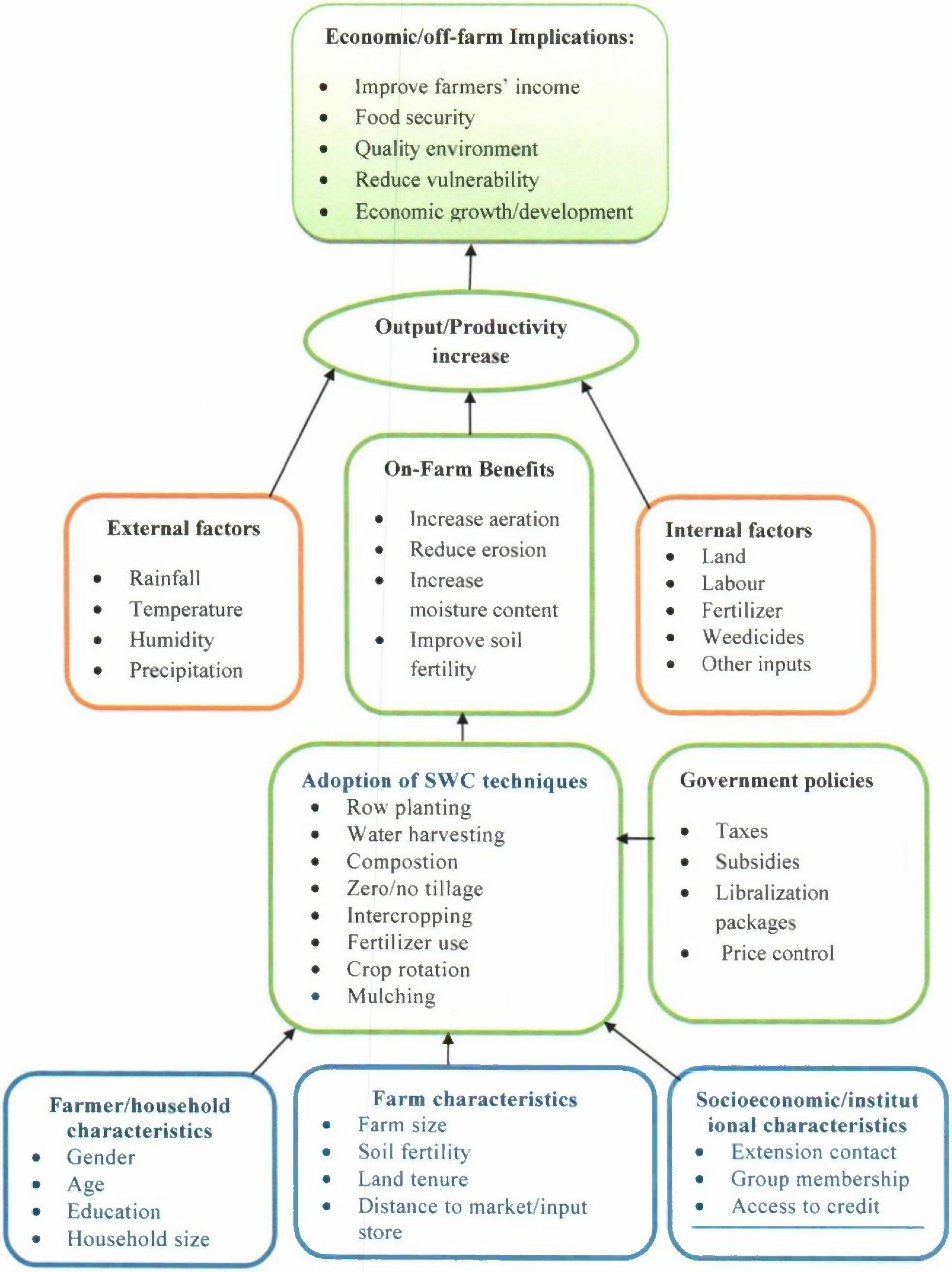

Figure 2.1: Conceptual Model of SWC Technique Adoption

Source: Adapted from Loewinsohn *et al.* (2012)

2.7 THEORETICAL FRAMEWORK FOR ADOPTION OF SWC TECHNIQUES

Several studies have explained how new technologies are adopted (Donkoh and Awuni, 2011; Nkegbe *et al.*, 2012) or how they spread across communities (Rogers, 1962; Feder *et al.*, 1985). In all these studies, the reason for the adoption or diffusion of a new technology or innovation is that the expected returns from adopting the technology outweigh the cost of its adoption. This is based on the assumption that farmers are rational. A detailed explanation to the underlying causes of technology diffusion is given by Foltz (2003) in Donkoh (2011). According Foltz (2003), four main (hypotheses) factors explain the rate of adoption/diffusion of a new technology, namely; resource scarcity hypothesis, capital constraint hypothesis, learning costs hypothesis and risk aversion hypothesis. Under resource constraint, Foltz (2003) argued that little or no access to a natural resource such as a fertile land would mean higher demand for a SWC technology that would be applied on an infertile land to make it fertile. That is to say that a farmer whose land is infertile is likely to adopt fertilizer more than the one whose land is fertile.

The capital constraint hypothesis also underscores the important role that capital plays in the adoption of a new technology. Foltz (2003) observed that new technologies would spread faster among farmers with better access to capital to pay for the new technology than farmers with little or no access. Thus farmers with better access to capital would be the first to adopt the technology while their poor counterparts may adopt late or may not adopt the technology at all.

The learning-cost-hypothesis also suggests that technology adoption or diffusion is facilitated by the opportunity for farmers to learn about the technology and evaluate its viability. It is against this background tha farmers' ability to read and write as well as their access to extension services, training programmes and demonstration farms are important in technology adoption and diffusion.

The learning-cost hypothesis has relevance to the risk-aversion hypothesis which argues that adoption is high for the technology to which farmers do not associate any serious risk, as opposed to the technology that have a lot of uncertainties surrounding its viability. If farmers are able to understand the information with respect to the use and viability of a new technology, through their own learning or through their contacts with extension/research staff it reduces the uncertainties surrounding that technology and therefore enhances its adoption or diffusion, but where farmers are ignorant about the technology, they may have negative perceptions about it and consequently that technology would not be adopted.

In Foltz's framework, technology adopters have a positive net willingness to pay for the technology. Such farmers have what he called a reservation price $P_r = (A, K, \eta)$ for the technology that is greater than or equal to the actual market price, P_m. He defined the reservation price as the amount that the farmer would be willing to pay for the technology given his asset position, A; other inputs he uses, K; and the parameter of his choice, η. Foltz stressed that P_m is the given price of the technology which is constant for all individuals. In the light of the aforementioned, for a given individual, the dependent variable y is defined as an index variable for whether or not individuals adopt the new technology. It takes on the value one (1) and zero (0) as follows:

$$\begin{aligned} y=1 \quad if \quad P_r(A,K,\eta)-P_m>0 \\ y=0 \quad if \quad P_r(A,K,\eta)-P_m\leq 0 \end{aligned} \qquad (2.1)$$

Where the variables are as defined. According to Foltz, the function $P_r = (A, K, \eta)$ represents shadow price for an individual adopting the technology. He stressed that the inference problem of the econometrician, then becomes a question of parameterizing the equation that defines the net benefits of the technology to farmers. The standard model in the literature is the random utility model. As researchers, we are not able to observe the preference parameters of the utility function but instead, we assume that they are known to decision makers.

Let these parameters be an unobserved variable so that the actual utilities of an individual can be written as

$$U_i = P_{ri}(A, K, \eta) - P_m = \beta' x + \varepsilon \qquad (2.2)$$

where x is a set of characteristics of the decision maker observable to the econometrician, and β is a parameter vector. Hence $\beta' x$ becomes an index function that allows us to estimate the probability of adoption $Y = 1$ in the following fashion:

$$\Pr ob[P_r(A, K, \eta) - P_m > 0 = \Pr ob(\beta' x + \varepsilon > 0) \qquad (2.3)$$

Assuming that the disturbance term is normally distributed, this becomes a standard probit model. By symmetry of the normal distribution, we get:

$$\Pr ob(P_r - P_m > 0) = \Pr ob(\varepsilon < \beta' x) = F(\beta' x) \qquad (2.4)$$

where $F(\cdot)$ is the cumulative densityfunction of the normal distribution.

This then is estimated using the maximum likelihood estimation, in which the likelihood function is as follows:

$$\ln L = \sum_{y_i=0} \ln(1 - \Phi_i) + \sum_{y_i=1} \ln(\Phi_i) \qquad (2.5)$$

Note that the probit model is a discrete choice model which is applicable where only one technology is involved. In situations where more than one technology is involved the

Poisson model is the most suitable. In chapter three a detailed explanation to the Poisson model is given.

2.7.1 The Economic Effects of Adoption of SWC Techniques

Globally, the economic benefits of soil and water conservation techniques can be either on-site or off-site. In the United States for instance, Uri *et al.* (1999a) estimated that the realised erosion benefits (avoided losses from sheet, rill and wind erosion) from using conservation tillage ranged from US$ 90.3 million to US$ 288.8 million in 1996. Uri *et al.* (1999a) further pointed out that adoption of soil and water conservation techniques at the farm level is associated with lower labour and farm power inputs, more stable yields and improved soil nutrient. Stonehouse (1997) simulated full-width no-plough and no-till use in southern Ontario, Canada, and found that both provided modestly higher on-farm benefits than did conventional tillage. The off-site benefits considered were downstream fishing benefits and reduced dredging costs which accounted for 43 percent and 10 percent, respectively, of the net social benefits from conservation tillage. Kelly *et al.* (1996) find that strict no-till produces higher returns than conventional tillage and reduces an environmental hazard from 78.9 to 64.7 percent. Other off-site effects observed in the study include prevention of pollution of water bodies and air, and attraction of more attention from researchers and policy-makers in the developed world.

On farm studies by Arora and Bhatt (2004) in India showed that soil moisture storage in maize increased to 2.25, 4.01 and 10.77 % at 60 days after sowing. Their results further indicate that the application of mulch on the whole plot resulted in 48.4, 61 and 138 % higher soil moisture content at 40, 60 and 80 days after sowing respectively while fully covered plots had more than 150 % higher dry matter yield of maize compared to unmulched plots. They also noted 11 % increase in maize grain yield in ridge and furrow sowing over farmers' practice. Mulch spread on the whole plot increased the grain and straw yield of maize by 58.6 and 35.0 % as compared to unmulched control as they further indicated.

In Africa, some of the on-farm effects are determined through outputs of maize. For instance, in an assessment of the effect of long-term effects of conservation agriculture on maize grain yield under rain-fed conditions in southern Africa, Rusinamhodzi*et al* (2011) found an increase in maize yield over time with conservation agriculture practices. In a similar study, Okeyo*et al* (2014) also evaluated three soil and water conservation technologies (mulching, minimum tillage and tied ridging) for two cropping seasons in order to determine effects of these technologies on runoff, sediment yield and nutrient loads in sediment, and to assess influence of the technologies on maize yields in Kenya. Their results generally showed reduced nutrient losses and increased maize yields with the adoption of the technologies. In a study to determine the yield response of maize to SWC techniques on Entisols and Vertisols of the eastern Ethiopian highlands, Gebrekidan and Uloro (2014) found the yield of maize to respond significantly to SWC techniques under fertilized and unfertilized conditions. However, the magnitude of the yield response and the relative efficiency of the techniques varied with soil type, fertilization, and the total amount and distribution of rainfall during cropping season.

From the forgoing discussions, it is evident that while numerous studies have been conducted on the economic effects of soil and water conservation techniques, majority relate to the developed and emerging economies. It is also important to note that findings from these studies are far from being general conclusion since differences exist in terms of agro-ecological zones and technologies as well as socio-economic setting under which production takes place. In Ghana for instance, attention is focused on understanding the factors influencing the adoption of SWC techniques while the effects of these techniques on maize output are given little attention. This study therefore adds to the existing literature on adoption by way of examining the factors that influence adoption and how adoption influence output of maize.

2.8 ADOPTION OF INNOVATION

Several studies have tried to define adoption and thus bringing to light, the differences and similarities it shares with diffusion. Example is the most influential work of Rogers (1962) in which diffusion is argued as an idea, practice or object that is perceived as new by an individual or other unit of adoption. For Rogers, diffusion is a process that is argued as new idea spread from its source of invention or creation to its ultimate users or adopters while adoption process is argued to be a mental process which an individual passes from first hearing about an innovation till he/she finally decides on adoption. For him, the diffusion process is a group process which occurs within society while the adoption process pertains to an individual. However, Rogers' account for innovation adoption and diffusion does not give theoretical explanations to how adoption decisions are actually made. A classic article by Feder*etal.* (1985) is a frequent departure for theoretical analysis of decision making. This line of studies is mainly pursued by economists.

Another study is that of Donkoh *etal.* (2011) in which adoption is defined as the level of use of a new technology or innovation. Hall and Khan (2002) also defined adoption as the stage in which a technology is selected for use by an individual or an organ. Feder*etal.*, (1985) as cited by Donkoh *etal.* (2011), stressed that adoption takes place only in a long run equilibrium when the farmer has full information about the technology and its potential. The terms adoption and diffusion, though interrelated are different, in the sense that adoption is when an individual makes use of an innovation, while diffusion means the spread of the innovation among a community or even globally (Feder*etal.*, 1985). Chi and

Yamada (2002) defined adoption of an innovation as a process by which a particular farmer is exposed to, considers, and finally rejects or practices a particular innovation.

Technology adoption is therefore defined as the choice to acquire and use a new invention or innovation (Hall and Khan, 2002).Innovation is similarly used with the nuance of a new or "innovative" technology being adopted. Diffusion refers to the stage in which the technology spreads to general use and application. According to Kato*etal.*, (2009), in the adoption of technologies, farmers consider not only impacts on crop yields but also risk effects.Though farmers have positive perception oftechnology, they are faced with problems in technology application due to lack of capitalanduncertainty in the direction of government and extension on the technology.The lackof compensation policy or yield insurance also influences farmer adoption decisions.

The decision of use of technologies is also dependent on how farmers perceive that technology.Perception acts as a filter through which new observations are interpreted.Perception is the process by which we receive information or stimuli from our environment and transform it into psychological awareness. Decision making model of Norton and Mumford cited by Kato *etal*. (2009), shows that, on the basis of perception of the problem, farmer assesses expected outcomes. The farmer'schoice of action (decision) will depend on hisevaluation of this and other outcomes, in terms of his own personal perspectives.

The influence of incentives on adoption of an innovation cannot be left out. Many change-agencies award incentives or subsidies to clients to speed up the rate of adoption of innovations. The main function of an incentive for adopters is to increase the degree of relative advantage of the new idea as argued by Rogers (1962). The factors associated with monetary incentives are output prices, input prices, and access to markets (Reardon and Vosti, 1997; Malla 1999; Sanders and Cahill 1999; Bekele, 2003).

In general, adoption of resource conservation technologies is a function of the characteristics of the technology proposed, farmers' perception of its advantages and need, as well as availability and distribution of production factors (i.e. land, labour/time, capital, knowledge, skills, etc.).Other factors are farmers' attitude towards experiments and risk, institutional support/knowledgesharing and the policy environment (Drechsel et al, 2000).

2.9 ADOPTION/DIFFUSION THEORIES

Rogers (1962) presented four adoption/diffusion theories. These theories categorised adoption/diffusion on the basis of stage, time sequence, relative speed and the quality upon which an innovation is judged. These include the following.

2.9.1 Innovation Decision Process Theory

According to Rogers (1962), potential adopters of a technology progress over time through five stages in the diffusion process. The first stage which is the Knowledge Stage occurs when an individual is exposed to the innovation's existence, learn about the innovation and gains some understanding of how it functions. The second stage is the persuasion stage. Persuasion Stage occurs when an individual forms a favorable or unfavorable attitude toward the innovation. The individual must be convinced of the value of the innovation. The individual then decide to adopt the innovation or not. This is termed as the Decision Stage which is the third stage. Prior to the decision, the individual engages in activities that lead to a choice to adopt or reject the innovation. Implementation Stage which is the fourth stage occurs when an individual puts an innovation into use. Finally, the decision must be reaffirmed or rejected. This is termed as the Confirmation Stage. This occurs when an individual seeks reinforcement of an innovation-decision already made, but he or she may reverse this previous decision if exposed to conflicting messages about the innovation. The focus is on the user or adopter.

For Rogers (1962), these stages typically follow each other in a time-ordered manner. This process is shown in Figure 2.2.

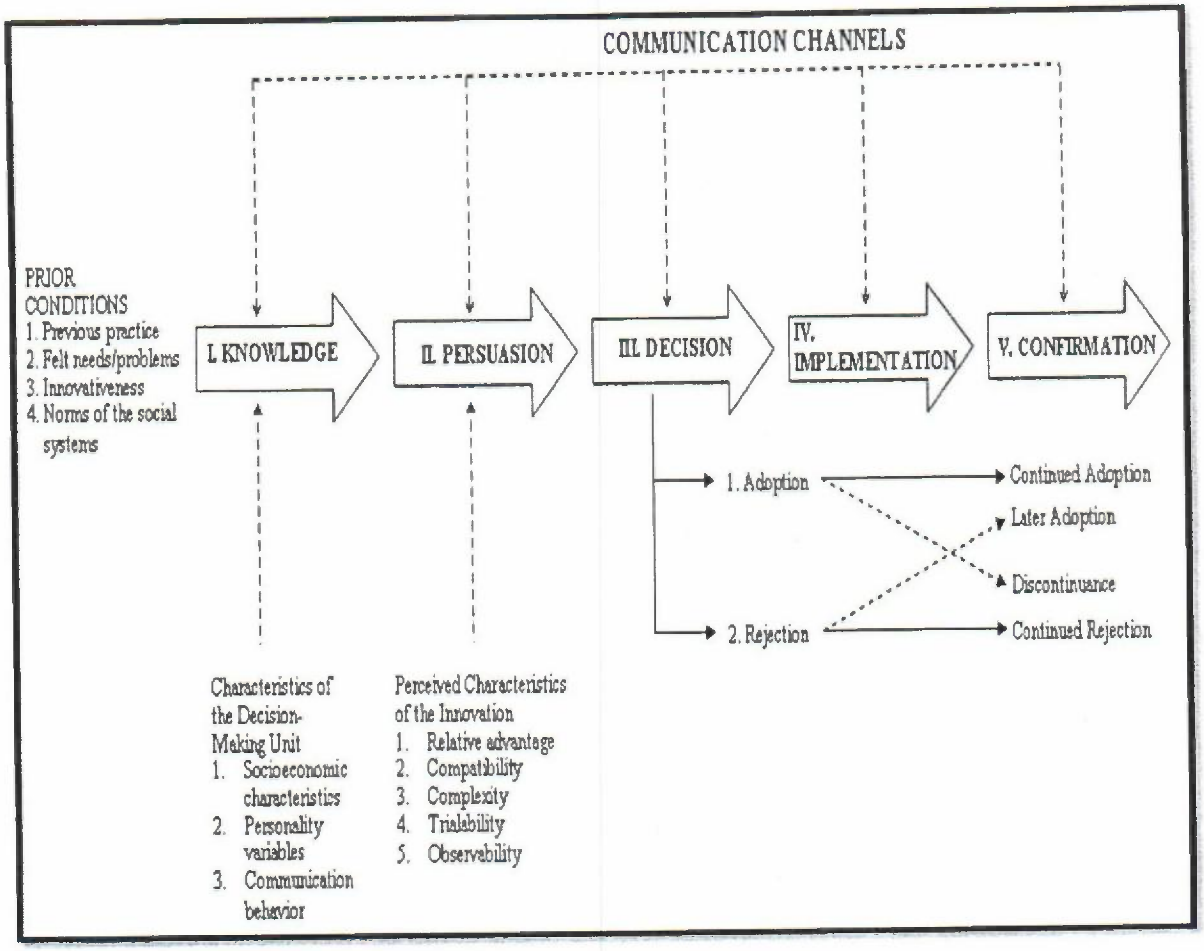

Figure 2.2:A Model of Five Stages in the Innovation-Decision Process

Source: Rogers, 1962.

2.9.2 Individual Innovativeness Theory

Innovativeness is the degree to which an individual is take up new ideas compare with other members of a system. For Rogers (1962), not all individuals in a social system adopt an innovation at the same time. Rather, they adopt in a time sequence. He therefore classified them into adopter categories. In other words, his classification was based on the time of adoption. According to him, individuals who are risk takers will adopt an innovation earlier than others in the continuum of adoption/diffusion. This group is known as the innovators. Venturesomeness is almost an obsession with innovators. They are very eager to try new ideas. This interest leads them to social relationships. Communication patterns and friendships among a clique of innovators are common, even though the geographical distance between the innovators may be considerable. Being an innovator has several prerequisites. These include control of substantial financial resources to absorb the possible loss owing to an unprofitable innovation and the ability to understand and apply complex technical knowledge. The innovator must be able to cope with the high degree of uncertainty about an innovation at the time that the innovator adopts.

Early adopters are a more integrated part of the local social system than are innovators. Whereas innovators are cosmopolites, early adopters are localities. This adopter category has the greatest degree of opinion leadership in most social systems. Potential adopters look to early adopters for advice and information about the innovation. The early adopter is considered by many as "the individual to check with" before using a new idea. This adopter category is generally sought by change agents to be a local missionary for speeding the diffusion process. Because early adopters are not too far ahead of the average individual in innovativeness, they serve as a role model for many other members of a social system. The early adopter is respected by his or her peers, and is the embodiment of successful and discrete use of new ideas. The early adopter knows that to continue to earn this esteem of colleagues and to maintain a central position in the communication structure of the system, he or she must make judicious innovation decisions. So the role of the early adopter is to decrease uncertainty about a new idea by adopting it, and then conveying a subjective evaluation of the innovation to near-peers by means of interpersonal networks.

The early majority adopt new ideas just before the average member of a social system. The early majority interacts frequently with their peers, but seldom holds leadership positions. The early majority's unique position between the very early and the relatively late to adopt makes them an important link in the diffusion process. They provide interconnectedness in the system's networks. The early majority may deliberate for some time before completely adopting a new idea. Their innovation-decision period is relatively long compared with that of the innovator and the early adopter. They follow with deliberate willingness in adopting innovations, but seldom lead.

The late majority adopt new ideas just after the average member of a social system. Adoption may be both an economic necessity and the answer to increasing network pressures. Innovations are approached with a skeptical and cautious air, and the late majority do not adopt until most others in their social system have done so. The weight of system norms must definitely favor the innovation before the late majority is convinced. They can be persuaded of the utility of new ideas, but the pressure of peers is necessary to motivate adoption. Their relatively scarce resources mean that almost all of the uncertainty about a new idea must be removed before the late majority feel that it is safe to adopt.

Laggards are the last in a social system to adopt an innovation. They possess almost no opinion leadership. They are the most localite in their outlook of all adopter categories; many are near isolates in social networks. The point of reference for the laggard is the past. Decisions are often made in terms of what has been done in previous generations and these individuals interact primarily with others who also have relatively traditional values. When laggards finally adopt an innovation, it may already have been superseded by another more recent idea that is already being used by the innovators. Laggards tend to be frankly suspicious of innovations and change agents. Their traditional orientation slows the innovation-decision process to a crawl, with adoption lagging far behind awareness-knowledge of a new idea. While most individuals in a social system are looking to the road of change ahead, the laggard's attention is fixed on the rear-view mirror. This resistance to innovations on the part of laggards may be entirely rational from the laggards' viewpoint, as their resources are limited and so they must be relatively certain that a new idea will not fail before they can afford to adopt. The laggard's precarious economic position forces these individuals to be extremely cautious in adopting innovations. Laggards are late to adopt.

For Rogers, innovativeness helped in understanding the desired and main behavior in the innovation-decision process. Thus, he categorizes the adopters based on innovativeness. As Figure 2.3 shows, the distribution of adopters is a normal distribution.

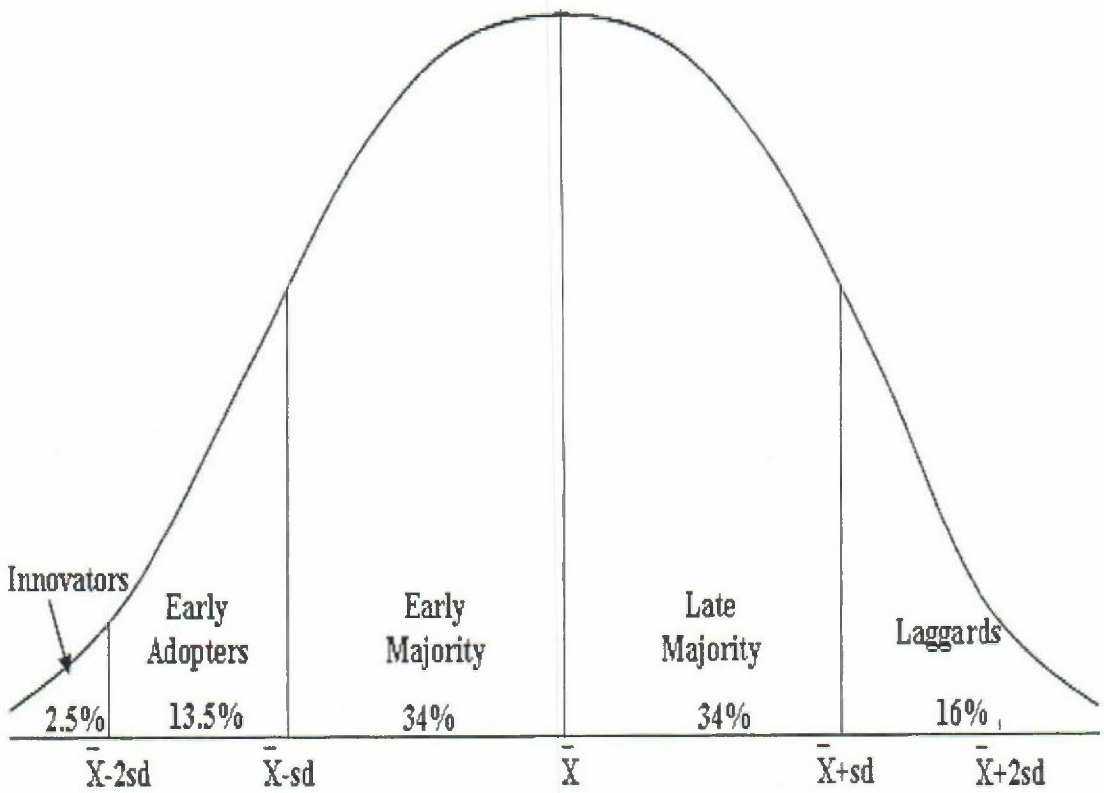

Figure 2.3: Adopter Categorization on the Basis of Innovativeness

Source: Rogers, 1962.

To Moore (1991), these groups are different "markets" in the "selling" of an innovation to faculty adopters. He therefore suggests that the transition from the early adopters to the early majorityoffers particular potential for breakdown because the differences between the two groups are so striking.

In general, the diffusion of innovation is described as S-shape curve as shown below (Figure 2.4). The original diffusion research was done by the French sociologist Gabriel Tarde as early as 1903. Tarde (1903) plotted the original S-shaped diffusion curve. In 1940, Bryce Ryan and Neal Gross also published their study of the diffusion of hybrid seed among Iowa farmers and thus renewing interest in the diffusion of innovation S-curve. At the beginning of the adoption process, there are few early innovators. A steep rise is observed as the early and late majority take up the innovation. The laggards then complete the diffusion process causing the curve to look like S-shape as argued by Rogers(1962).

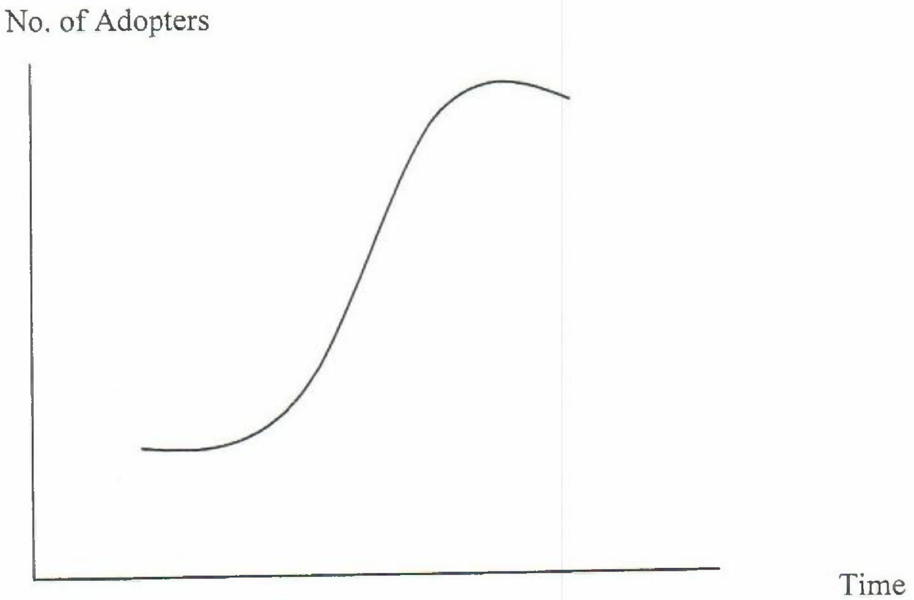

Fig 2.4:The S-Shaped Curve

Source: Rogers, 1962.

2.9.3 Rate of Adoption Theory

Rate of adoption is the relative speed with which an innovation is adopted by members of a social system. It is generally measured as the number of individuals who adopt a new idea in a specified period, such as each year. So the rate of adoption is a numerical indicator of the steepness of the adoption curve for an innovation. Diffusion takes place over time with innovations going through a slow, gradual growth period, followed by dramatic and rapid growth, and then a gradual stabilization and finally a decline.

2.9.4 Perceived Attributes Theory

Perceived Attributes Theory assumes that there are five attributes upon which an innovation is judged: that it can be tried out (trialability), that results can be observed (observability), that it has an advantage over other innovations or the present circumstance (relative advantage), that it is not overly complex to learn or use (complexity), that it fits in or is compatible with the circumstances into which it will be adopted (compatibility). The details of these attributes are discussed below.

The trialabilityis the degree to which an innovation may be experimented on limited basis. New ideas that can be tried will generally be adopted more rapidly than innovations that are not experimental as they build the confidence level of the adopter. Some innovations are more difficult to divide for trial than others. The trialability of an innovation, as perceived by members ofa social system, is positively related to its rate of adoption as argued by Fliegel and Kivlin (1966a), Singh (1966), and Fliegel*etal.* (1968).

Observabilityis the degree to which the results of an innovation are visible to others. The results of some ideas are easily observed and communicated to others, whereas some innovations are difficult to describe to others. The observabilityof an innovation, as perceived by members of a social system, ispositively related to its rate of adoption.

Relative advantage is the degree to which an innovation is perceived as being better than the idea it supersedes. The degree of relative advantage is often expressed in economic profitability, in status giving, or in other ways. The nature of the innovation largely determines what specific type of relative advantage (such as economic, social, and the like) is important to adopters, although the characteristics of the potential adopters also affect which dimensions of relative advantage are most important.

Complexity is the degree to which an innovation is perceived as relatively difficult to understand and use. Any new idea may be classified on the complexity-simplicity continuum. Some innovations are clear in their meaning to potential adopters while others are not. The complexity of an innovation, as perceived by members of a social system, is negatively related to its rate of adoption as concluded by some studies (Kivlin, 1960; Singh, 1966; Petrini, 1966 and Graham, 1956).

Compatibility is the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters. An idea that is more compatible is less uncertain to the potential adopter. An innovation can be compatible or incompatible (1) with socio-cultural values and beliefs, (2) with previously introduced ideas, or (3) with client needs for innovations. Each of the above can be considered in the context of either a top-down or a bottom-up adoption/diffusion process and in either macro-level or micro-level reforms.

Aside the five qualities recognized by diffusion scholars as the main determinants of the success of an innovation, reinvention is another key principle in diffusion of innovations. The success of an innovation depends on how well it evolves to meet the needs of more demanding and risk-averse individuals in a population as argued by Robinson (2009).

Using the history of the mobile phone as a perfect example, he further argued that reinvention ensures continuous improvement of product or process until it is successful.

Other adoption/diffusion theory which contrast with the five attributes but relevant in this study is the determinist (developer-based) focus and the instrumentalist (adopter-based) focus. While the determinists regard technology as the primary cause of social change, the instrumentalistview technology as a series of revolutionary advances that are thought to be out of direct human control. Focus of determinist is on an innovation's technical characteristics which lead to successful adoption/diffusion while the focus of the instrumentalist is on the user (adopter) of a technology and its value which bring about desired change. The innovation's developer is viewed as the primary change agent by the determinist while the technology is the cause of change as viewed by the instrumentalist. For instrumentalist the process is evolutionary, and the causes of change are in social conditions and in human aspirations for change and improvement. Human control over the innovation is therefore a key issue and it is considered essential to understand the social context in which it will be used and the function that it will serve.

2.10INTER-PERSONAL TECHNOLOGY TRANSFER

Technology can reach farmersthrough inter-personal contacts or exchange of ideas. Technologytransfer refers to the general process ofmoving information and skills or knowledge from 'generators' such as researchlaboratories and universities to clients such asfarmers.The outcome of new technologytransfer is the farmers' adoption and bringing this into practice and further diffusion to otherindividuals in the community. Regarding adoption, farmerssometimes discover problems in puttingrecommendation into practice, the extent ofadoption, adjustment or rejection depends onfarmers' behavior (Chi and Yamada, 2002).

The Innovation DecisionModel shows the processthrough which an individual (or other decisionmaking unit) passes from first knowledge ofan innovation to final confirmation of a decision.Diffusion is the process by which aninnovation is communicated through certainchannels overtime among the members of asocial system. When newideas are invented, they are diffused andadopted or rejected.

2.11 SOIL AND WATER CONSERVATION PRACTICES IN GHANA

Like other complex approaches to agricultural development, soil and water conservation (SWC) has numerous definitions. The World Overview of Conservation Approaches and Technologies (WOCAT) contribute the following definitions. The WOCAT definesSWC as activities at the local level which maintain or enhance the productive capacity of the land in areas affected by, or prone to, degradation (World Bank, 2007). It also defines as a way of preventing and controlling land degradation and at the same time, enhancing productivity in the field. It can also be defined as the use of land resources, including soils, water, animals, and plants, for the production of goods to meet changing human needs while simultaneously ensuring the long-term productive potential of these resources and ensuring their environmental functions. For Noordwijk (2000), Soil conservation is simply a way of maintaining the functions of the soil to sustain plant growth. Soil conservation practices involve managing soil erosion and its counterpart process of sedimentation, reducing itsnegative impacts and exploiting the new opportunities it creates. Young (1997) defined soil conservation as a combination of controlling erosion and maintaining soil fertility.

Improving soil health as a means of enhancing farm yields has been the focus of both research and extension services in Ghana. Below are some of the SWC techniques practiced in Ghana and have been promoted by IFPRI.

2.11.1 Minimum Tillage/Zero Tillage

Zero tillage (also known as no-till or direct seeding) is a method of plowing or tilling a field in which the soil is disturbed as little as possible by, essentially, not plowing the field. The crop is planted directly into a seedbed which has not been tilled since the harvest of the previous crop. In this system, simple farm equipment such as hoes and digging sticks are used to prepare land and plant food crops. Spraying herbicide kills weeds, and all plant residues (including weeds) are returned into the soil. While more intensive tillage generally increases porosity of the topsoil and reduced barriers to infiltration of the soil surface, it normally interrupts the continuity of the macro-pores in the soil and can reduce deep infiltration, especially if a plough-pan is formed. No till systems that are implemented on soils that have never been ploughed or compacted by the use of heavy machinery generally maintain the high infiltration rates of forest soils. Transitions from ploughing to minimum tillage systems often involve a number of years of reduced infiltration, before new continuous macro-pore system is re-established by the activity of earthworms and other soil engineers (Noordwijk, 2000).

2.11.2 Crop Rotation

Crop rotation is a system where various crop species are grown in sequence on the same plot. It involves alternating crops of different families every year in a field in order to reduce incidences of crop diseases and pest attacks as well as contribute to improved soil composition. In this technique, the farmer makes sure he alternates crops that make different demands on soil requirements. In most cases, the farmer plant legumes after cereals for the purpose of nitrogen fixation in the soil. The different rooting pattern of different crop species planted may help on soil structure formation and improve water percolation. This cropping pattern can vary from year to year depending on market price or on soil/weather condition, but they are chosen for the same purposes: better soil physical and nutrient condition, interrupts life cycle of weed/pest/ plant disease (Noordwijk, 2000). In the study of factors affecting smallholder farmers' adoption of soil and water conservation practices, Chomba (2004) found that the most common soil/water conservation practice used by farmers was crop rotation.

2.11.3 Fertilizer use

Fertilizer use is required to replace crop land nutrients that have been consumed by previous plant growth. It is essential for economic yields. However, excess fertilizer use and poor application methods can cause fertilizer movement into ground and surface waters. It is estimated that 25% of all pre-plant nitrogen applied to maize is lost through leaching or denitrification (MoFA, 2011). Applying the appropriate form of fertilizer can reduce leaching. Also, correct fertilizer placement in the root zone can greatly enhance plant nutrient uptake and minimize losses. Fertilizer applications should be timed to coincide as closely as possible to the period of maximum crop uptake (Noordwijk, 2000).

In Africa and Ghana in particular, the success has not been sustained over longer periods. The limited use of adapted high yielding varieties is one explanation to low consumption figures. Production risks are also more prominent with degraded soils where fertilizer has limited response and larger weather variability and moisture stress that deters risk-averse farmers. Farm gate fertilizer prices are much higher and profitability of fertilizer use is often less convincing. Access to, availability and timeliness of fertilizer delivery discourage adoption. Elimination or varying and uncertain subsidisation of the input has impacted consumption. Due to small markets and sales volumes, economies of scale have not been exploited in fertilizer procurement and distribution. This adds to the importance of using the right fertilizer composition, amount, and application; requirements that have not always been met.

It is therefore not surprising that many initiatives promote higher fertiliser use, i.e. the proposed increase to 50 kg/ha in 2015 from the 2007 9.6 kg/ha (Toborn, 2011). However, how to increase fertilizer consumption and simultaneously use agronomic and managerial innovations to restore/improve the natural resource base is the unresolved dilemma.Below are Tables 2.4 and 2.5 showing fertilizer consumption by country, region, and developed/developing nations. African fertilizer consumption is extremely low, and few countries deviate from the pattern; Egypt being the notable exception. Figures show annual use of fertilizer per hectare, which may be distributed over two crop seasons.

Table 2.4: Fertilizer Use Intensity by Region, Developed/Developing Nations

Region	Intensity (kg/ha)
Asia	222.2
Central America & Caribbean	68.1
Europe	152.3
Middle East and North Africa	144.3
North America	161.0
Oceania	167.3
South America	195.0
Sub-Saharan Africa	9.6
Developed countries	165.3
Developing countries	180.1

Source: Toborn, 2011.

Table 2.5: Fertilizer use in African countries

Country	Fertilizer use (kg/ ha)	Country	Fertilizer use(kg/ ha)
Algeria	13	Mali	Na
Angola	3	Mauritania	Na
Benin	0	Morocco	52
Burkina Faso	7	Mozambique	5
Burundi	1	Namibia	2
Cameroon	8	Niger	0
Central A. R.	Na	Nigeria	6
Chad	Na	Rwanda	Na
Congo, D.R.	Na	Senegal	22
Congo, Rep.	Na	Sierra Leone	Na
Cote d'Ivoire	10	South Africa	49
Egypt	572	Sudan	4
Eritrea	1	Tanzania	13
Ethiopia	3	Togo	6
Ghana	4	Tunisia	26
Guinea	2	Uganda	1
Kenya	44	Zambia	Na
Madagascar	3	Zimbabwe	30
Malawi	23		

Source: WARDA, 2008.

2.11.4 Mulching

Mulches are materials placed over the soil surface to maintain moisture and improve soil conditions. Mulching is one of the most beneficial things a farmer can do for the health of a crop. Mulch can reduce water loss from the soil, minimize weed competition, and improve soil structure. Properly applied, mulch can give landscapes a handsome, wellgroomed appearance. Mulch must be applied properly; if it is too deep or if the wrong material is used, it can actually cause significant harm to trees and other landscape plants (ISA, 2005).

2.11.5 Row Planting

According to Noordwijk (2000), row planting involves growing seeds in straight line. It is the traditional way of planting vegetables, crops and trees. However, there are other methods of planting available. Choosing the best method depends on your needs and experience as a gardener or farmer. Being familiar with row planting gives you the advantage of combining planting methods to achieve certain harvesting objectives (csmuedu.org).

2.11.6 Water Harvesting

Water harvesting is the collection of runoff for productive purposes. Instead of runoff being left to cause erosion, it is harvested and utilized. In the semi-arid drought-prone areas where it is already practiced, water harvesting is a directly productive form of soil and water conservation.

Water harvesting (WH) can be considered as a rudimentary form of irrigation. The difference is that with WH the farmer (or more usually, the agro-pastoralist) has no control over timing. Runoff can only be harvested when it rains. In regions where crops are entirely rainfed, a reduction of 50% in the seasonal rainfall, for example, may result in a total crop failure. If, however, the available rain can be concentrated on a smaller area, reasonable yields will still be received (FAO, 2009). Many water harvesting case studies and experiments (exampleRosegrant*etal.*, 2002) have shown increases in yield and water use efficiency. However, it is not clear if the widespread use of these technologies is feasible.Construction and maintenance costs of water harvesting systems, particularly the labor costs, are very important in determining if a technique will be widely adopted at the individual farm level. The initial high labor costs of building the water harvesting structure often provide disincentives for adoption. The initial labor costs for construction generally occur in the dry season when labor is cheaper but also scarce due to worker migration; maintenance costs, on the other hand often occur in the rainy season when labor costs are higher due to competition with conventional agriculture. Thus, while many case studies of water harvesting methods show positive results, these methods have yet to be widely adopted by farmers.

2.11.7 Composting

Cooperband (2002) describes composting as a controlled decomposition or the natural breakdown process of organic residues. Composting transforms raw organic waste materials into biologically stable, humic substances that make excellent soil amendments. Compost is easier to handle than manure and other raw organic materials, stores well and is odor-free. Compost is an organic matter source with a unique ability to improve the chemical, physical, and biological characteristics of soils. It improves water retention in sandy soils and promotes soil structure in clayey soils by increasing the stability of soil aggregates. Adding compost to soil increases soil fertility and cation exchange capacity and can reduce fertilizer requirements up to 50% (Rynk, 1992). There is no fixed time to produce finished compost as explained in the work ofReal and Baptista (1996). Duration depends on feed stocks, composting method used and management. It can take as little as three months and as long as two years. Compost is considered finished when the raw feed stocks are no longer actively decomposing and are biologically and chemically stable. The cost structure includes site development feedstock, equipment, labor; management and marketing cost. The cost is usually high and hence deters most farmers from practicing the technique.

2.11.8 Intercropping

Intercropping is the simultaneous cultivation of more than one species or cultivar on the same piece of land (MousaviandEskandari, 2011). It is the practical application of ecological principles such as diversity, crop interaction and other natural regulation mechanisms. Intercropping has many advantages, mainly related to the complementary use of environmental resources by the component crops which results in increased and more stable yields, better nutrient recycling in the soil, better control of weeds, pest and diseases and an increased biodiversity. Aside the potential of increasing organic cereal and grain legume protein production, intercropping can enhance biodiversity in farming systems and safeguard the organic farmers earnings. Cereals and legumes, both for forage and for grain are the most common intercrops. The main advantage of the legume-cereal intercrop is the input of nitrogen to the system by the fixation of atmospheric N_2 by the legume, which results in improve use of renewable nitrogen sources.Despite its advantages, intercropping has traditionally been neglected in research on plant production systems in temperate agricultural ecosystems, due to its complexity and because of the difficulties for its management lesser relevance in cropping systems based on agrochemicals.

The above discussed practices were largely practiced by Ghanaian farmers and promoted by IFPRI. This study will specifically focus on minimum or zero tillage, crop rotation, fertilizer use, mulching, row planting, water harvesting and intercropping since they are promoted by IFPRI.

2.12EMPIRICAL STUDIES ON ADOPTION DECISIONS

Several disciplines have looked at adoption and diffusion from their own perspectives. Sociologists explained adoption and diffusion in terms of the nature of communication channels and differences in social positions, while economists explained adoption and diffusion in terms of profitability. Anthropologists and geographers also explained adoption and diffusion as the compatibility of innovation and information flow respectively (Boahene, 1995).

According to Feder*etal.*(1985) rural sociologists were the first to undertake adoption and diffusion studies. These sociological studies, especially those by Ryan and Gross (1943) and Rogers (1962), provide the basis for economic studies. Rogers (1962), like others found that, diffusion was an S-shape function of time. This was interpreted to mean that, when a technology is first released, only few people adopt it. More people adopt it later thereby increasing the rate of adoption. The number of new adopters however decreases with time resulting in a decrease in the rate of adoption. Thus, the rate of adoption in a community increases initially and finally decreases.

Other studies that offer good economic approach to the study of diffusion and adoption of technology include Griliches (1957) and Feder *et al.* (1985). These studies attempted to test the relationship of key variables to adoption behavior. Griliches (1957) deals with the variation in parameters across districts using market size, corn acreage per farm and differences in profitability in the districts. Feder*etal.*(1985)summarises findings on individual adoption with respect to seven major explanatory variables: farm size, risk and uncertainty, human capital, labour availability, the credit constraint, tenure, and supply constraints.Feder*et al.* (1985) found that, adoption decisions are influenced by farm size, risk and uncertainty, human capital, labour availability, credit constraints, land ownership and rentalarrangements.

Recent studies include that of Boyd *etal.*(2000) which dealt extensively on SWC practices in Sub-Sahara Africa (SSA) using Tanzania and Uganda as case studies. In this study, the analysis was extended to include livelihood approaches to SWC, issues that have to do with farming systems, access to assets, transformation of structures and processes, institutions and policies. Bayard*etal.*(2006) also studied the adoption and management of soil conservation practices in Haiti. In this study, they identified and analyzed factors influencing farmers' decisions to adopt rock walls. They also examined the factors which played a significant role in the management of land improvement technology. In their findings, it was discovered that age, education, group membership, and per capita income negatively influenced the ability to manage the rock walls, while age squared and the interaction between age and per capita income positively influenced the management. They asserted that, factors influencing management of rock walls may be different for each farmer or group of farmers depending upon the constraints they faced.

Another study (Onweremadu*etal.,* 2007) which dwelled on adoption levels revealed that, arable farming was dominated by relatively young and educated people who can enhance adoption and soil management technological transfer. The results in this study also indicated that, farmers were exposed to a wide range of impersonal sources of soil information and had potentials of disseminating such soil information to neighboring farmers. The study in question also found out that age, education, and income dictate the adoption status in the study area.

In Ghana, Donkoh and Awuni (2011) did a similar work but their study was based only in the North, besides the study focused only on the determinants, but not the effects of adoption. Also, the uniqueness of their study is the use of Kendall's Coefficient of Concordance and an Ordered Probit Model in the analysis. The results of the Probit model showed that extension visits, experience and training had a positive influence on the adoption of farm practices, while farm size and input distance had a negativeeffect on adoption. Studies which proceeded to assess the impact of SWC techniques include Kato *etal.*, (2009), Olarinde*etal.* (2012) and Kassa*etal.* (2013). However, the main limitation of Kassa*etal.* (2013) is that, it investigated farmers' perceptions about the impact of SWC techniques. Much as the perceptions of farmers with respect to the efficiency of SWC techniques are important, the approach is limited as farmers' perceptions may not be right or accurate. A methodology to measure the effects of SWC techniques in quantitative terms is more preferable. In this case, the studies by Kato *etal.* (2009) and Olarinde*etal.* (2012) were expedient. However, they estimated an average response model, and in the case of the latter, also used the propensity score matching. Estimation of technical efficiency is superior to these methods as it does not only give us the opportunity to measure the efficiency of individual farmers against the average but we are able to also know the determinants of such efficiency levels. This allows for a more pragmatic policy formulation.

The present study contributes to the technology adoption literature with the examination of the factors influencing farmers' decision to adopt SWC techniques, effect of adoption on output andthe determinants of technical efficiency from the perspective of a developing country.

2.13 TECHNICAL EFFICIENCY

The concept of technical efficiency can be traced back to productive efficiency as first introduced by Farrell (1957) who argued that there were two components of efficiency: technical efficiency and allocative efficiency. According to Farrell's methodology, economic efficiencyis equal to the product of technical efficiency and allocative efficiency where, technical efficiency is associated with the ability to produce on the frontier isoquant, while allocative efficiency refers to the ability to produce at a given level of output using the cost-minimizing input ratios. In other words, technical inefficiency reflects deviations from the frontier isoquant, and allocative inefficiency is related to deviations from the minimum cost input ratios (Farrell 1957; Kopp and Diewert 1982).

In Figure 2.5, it is assumed that there are two inputs ($X_1$and X_2) used by a firm to produce a single output (Y) with assumption of constant returns to scale. The I_1I_2curve represents the isoquant of fully efficient firms, and could be used to measure technical efficiency. If the firm employs amount inputs at point R to produce a unit of output, the technical inefficiency of that firm could be measured by the distance RS. This is the proportion by which the use of inputs could be reduced without a decrease in output. This is expressed in percentage terms by the ratio SR/OR, which stands for the percentage by which all inputs need to be reduced to gain production which is technically efficient. The technical efficiency of a firm is measured by the ratio: Technical efficiency = OS/OR. If a firm has technical efficiency equal to 1, it is technically efficient. The firm is technically inefficient if its technical efficiency value is less than 1. At point S the firm could gain full technical efficiency because point S lies in the efficient production indifference curve.

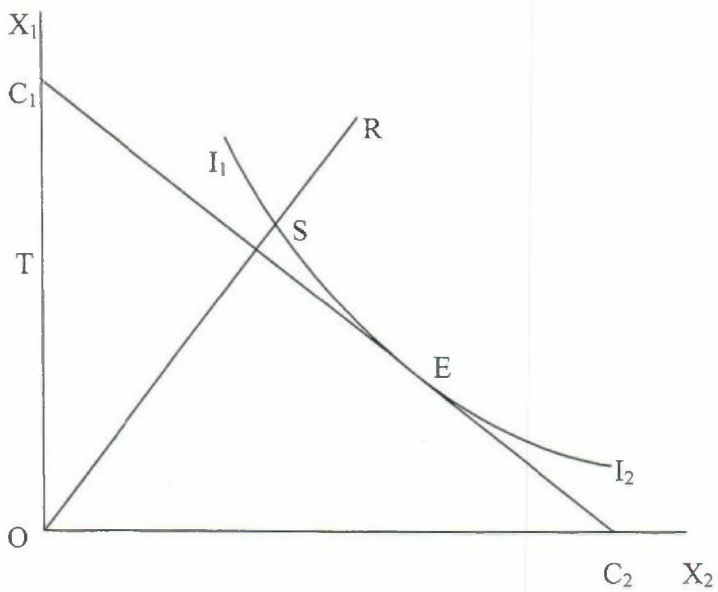

Figure 2.5: Technical, Allocative and Economic Efficiency

I_1I_2 is isoquant and C_1C_2 is the isocost where the latter is tangent to the former at point E. The marginal rate of technical substitution between the two inputs is equal to input price ratio at this point. At E the cost of producing a given level of output is the minimum as it represents the most efficient allocation of inputs. For output quantity produced at point S, the best use of inputs is at point Ebecause it represents the minimum cost. The allocative efficiency of the firm can be defined as: Allocative Efficiency = OT/OS. The firm is technically as well as allocatively efficient at point E.

The range from T to S shows the reduction in cost of production provided production were to take place at allocatively and technically efficient point Erather than point S which is technically efficient but allocatively inefficient. The firm would be fully allocatively efficient if its AE value is 1 and allocatively inefficient if its AE value is less than 1. The economic efficiency is a combination of technical and allocativeefficiency and can be obtained by multiplying TE and AE.

$$EE = TE * AE \qquad (2.6)$$

$$EE = \frac{OS}{OR} * \frac{OT}{OS} \qquad (2.7)$$

$$EE = \frac{OT}{OR} \qquad (2.8)$$

$$AE = \frac{OT}{OS} \qquad (2.9)$$

$$TE = \frac{EE}{AE} \qquad (2.10)$$

$$TE = \frac{OT}{OR} \div \frac{OT}{OS} \qquad (2.11)$$

$$TE = \frac{OS}{OR} \qquad (2.12)$$

The index of EE also varies between 0 and 1 where the latter implies that the firm is economically efficient. If the value of EE is less than 1 then the firm is economically inefficient. The distance from Rto Talso represents the cost reduction in production if a firm produces at point Twith technical and allocative efficiency, instead of at point Rwith technical and allocative inefficiency. Economic efficiency is a combination of technical and allocative efficiency.

It is important to note that technical efficiency can be determine through the stochastic frontier production function.

2.14THE STOCHASTIC FRONTIER PRODUCTION FUNCTION AND TECHNICAL EFFICIENCY

The basis of a frontier function can be illustrated with a farm using n inputs ($X_1, X_2 ... X_n$) to produce output Y. Efficient transformation of inputs into output is characterized by the production function $f(X_i)$, which shows the maximum output obtainable from various input vectors. The stochastic frontier production function assumes the presence of technical inefficiency of production. Hence, the function is defined as:

$$Y_i = f(X_i;\ \alpha_i) + \quad \varepsilon \tag{2.13}$$

For i= 1, 2, 3...... ....n

Whereby $Y_i$is the output of farmer i, $X_i$are the input variables, $\alpha_i$are production coefficients and ε is the error term that is composed of two elements, that is:

$$\varepsilon = v_i - u_i \tag{2.14}$$

Where v_i is the stochastic error which is assumed to be identically, independently and normally distributed with zero mean and a constant variance (σ_v^2). The other second component (u_i) is a one-sided error term which is independent of v_i and is normally distributed with zero mean and a constant variance (σ_u^2), allowing the actual production to fall below the frontier but without attributing all short falls in output from the frontier as inefficiency.

We follow Jondrow *et al.*, (1982) that the technical efficiency estimation is given by the mean of the conditional distribution of inefficiency term u_i given ε; and thus is defined by:

$$E(u|\varepsilon_i) = \frac{\sigma_u - \sigma_v}{\sigma} - \left[\frac{f(\varepsilon_j\lambda|\sigma)}{1 - F(\varepsilon_i\lambda|\sigma)} - \frac{\varepsilon_i\lambda}{\sigma}\right] \quad (2.15)$$

Where;

$$\lambda = \frac{\sigma_v}{\sigma_u} \quad (2.16)$$

$$\sigma^2 = {\sigma_u}^2 - {\sigma_v}^2 \quad (2.17)$$

While f and F stand for the standard normal density and cumulative distribution function, respectively evaluated at $\varepsilon_j\lambda/\sigma$. We define the farm–specific technical efficiency in terms of observed output (Y_i) to the corresponding frontier output (Y_i*) using the existing technology derived from the equation above as:

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{E(Y_i|u_i, X_i)}{E(Y_i|u_i = 0, X_i)} = e^{-[E(u_i|\varepsilon_i)]} \quad (2.18)$$

The values of TE range between 0 and 1 where the latter shows that the farm is fully efficient.

2.15REVIEW OF EMPIRICAL STUDIES ON TECHNICAL EFFICIENCY

There has been growing literature on the technical efficiency of smallholder farmers. Prominent among these works include Basnayake and Gunaratne, 2002; Barnes, 2008; Duvel*et al.*,2003; Shapiro and Muller, 1977; and Seyoum*et al.*, 1998. However, the beginning of theoretical developments in measuring technical efficiency can be trace back to the works of Debreu (1951) and Farrel (1957) known as Debreu-Farrell measure. These studies have shown that technical efficiency is low and varies among small-scale farmers especially in developing countries as it is reported to be less than 0.80. In most of these studies, technical efficiency is reported to be associated with factors such as gender, farmers` age, education level, farm size, access to extension, access to credit, owned, farmers` family size, market access, and farmers` access to improved technologies (such as fertilizer, agro-chemicals, tractor and improved seeds). However, influence of these factors on technical efficiency of farmers vary in different studies.

For instance, farmers` age and education, access to extension, access to credit, family size, and farmers access to fertilizer, tractors and improved seeds variable are reported by many studies as having a positive effect on technical efficiency (e.g. Amos, 2007; Ahmad *et al.*,2002;Tchale and Sauer 2007; and Basnayake and Gunaratne, 2002) while other studies (Asante *et al.*, 2014,) found age, education and family size to have negative effect on technical effeciency of farmers.

Other studies have also measured technical efficiency using the stochastic frontier method because of its advantages. Bravo-Ureta and Pinheiro (1993), Parikh and Shah (1994), Ajibefun and Abdulkadri (1999), Ajibefun and Daramola (1999), Sharma *et al.*, (1999) and Ajibefun*et al.*, (2002) have used the stochastic parametric model to measure the technical, allocative and economic efficiencies in recent agricultural production efficiency

CHAPTER THREE

METHODOLOGY

INTRODUCTION

This chapter presents the conceptual and analytical approach to the study. The chapter provides a definition of the key concepts used in the study. It provides a clear explanation of how this study was conducted, providing a background of the study area as well as the description of thesources and types of data namely; sampling procedure,data processing and analysis.The chapter also discusses the models used and the approaches used in the estimation of the models.According to Panneerselvam (2009), methodology is a system of models, procedures and techniques used to find the results of a research problem.

3.1 STUDY AREA

3.1.1 Location and Size

Located on the West African coast,Ghana shares boundaries with Togo to the east, La Cote d'Ivoire to the west, Burkina Faso to the north and Gulf of Guinea to the south. A recent discovery of oil in the Gulf of Guinea offers opportunity for Ghana to accelerate its pace of development through investment in other major sectors of the economy especially agriculture which dominates by employing 40% of the population. Ghana is one of the leading exporters of cocoa in the world. It is also a significant exporter of commodities such as gold and lumber.

Ghana covers an area of 238,500 square kilometers with an estimated population of 24 million, drawn from more than one hundred ethnic groups - each with its own unique language. English, however, is the official language, a legacy of British colonial rule.

3.1.2 Topography and Natural Resources

Ghana is a lowland country, except for a range of hills on the eastern border. The sandy coastline is backed by a coastal plain that is crossed by several rivers and streams, generally navigable only by canoe. In the west the terrain is broken by heavily forested hills and many streams and rivers. To the north lies an undulating savanna country that is drained by the Black and White Volta Rivers, which join to form the Volta, which then flows south to the sea through a narrow gap in the hills.

The local classification system of soil in Ghana is based on characteristics that are the result of the major climatic differences that in turn have given rise to two major distinct vegetation belts, namely, Forest and Savannah. The soils of the Forest belts of Ghana are easily distinguished from those of the Savannah belts by the greater accumulation of organic matter in the surface horizon resulting from the more abundant leaf-fall under Forest vegetation and the slower rate at which humus is oxidized. The soils of the Savannah belts are on the other hand generally lower in organic matter within the surface horizon due to the fact that grass is the dominant vegetation. In addition, over extensive areas, such soils have unfavourable moisture relationships due mainly to the fact that rainfall is less reliable in occurrence than in the Forest belts (Obeng, 2000).

3.1.3 Climate and Rainfall Conditions

The climate of Ghana is tropical, but temperatures vary with season and elevation. The south has two rainy seasons which occur from April to July and from September to November whilethe north has one rainy season which begins in April and lasts until September. Annual rainfall ranges from about 1,100 mm (about 43 in) in the north to about 2,100 mm (about 83 in) in the southeast. The harmattan, a dry desert wind, blows from the northeast from December to March, lowering the humidity and creating hot days and cool nights in the north. In the south the effects of the harmattan are felt in January. In most areas the highest temperatures occur in March, the lowest in August. The average annual temperature is about 26°C (about 79°F) and the annual rainfall is 736.6mm / 29".The coolest time of the year is between June and September when the main rainfall occurs. Variations in temperature both annually and daily are quite small. The minimum temperature is around 23°C (73°F), warm and comparatively dry along southeast coast; hot and humid in southwest; hot and dry in north.

3.2 RESEARCH DESIGNAND DATA

Research design is the overall plan employed to obtain answers to the research questions raised and to test the hypotheses formulated (Agyedu*etal.*, 2013). Looking at the nature of the problem at hand, it became obvious that the best data for the research would be a combination of both qualitative and quantitative approaches (i.e. quasi-experimental design). The target population is Ghanaian maize farmers who are into small scale production and are either adopters or non-adopters of SWC techniques. The study therefore employed a cross-sectional baseline survey data from the Ministry of Food and Agriculture (MoFA). The data is a national data which has been well collected, cleaned and comprehensive enough for this study. Also, time and resource constraints would not allow an individual to collect a data of such quantity.The data involves a survey of cropping systems undertaken by the Statistics Research Information Directorate (SRID) of the Ministry of Food and Agriculture (MoFA) and thus captures SWC techniques used by farmers. The first phase of the survey was piloted in twenty (20) districts across the country during the 2011/2012 cropping season and implemented by SRID with technical and financial support from the Ghana Strategy Support Program (GSSP) of the International Food Policy Research Institute (IFPRI). Two districts were selected from each of the ten regions. Forty (40) enumeration areas were then selected from each of the 20 districts covering a total of 800 enumeration areas from the 20 districts in Ghana.

The variables that constitute the data includemaize output, number of SWC techniques adopted by farmers, gender, age, number of years of education, farm size, household size, group membership, number of extension visits, total credit obtained by the farmer and distance to market/input store. Other data include reasons for adoption of SWC techniques, occupational status, quantity of fertilizer used, labour, religious and marital status of the farmers.

3.2.1 Sampling Procedure

A three stage multi-sampling design was applied by the Statistics Research and Information Directorate (SRID) in order to address the Government of Ghana's requirement for reliable agricultural statistics at the national, regional and district levels. This includes a first stage involving a total of 20 districts. Two (2) from each of the 10 regions were randomly selected, using districts' population in year 2000 as a measure of size. Eleven Metropolitan and Municipal Assemblies (Kumasi, Sunyani, Cape Coast, New Juaben, Accra, Tema, Tamale, Bolgatanga, Wa, Ho and Shama-Ahanta East) were excluded from the study, given their urban predominance (MoFA, 2012).

The second stage sampling also involved a total of 800 EAs; 40 EAs were randomly selected with probability proportional to size in each district, using the list of EAs compiled by the 2010 Census as a sample frame, and projected total population as a measure of size. In the Kassena-Nankana East district, 53 of the 187 EAs compiled by the 2010 census were excluded from the study because of the land disputes prevalent in the area in early 2011 (MoFA, 2012).

At the third stage sampling, ten (10) holders were randomly chosen in each EA, using as a sample frame, the full list of all holders, compiled from the Household and Holders Listing questionnaire. This provides a total sample of 8000 holders, consisting of 400 holders per district (MoFA, 2012).

Finally at the fourth stage, the relevant data necessary for this study was then sorted to get the maize producers in each district. The data set (used for the analysis in this study) is therefore made up of 1530 farmers, consisting of farmers from each of the 20 districts.The 20 districts selected for the pilot include the following (see Table 3.1) and can be seen on Figure 3.1 below.

Table 3.1: Regions and Districts Selected

Region	District	Region	District
Ashanti	Amansie West	Northern	Gushiegu
	SekyereAfram Plains		Yendi
BrongAhafo	Dormaa East	Upper East	Bawku municipal
	TechimanMunicipal		Kassena-Nankana East
Central	AssinNorthMunicipal	Upper West	Lawra
	Mfantsiman		Sissala East
Eastern	Atiwa	Volta	Keta
	West Akim		North Tongu
Greater Accra	Ga East	Western	Bia
	Ga West		PresteaHuni Valley

Source: MoFA, 2012.

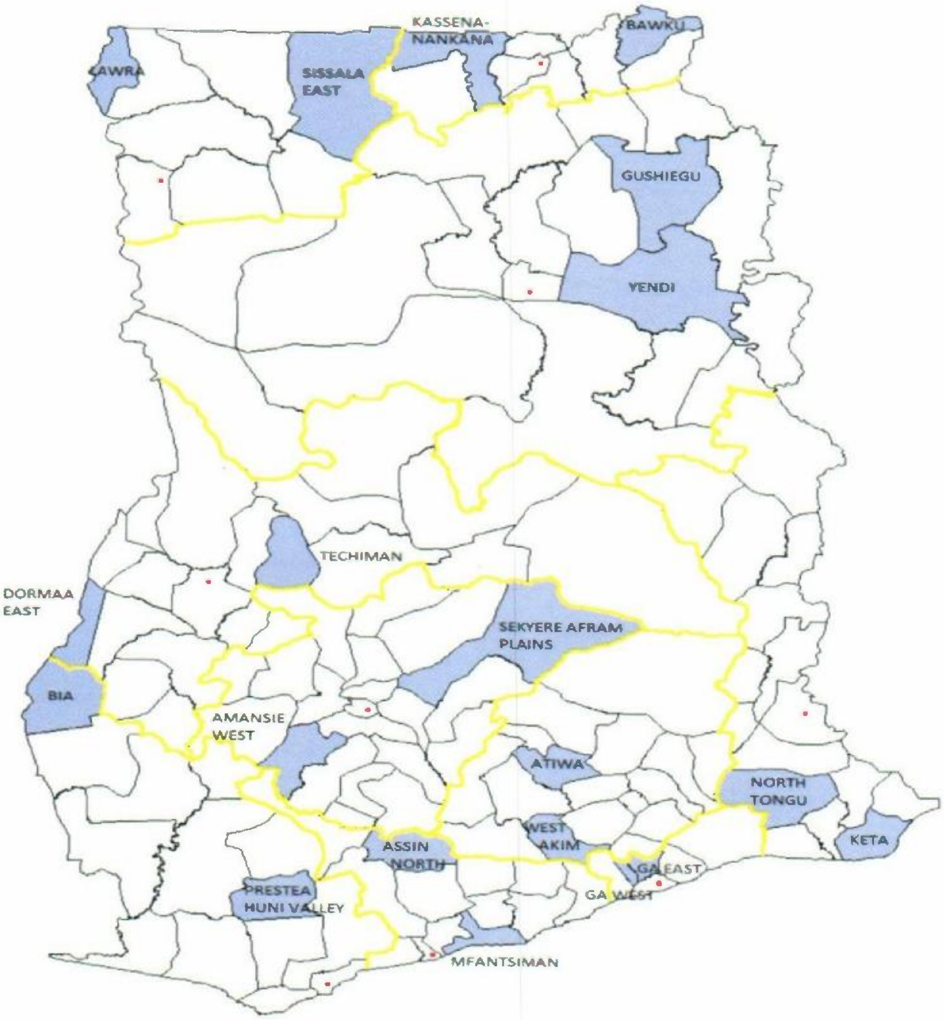

Figure 3.1: Map of Ghana Showing the Study Areas.

3.3 DATA PROCESSING AND ANALYSIS

The data used for the study were recorded into different SPSS templates with each containing information about the communities, households, household members, holders, farms, crop production and marketing and animal production. Not all the information was needed for the study. As a result of this, all the data were exported to EXCEL where sorting, editing and recoding were carried out to get the variables for this study. The variables were exported back to SPSS and STATA 11 for analysis.

3.4 THEORETICAL MODEL TO EXPLAIN TECHNOLOGY ADOPTION AND ITS EFFECTS ON OUTPUT/TECHNICAL EFFICIENCY

In chapter two, the adoption model was specified as follows:

$$Prob(P^* - P > 0) = Prob(\varepsilon < \beta' X) = F(\beta' X) \quad (3.1)$$

Where **X** is a set of characteristics of the decision maker and β is the parameter vector and $\beta' X$ becomes an index function that allows the estimation of the probability of adoption as indicated earlier.

The specification above is useful when the technology under consideration is only one and the dependent variable assumes a binomial situation (i.e. probit/logit model). In situations where the technology is more than one, the farmer may adopt more of the technologies. Now assuming we have such cases, a series of repeated binomial choices will be the outcome. Statistical theory states that a repetition of a series of binomial choices, from the random utility formulation, asymptotically converges to a Poisson distribution as the number of technologies becomes large and probability becomes small.

Since the SWC techniques are more than one in this study, farmers make series of discrete household decisions that sums across an aggregation of choices to a Poisson distribution. The function for the Poisson regression is:

$$\Pr(y_i/x_i) = \frac{e^{-\lambda}\lambda^{y}}{y!}, i = 0, 1, 2 \quad (3.2)$$

Where $Pr(y_i/x_i)$is the probability of farmer i adopting y_i techniques at a time and λ_i is the Poisson parameter for farmer i.Given that the expected number of SWC techniques adopted per period is $E(y|x_i)$, then the mean parameter as the function of the regressorsx_i and a parameter vector β is given by:

$$E(y|x_i) = \lambda = exp(x'\beta) \quad (3.3)$$

The parameter λ is assumed to be log-linearly related to regressors x_i. Therefore,

$$\ln(\lambda) = \beta' x_i \quad (3.4)$$

The log-likelihood function is given by the equation:

$$lnL = \sum_{i=1,2,......n} [-\lambda_i + y_i\beta' x_i - lny_i!] \quad (3.5)$$

The expected number of SWC practices per farm is given by the equation:

$$E[y_i|x_i] = Var[y_i|x_i] = \exp(x_i\beta' + \mu_1) \quad (3.6)$$

Where β is a 1 × k vector of parameters; x is a k × 1 vector with the values of k independent variables in the i^{th} observation and n is the number of observations.

The equation can also be expressed as:

$$E[Y_i] = exp^{(\beta_i x_{1i})} exp^{(\beta_2 x_{2i})} \ldots \ldots . exp^{(\beta_k x_{ki})} \quad (3.7)$$

$$= \exp(\beta_j X_{jn})\, C_i \qquad (i = 1, 2 \ldots \ldots \ldots \ldots \ldots \ldots . . n) \quad (3.8)$$

Where, j can take any value from 1 to k and identifies a specific explanatory variable and C_i is a constant representing the product of the remaining exponential terms in equation (3.5).

For dichotomous explanatory variables, if $x_{ji} = 0, E(Y_i) = C_i$, and when $x_{ji} = 1, E(Y_i) = \beta_j C_i$, Therefore,100 × $(exp^{\beta_j} - 1)$calculates thepercentage change on E(Y) when x_j goes from zeroto one, for all observations (i). In general, forindependent variables that take several integer values, the percentage change in the expected level ofadoption when x_j goes from x_{j1} to x_{j2} can be calculatedas:

$$100 \times \frac{exp^{\beta_j x_{j2}} - exp^{\beta_j x_{j1}}}{exp^{\beta_j x_{j1}}} \qquad (3.9)$$

Based on the theoretical framework, the empirical model was estimated using the farmers' characteristics that conditioned adoption behavior. These included gender, age, age square, education, farm size, household size, group membership, number of extension visits, total credit obtained by the farmer and distance to market/input store.

The empirical model is therefore specified as:

$$y_i = (\beta_0 + \beta_1 Gender + \beta_2 Age + \beta_3(Age^2) + \beta_4(Edu) + \beta_5(FSize) + \beta_6(HHsize) + \beta_7(Group\_Mem) + \beta_8(Ext) + \beta_9(AC) + \beta_{10}(distance) + \varepsilon_1) \qquad (3.10)$$

Where; y = 1if a farmer adopted any two of the eight SWC techniques during the farming season under review;

y = 2 if a farmer adopted any two of the eight SWC techniques during the farming season under review;

y = 3 if a farmer adopted any three of the eight SWC techniques during the farming season under review;

y = 4 if a farmer adopted any four of the eight SWC techniques during the farming season under review;

y = 5 if a farmer adopted any five of the eight farming practices during the farming season under review;

y = 6 if a farmer adopted any six of the eight SWC techniques during the farming season under review;

y = 7 if a farmer adopted any seven of the eight SWC techniques during the farming season under review;

y = 8 if a farmer adopted all the eight SWC techniques and

y = 0 if a farmer failed to adopt any of the eight SWC techniques during the farming season under review;

βs represents the coefficient of the variables

ε_1 represents the stochastic term

3.5 EFFECT OF ADOPTION OF SWC TECHNIQUES ON MAIZE OUTPUT

In assessing the performance of any agricultural innovation, it is important to understand the factors that have influenced the adoption process. However, simply knowing about adoption is not enough, because adoption is only a means to an end. The immediate objective may have been to develop and disseminate innovation for farmers, but the ultimate goal of developing the innovation is to improve the well-being of poor farmers (Morris *et al.,* 1999). In that context, it is necessary to look beyond the question of adoption and to focus on the question of impacts. It is in this light that this study attempt to assess the impact of SWC technique adoption on output.

However, any assessment of impact that requires attribution of specific effects to specific interventions faces formidable challenges such as the impossibility to observe the counterfactual corresponding to any change induced by a treatment or intervention and also the possibility of selection bias as argued in a sample of studies (see for instance Ravallion, 2001; Cameron and Trivedi, 2005; Imbens and Wooldridge, 2009). The former problem arises because it is necessary to observe the counterfactual in order to assess the impact of the change on any individual population unit while the latter arises because SWC programmes may be introduced in areas that are susceptible to soil and water degradation or because selection of individuals into the programme may not have been random.

Many studies (Rubin, 1974; Heckman and Rob, 1985; Mouelhi 2009; Olarinde *et al.*, 2012) have produced literature concerned with estimating the impact of adoption, interventions or programmes on output. In this study, we follow a two-stage impact estimation method that is similar to that outlined by Oduol *et al.*, (2011) and described in Asante *et al.*, (2014).

In the first stage, as explained in Asante *et al.*, (2014), the probability of adoption SWC techniques is estimated and the scores of SWC techniques are generated. In the second stage, the scores of SWC techniques in addition to other variables are regressed on output to determine the real effect of SWC techniques. This approach corrects for endogeneity in adoption before incorporating it into the output estimation as argued by Oduol *et al.*, (2011).

In this study, the adoption model (which is a Poisson model) is therefore explicitly expressed:

$$A_i = x_i\beta' + \mu_1 \quad (3.11)$$

Where A_i is the number of SWC techniques adopted; x_i denotes gender, age, age square, education, farm size, household size, group membership, number of extension visits, total credit obtain by the farmer and distance to market/input store; β *is* parameter of the x_i variables and μ_1 is the random error term in the Poisson model.

The second stage involves the estimation of the stochastic frontier production function, which includes the predicted probability of adoption of the SWC techniques.The function is specified as:

$$Y = f(X_1, X_2, X_3, X_4) \quad (3.12)$$

Where Y is the output of the farmer and X_1, X_2, X_3 and X_4 are the inputs (Land, Labor, Fertilizer and Score of SWC techniques).

According to Kopp and Smith (1980), functional forms have a limited effect on empirical efficiency measurement. Battese (1992) has reported that any empirical studies relating to developing countries have used Cobb-Douglas functional forms. The Cobb-Douglas functional form also meets the requirement of being self-dual, allowing an examination of economic efficiency. The Cobb-Douglas specification of the stochastic frontier is specified as follows:

$$Y_i = \beta_o \times \prod_{i=1}^{4} X_i^{\beta_i} \times e^{(V_i - U_i)} \quad (3.13)$$

Which, when linearized, becomes:

$$\ell n Y_i = \beta_0 + \beta_i \sum_{j=1}^{4} \ell n X_{ij} + \varepsilon_i \quad (3.14)$$

Where Y_i is the output of farmer *i*, The βs are unknown parameters to be estimated, X_1 farm size in acres; X_2 represents labor input; X_3 represents other variable cost (fertilizer); X_4 represents Score of SWC techniques used and ε_i is a "composed" error term. The error term (ε_i) is explained as $\varepsilon_i = (v_i - u_i)$, $i = 1, 2... N$. v_i is a two sided ($-\infty < v < \infty$) normally distributed random error ($v \sim N\ [0,\sigma_v^2]$) that represents the stochastic effects outside the farmer's control (e.g. weather, natural disasters, and luck),measurement errors and other statistical noise, u_i is a one-sided ($u \geq 0$) efficiency component that represents the technical inefficiency of the farm (Thiam *et al.*, 2001). This one-sided term of distribution can be half-normal, exponential, or gamma (Aigner *et al.*, 1977; Meeusen and Broeck, 1977). In this study, it is assumed that u_i is a half-normal distribution ($u \sim N\ [0, \sigma_u^2]$) as it is typically used in the applied stochastic frontier literature. The two components v_i and u_i are also assumed to be independent of each other. By Battese and Coelli (1998), the technical inefficiency effects are defined by:

$$u_i = Z_i\delta + w_i \qquad (3.15)$$

Where Z_i is a (1xm) vector of explanatory variables associated with the technical inefficiency effects; θ is a vector of unknown parameters to be estimated; and w_i is an unobservable random variable. The parameters indicate the impacts of variables in Z on TE. A negative value suggests a positive influence on TE and vice versa.The empirical models are therefore specified using farm size, labour, fertilizer, score of SWC techniques, gender, age, age square, education, farm size, household size, group membership, number of extension visits, total credit obtained by the farmer and distance to market/input store as follows:

$$\text{lnoutput} = \beta_0 + \beta_1\text{lnFsize} + \beta_2\text{lnlabour} + \beta_3\text{lnfert} + \beta_4\text{Score\_SWC} \qquad (3.16)$$

$$u_i = \delta_0 + \delta_1\text{gender} + \delta_2\text{age} + \delta_3\text{agesq} + \delta_4\text{edu} + \delta_5\text{fsize} + \delta_6\text{HHsize} + \delta_7\text{group\_mem} + \delta_8\text{ext} + \delta_9\text{credit} + \delta_{10}\text{distance} \qquad (3.17)$$

It is worth noting that the pure effect of adoption of SWC techniques is determined by using the predicted scores (as shown in equation 3.16) rather than just the observed variable.

The description, measurement and *a priori* expectations of the variables used in the model are given in Table 3.2.

Table 3.2: Description, Measurement and Expected Signs of the Variables in the Adoption Model

Variables	Definition	Expected Sign
Output	In kilograms	
Fertilizer	In kilograms	
Number of SWC techniques	Total number of SWC techniques adopted by a maize farmer	
Labour	Number of people	+
Gender	Dummy (male = 1; female = 0)	+
Age of the farmer	In years	+/-
Education	Years spent in formal schooling	+
Farm size	Total farmland area in acres	+
Household size	Number of household members	+
Number of extension visits	Number of visits made to extension services and by extension agents (per year)	+
Membership association	Dummy(1 if the farmer is a member of a group and 0 for otherwise)	+
Credit	Dummy (1 if the farmer received credit and 0 for otherwise	+
Distance/proximity to input store	In kilometers	-

3.6 ASSUMPTIONS IN POISSON REGRESSION

The Poisson regression possesses some assumptions and violation of which restrict its application. The assumptions include the following.

i. Logarithm of the event rate changes linearly with equal increment in the exposure variable.

ii. Changes in the rate from combined effects of different exposures or risk factors are multiplicative.

iii. At each level of the covariates, the number of cases has variance equal to the mean.

iv. Observations are independent.

Plots of residuals versus the mean at different level of predictor variable and a test of overdispersion/underdispersion are the methods used to identify the violation of assumption (iii) i.e. to determine whether the variances are too large or too small. In this study, a test of overdispersion is applied.

3.7 OVERDISPERSION

The Poisson model is rarely entirely satisfactory although its simplicity makes it attractive. Though it may predict the mean event count accurately, it frequently tends to underpredict the frequency of zeros and large counts. This happens if the variance of the actual is larger than the variance predicted by the Poisson model. This failure of the model is known as overdispersion. Therefore before accepting a Poisson regression model, it is highly advisable to test for overdispersion (Cameron and Trivedi, 1986; Grogger and Carson, 1991; Winkelmann, 2000). If overdispersion problem does exist, the conditional mean estimated with a Poisson model is still consistent, though the standard errors of β are biased downwards (Grogger and Carson, 1991).

3.8 CHOICE OF VARIABLES FOR THE MODEL

The study models the adoption of the SWCtechniques introduced in the study area. A review of past research findings (see for instance Boahene, 1995; Donkoh and Awuni, 2011 and Teshome, 2013)on factors that affect the adoption of SWC of farmers were used to establish working hypotheses of this study. Among a number of factors which have been related to the adoption of SWC techniques by these studies and are relevant in this study include gender, age of the farmer, extension contacts, farm size, labour, household size, number of years spent in formal schooling, membership of farmers' association, credit access and farm distance to the market or input store. The expected relationships between these factors and adoption of SWC techniques summarise in Table 3.2 are explained below.

Gender

In Ghana households are usually headed by males who are always considered as the decision-makers in terms of resource use. Females only make decisions in the absence of males. There is gender discrimination when it comes to decisions concerning resource use particularly, in extension message delivery due to resource limitations (Chiputwa et al., 2011). Therefore male farmers are more likely to adopt soil and water conservation techniques than their female counterparts. Adoption is therefore expected to be positive for male farmers.

Age of the Farmer

The likely effect of age of farmer on adoption decision is mixed. Some (Hill and Kau, 1973) argue that young farmers are more amendable to change old practices than older farmers because they tend to be more aware and knowledgeable about new technologies, while others (Donkok and Awuni, 2011) argue that older farmers may be in a better position to adopt new technologies due to their comparative advantage in terms of capital accumulated, number of extension contacts or visits and credit worthiness.

Number of Extension Visits/Contacts

Number of extension visits is also one variable that can influence farmers' probability of adoption since the uptake and use of a new technology is facilitated by the farmers' contact with extension services. Extension officers provide both inputs and technical advice of a technology to farmers(Teshome, 2013). It is therefore expected that farmers with high number of extension contacts would understand and adopt more of the technologies. Extension visits is therefore expected to have a positive influence on intensity of adoption.

Farm Size

The impact of farm size on adoption is ambiguous. Most technologies are labour-intensive, time consuming and expensive. Therefore, a farmer with a larger farm size might not afford the time and labour needed in the preparation of compost for instance. In this case, adoption will be positive for farmers with smaller farm size. On the other hand, cost (especially fixed cost) involved in the adoption of a new technology prevents small farmers from adopting the technology because the low output associated with small farms leads to high average fixed cost.Large farm size also gives a farmer the capacity to use land intensive conservation practices (elements) such as crop rotation (Thangata*et al.*, 2002). Larger farm size in this case is expected to be positively related to adoption.

Labour

The dynamics of the practice of some of the technologies with respect to labour is a bit complex. The labor requirements during the establishment stage of a technology could be double the labour requirements during later stages on the same piece of land (FAO, 2001b; MACO and ORGUT, 2003;Haggblade and Tembo, 2003b). At the initial stage for instance, labour is required for land preparation and application of some of the SWC techniques (example composting, mulching, crop rotation, water harvesting etc.) that are labour demanding. This being the case, the relationship between the adoption and labor is expected to be positive or negative depending on the stage of establishment.

Household/Family Size

Household/Family size is defined in this study as the number of people who depend on the farmer for their livelihood. Household size can also affect the farmer's farming strategy. A farmer with large family is assumed to have more responsibilities than the one with a small family size. Farmers with larger household size tend to spend more on food and other basic household requirement. The high expenditure associated with larger household size makes them resource constrained hence the need for adoption of technologies in order to increase output and to meet the food demands of the members. Also, farmers with larger families are more likely to be better resource endowed in terms of labour than otherwise and hence more willing to try out new technologies. Household size is therefore postulated to have a positive impact on adoption as argued by some. Others (Donkoh and Awuni, 2011)also argue that larger households spend a lot on their basic needs such as food, clothing and shelter, such that they have little or none for technology adoption.

Education

New technology goes with risks because of imperfect information associated with it and increases the possibility of mistakes. Information from extension services could have been a help but however, not equally or easily accessible to all the farmers. Farmers who are educated may have a comparative advantage over other farmers in the use of a techniqueas observed in many studies (Clearfield and Osgood, 1986; Manyong*et al.*, 1999; FAO, 2001b; Clay *et al.*, 2002; Place *et al.*, 2002; Haggblade and Tembo, 2003b). Normally, the educated farmer has access to improved knowledge about the SWC techniques as they are taught in schools. In terms of information search, the educated farmer will be able to evaluate, understand and update their knowledge of the technology more rapidly and follow the procedures relating to the use of the technology more easily and thus adopt it earlier compared to others (Jalloh, 2001;Boahene, 1995). Formal schooling expressed as the number of years of schooling is therefore hypothesised to be positively related to adoption.

Group Membership

Institutional factors such as membership of farmer associations are also assumed to be positively related to adoption decisions. This is because a farmer's group can provide him with information about the use of the technology and the procedure involve in the use of the technology. Also, farmers who constitute themselves into groups take turns to work on members' farms without members making any payment.

Credit

Adoption of technologies may require high initial investment in acquisition of information. Lack of cash or credit may prevent smallholder farmers from adopting new technologies that require initial investments. Access to credit is therefore assumed to be positively associated with adoption.

Distance to Market/Input Store

The closer the market or input store is to the farmer's farm the greater his probability of adopting the inputs sold. This is because easy access to the market creates an enabling environment for timely acquisition of inputs, and reduce market transactions cost (Reardon and Vosti 1997a; Malla 1999; Sanders and Cahill 1999; Sayre *et al.,* 2001; Bekele 2003). In the case of fertilizer and agrochemical use, easy access to market or input store is expected to have a positive influence on the adoption.

3.9 TESTS OF HYPOTHESES

The following hypotheses were tested:

- $H_0: var[y_i] = \mu_i + \alpha g(\mu_i)$, over-dispersion is present and the estimated negative binomial model is preferable to the Poisson model.
- $H_0: \beta_{jk} = 0$, coefficients of the second order variables are zero which implies that the Cobb Douglas function statistically best fit the data.
- $H_0: \gamma = \delta_0 = \delta_1 = \delta_2 = \cdots \ldots = \delta_{10} = 0$, inefficiency effects are absent from the model at all levels.
- $H_0: \gamma = 0$, which implies that inefficiency effects are non-stochastic. Thus, stochastic frontier model minimizes to the original average response function
- $H_0: \beta_4 = 0$, meaning that there is no effect of SWC technique adoption on output.

The hypotheses (especially 1 – 5) were tested using the generalized likelihood ratio test that is calculated using the formula:

$$LR = -2\left\{ln\left(\frac{L(H_0)}{L(H_1)}\right)\right\} = -2\{ln[L(H_0)] - ln[L(H_1)]\} \qquad (3.22)$$

Where $L(H_0)$is the value of the log likelihood function for the restricted stochastic frontier model and $L(H_1)$being the value of log likelihood functions for the unrestricted stochastic frontier model. If the null hypothesis is true, the test statistic has approximately a chi-squared or a mixed chi-squared distribution, with degrees of freedom equal to the difference between the numbers of the parameters involved in the alternative and null hypotheses (Coelli, 1995).

CHAPTER FOUR

RESULTS AND DISCUSSIONS

INTRODUCTION

This chapter presents and discusses the results of the study. The results are presented in line with the specific objectives of the study. First, the levels of adoption of SWC techniques by farmers are presented. Second, the factors influencing the adoption of SWC techniques are discussed. The third section of the the study presented and discussed the effects of adoption of SWC tecniques on maize output/technical efficiency. The fourth and fifth sections of the study then presented and discussed the level of technical efficiency as well as the factors affecting technical efficiency of maize farmers in Ghana.

4.1 ADOPTION LEVELS OF SWC TECHNIQUES IN GHANA

The first objective of this study was to identify the levels of adoption of SWC techniques in Ghana. The SWC techniquesadopted and practised in Ghana by maize farmers are shown in Table 4.1. The farmers practiced one or more of these technologies on their fields but some of them practised none of these technologies probably due to inadequate knowledge about the benefits of these technologies. The most practiced technology was found to be row planting, representing 27.5% followed by fertilizer use, representing 26.1%. The dominant use of row planting is probably due to its ability to allow the farmer to combine different SWC techniques on the same piece of land. Those who used fertilizer specified NPK as the main fertilizer used. The use of intercropping was also encouraging as about 24.8% practiced it. Mulching, crop rotation, composting, water harvesting and zero tillage recorded 2.7%, 11.2%, 3.9%, 0.9%, and 2.8% respectively.

Table 4.1: Soil Conservation Techniques Adopted by Maize Farmers in Ghana

Technology	Frequency	Percent
Mulching	42	2.7
Crop rotation	171	11.2
Composting	60	3.9
Water harvesting	14	0.9
Fertilizer use	400	26.1
Zero Tillage	43	2.8
Intercropping	380	24.8
Row planting	420	27.5

Source: Result from Data Analysis, 2015.

4.2 FACTORS INFLUENCING THE ADOPTION OF SWC TECHNIQUES IN GHANA

The second objective of the study was to investigate the factors influencing the adoption of SWC techniques in Ghana. These factors include farmer, farm and socioeconomic characteristics. As far as the adoption of SWC techniques is concerned, the description of the state of these variables is necessary. Table 4.2 presents the descriptive statistics of the state of these variables in the study area.The mean of the total value of output was found to be GH¢ 344.00 per acre. This was achieved by utilizing on average, 5 acres of land, GH¢ 3.00 of labour, GH¢ 12.00 of fertilizer and the adoption or otherwise of SWC technique. The average age of the farmers was 51 years indicating that maize production in Ghana is taken up by the most active population of the work group. The level of education among maize farmers was low, considering the mean schooling years of 4 withzero and 22 years as the minimum and maximum number of schooling years respectively. This shows that farming is taken up by people who can hardly read manuscripts as wellunderstand new technologies in farming. Thislowlevel of literacy of the farmers is likely to reflect on adoption of SWC techniques. The mean household size was 6 with 1 and 30 as the minimum and maximum number of household size respectively. This implies that on the average, labour is available to every farmer.About 41% of the farmers participated in group activities probably due to the benefits (cash and subsidies and educational programmes) associated with membership while 59% did not take part in any group activities. The average distance from the farm to the market/input store was 1 km and the average credit obtained per farmer was GH¢ 17.00.

Table 4.2: Descriptive Statistics of Variables used in Stochastic Production Function Analysis

Variable	Mean	Std. Dev.	Min.	Max.
Revenue	344.7582	738.2365	0	12000
Gender	0.7510	0.4326	0	1
Age	50.5582	15.8630	1	90
Education	3.7804	5.0670	0	22
Farm Size	5.0503	7.0475	1	125
Household Size	6.2018	4.1304	1	30
Fertilizer cost	11.7490	25.4426	0	270
Labour cost	2.5961	6.6627	0	86
Number of extension visits	0.0099	0.1517	0	4
Distance	0.9078	3.9349	0	40
Group membership	0.0209	0.1431	0	1
Number of SWC techniques	1.0856	1.3045	0	5
Credit	16.76	319.39	0	502

Source: Result from Data Analysis, 2015.

The estimation results of the Poisson model are presented in Table 4.3 (prior to estimation of diagnostic statistics as seen in Table 4.4). Note that, the dependent variable of the model (number of SWC techniques) is observed and not latent, therefore the coefficients of the variables are useful, in that they measure the direct effects of the explanatory variables on the dependent variable. The factors influencing farmers' adoption of SWC techniques included gender, age, age squared, farm size, household size, years of education, cooperative participation, number of extension visits, credit and distance to selling point/market.

Many of the right hand side covariates (about six variables) were significant and exhibited patterns consistent with our *a priori* expectations. The goodness of fit parameters of the model indicated that, the model adequately predicted the determinants of the adoption of SWC techniques. The chi-squared value was significant at 1%, implying that all the variables jointly determined the adoption of SWC techniques. Household characteristics such as gender, household size and years of education were found to be significant at 1% level of significance.

Gender and household size were positively related to the number of technologies adopted while years of education of the farmers was found to have negative influence on the number of techniques adopted. This means that male farmers tended to adopt more of the techniques than their female counterparts.

Also, farmers with larger household size tended to adopt SWC techniques relative to those with smaller households. This is consistent with the *a priori* expectation because the adoption of SWC techniques is laborious and needs more hands. The results however, contrast with the findings of Bekele and Drake (2003) and Amsalu and de Graaff (2007). In the former, household size was found to have a significantly negative relation with certain adoption choices while in the latter, household size did not show significant relationship with adoption.

The negative sign of the education variable means that those with no education or lower educational background tended to adopt the techniques more than those with higher level of education. This goes contrary to the findings of many studies (Abbey and Admassie, 2004; Doss and Morris, 2001; Foltz, 2003). In these studies, it is often argued that farmers who have better education and are able to read and write, understand information about the technology and therefore tend to have greater probability of adoption than their illiterate counterparts. This finding is quite plausible as a result of two reasons. First the adoption of SWC techniques does not require much formal education compared with some modern technologies. Second, SWC techniques are indigenous techniques which have been with the farmers since time immemorial; hence they do not need formal education to understand its adoption. Perhaps this also explains why the extension variable did not meet the *a priori* expectation. Second, the adoption of SWC techniques is quite laborious and time consuming, which means that it is unattractive to the educated farmers since they are normally busy with other non-farm activities.

Farm size was also found to be significant at 1% level of significance and maintained the expected positive sign. This implies that farmers with larger farm adopted more technologies than their counterparts. This result is consistent with the *a priori* expectation and confirmed that of other studies, especially Donkoh and Awuni (2011).

Group membership was also found to be significant at 1% level of significance and had a positive influence on adoption implying that farmers who belonged to a farmer group had greater probability of adoption than those who did not. Farmers in the area probably constitute themselves into worker groups and take turns to work on members' farms without members making any payment. The finding on the variable is consistent with previous studies from elsewhere (including Baidu-Forson, 1999; Bekele and Drake, 2003; Lapar and Pandey, 1999).

However, while the extension variable was significant at 10% level of significance, it showed a negative influence on adoption, hence inconsistent with the findings of Donkoh and Awuni (2011).

Similarly, the fact that, credit was significant and maintained its expected positive sign implies that credit is an important source of capital which facilitated SWC technique adoption in the cropping season. This is consistent with Foltz's (2003) hypothesis that, farmers who have better access to credit stand a better chance of adopting technology faster than those who are capital-constrained. Ekboir*et al.,* (2002) and Simtowe and Zeller (2006) had similar findings.

The closer an input store was to the farmer's field, the greater the adoption of SWC techniques. Proximity to an input store is not only an incentive for farmers to buy the inputs, but it reduces the cost of transporting the input to the farmer's house (Lapar and Pandey, 1999). This is consistent with the finding of Gebremedhin and Swinton (2003) in Ethiopia.

Table 4.3: Maximum Likelihood Estimation of the Determinants of Adoption of SWC Techniques

Number of SWCT Used	Coefficient	Std. Err.	Z
Gender	0.4402	0.0685	6.43***
Age	0.0049	0.0087	0.56
Age squared	-0.0001	0.0001	-0.72
Education	-0.0472	0.0056	-8.42***
Farm Size	0.0103	0.0027	3.85***
Household Size	0.0338	.0053	6.42***
Group membership	0.3916	0.1387	2.82***
Extension Visits	-1.2113	0.6432	-1.88*
Credit	0.0001	0.0000	2.58**
Distance	-0.0573	0.0117	-4.88***
Constant	-0.4495	0.2291	-1.96**
Number of observations	1530		
LR χ^2 (10)	291.67		
Probability χ^2	0.0000***		
Pseudo R^2	0.0634		
Log likelihood	-2153.3927		

*, ** and *** are levels of significance at 10%, 5% and 1% respectively.

Source: Result from Data Analysis, 2015.

4.3 EFFECTS OF SWC TECHNIQUES ON MAIZE OUTPUT/DETERMINANTS OF MAIZE OUTPUT IN GHANA

The third objective of this study was to analyse the effect of adoption of SWC techniques on output of maize in Ghana. Diagnostic statistics was therefore necessary in order to choose an appropriate production function that best fit the area. Based on the results of the diagnostic statistics in Table 4.4, the Translog production function was rejected in favour of the Cobb-Douglas production function. Also, the results of the diagnostic statistics indicate the presence of inefficiency effects in the model. Further, the results indicate that farm specific factors influence inefficiency in maize production. Finally the results indicate the importance of SWC techniques in maize output.

Table 4.4: Validation of Hypotheses

Null hypothesis	Log-likelihood (H_0)	Test statistics(λ)	Critical value (λ^2 0.05)	Decision
$H_0: var[y_i] = \mu_i$	-2153.3927	2.1054	2.7060	Accepted I
$H_0: \beta_{jk} = 0$	-3529.297	11.8650	17.6700	Accepted I
$H_0: \gamma = \delta_0 = \delta_1 = \cdots = \delta_{10} = 0$	-3630.4822	202.3708	17.6700	Rejected H
$H_0: \gamma = 0$	-3688.8574	319.1212	2.7060	Rejected H
$H_0: \beta_4 = 0$	-3545.442	32.2904	2.7060	Rejected H

Critical values are at 5% significant level and obtained from Table 1 of Kodde and Palm (1986).

The parameters and related statistical results obtained from the estimation of the stochastic frontier model are presented in Table 4.5. The study revealed a significant effect of SWC technique adoption on maize output in Ghana .This is consistent with the findings of Asante *et al*., (2014); Olarinde *et al.*, (2012); Kato *et al.*, (2009) and Mouelhi (2009). The result also concurs with that of Solis *et al.*, (2009) in which adoption of soil conservation is also associated with higher output. In addition to the SWC variable, all the conventional inputs were significant and maintained their expected sign, except fertilizer input, which although was significant had a negative sign.

The coefficients of farm size, labour and fertilizer represents elasticities of inputs with respect to the value of the output since the value of the output in this model was entered in a natural logarithm form. As shown in the table, all the input elasticities are elastic; indicating that a 100 percent increase in each input results in an increase or decrease in yield. For instance, farm size is consistent with ourexpectations as it indicates a positive and significant influence on output; a 100 percent increase in farm size leads to 32 percent increase in output. There is a positive and significant relationship between labour and maize output in Ghana. This implies that an increase in labour by 100 percent will lead to 18 percent increase in output. Labour is therefore a significant factor associated with changes in the output. This is similar to the findings of Elibariki et al., (2008) and Basnayake and Gunaratne (2002). Amount of fertilizer was also significant but did not show a positive sign. This implies that a 100 percent increase in fertilizer leads to 10 percent decrease in output and vice versa.

Table 4.5: Maximum-likelihood Estimates for Parameters of the Cobb-Douglas Production Function

Variables	Coefficient	Std. Err.	Z
Output function			
Constant	7.1182	0.0993	71.66***
Farm size	0.3219	0.0703	4.58***
Labour	0.1821	0.0636	2.86***
Fertilizer	-0.1045	0.0396	-2.64***
Score of SWCT	0.0902	0.0378	2.39**
Returns to scale	0.3995		
Log likelihood function	-3542.8356		

*, ** and *** are levels of significance at 10%, 5% and 1% respectively.
Source: Result from Data Analysis, 2015.

4.4 THE LEVEL OF TECHNICAL EFFICIENCY OF MAIZE FARMERS

The fourth objective of the study was to estimate the level of technical efficiency of maize farmers in Ghana The distribution of the technical efficiency of maize farmers is presented Table 4.6. The results showed that the predicted technical efficiencies vary greatly among the maize farmers. The results reveal that 93.7% of the farmers have technical efficiency ranging from 41% to 50%, followed by 2.16% also getting efficiency of at most 40%. Further, the results show that few of the farmers (1.96% each) had between 51 to 60% and 61 to 70% efficiency levels each. Also, the results indicate that about 0.20% of farmers were producing maize with technical efficiency ranging from 71 to 100%. The predicted mean technical efficiency of the farmers is 52%. This is less than 68% found by Rao *et al.*, (2003) in their study where they compared African agricultural sector with world agricultural sector using 1986-1990 panel data. Though comparisons cannot be made due to differences in geographical location of farmers and use of different technologies in production, the mean technical efficiency of Ghana is far below that of the averages for Central (95%), Eastern (85%), Northern (95%), Western (92%) and Southern Africa (96%) and Europe (90%)as revealed by Nkamleu *et al* (2006) and Andrew and Cesare (2008).This indicates that the maize farmers in the study area produced 52% of the potential stochastic frontier output based on the present state of technologies as well as the level of input. The implication is that 48% of potential output is not realized. Possibly, the adoption of the practice of technologies will increase maize production in the region by an average of 48% to enable these maize farmers to attain the potential stochastic frontier output level.

Table 4.6: The Distribution of Technical Efficiencies of Maize Farmers in Ghana

Efficiency class	Number of farmers	Percentage
≤ 0.40	33	2.16
0.41 – 0.50	1434	93.74
0.51 – 0.60	30	1.96
0.61 – 70	30	1.96
0.71 – 1.00	3	0.20
Total	1530	100

Source: Results from Data Analysis, 2015.

4.5 DETERMINANTS OF TECHNICAL EFFICIENCY OF MAIZE FARMERS IN GHANA

The last objective of the study was to determine the factors that affect the technical efficiency of maize farmers in Ghana. The sources of inefficiency are discussed using the estimated coefficients associated with the inefficiency effects in Table 4.7.The overall measure of technical inefficiency (Gamma) is equal to 0.98 indicating that almost all of the deviations from the frontier are as a result of inefficiency and not due to random error in the data. The result suggests that 97% of the variation in output among farmers was due to differences in technical efficiency while 3% of the variation was due to random shocks outside the farmer's control. This can also be interpreted to mean that the differences between actual (observed) and frontier output are dominated by technical inefficiency (that is, factors within the control of the farmers rather than outside their control). This is surprising, considering the fact that agriculture in Ghana is influenced by a lot of climatic factors that are beyond the control of the farmers. The sigma square (σ^2) in the area (16.15) is significantly different from zero and the correctness of the specified distributional assumption.The result is however higher and significantly different from that obtain in Ghana by Binam et al (2008) as they compare technical efficiency and productivity potential of cocoa farmers in West African countries.

Technical efficiency is usually estimated through the inefficiency model. Sources of inefficiency are discussed using the estimated coefficients associated with the inefficiency effects in Table 4.7. Variables with negative coefficients have negative relations with inefficiency. The opposite is the case for variables with positive coefficients.

From Table 4.7, variables that are significant in determining the technical efficiency of maize farmers in Ghana areeducation,credit and distance to market or input store. These variables hadnegative coefficients which mean negative effects on inefficiency but positive effects on efficiency. For instance, the negative sign of the education variable means farmers with more years of formaleducation tended to be more technically efficient or were less technically inefficient. This means that the tendency of a maize farmer to increase his/her production depends on the education, credit and distance to market/input store. Even though gender, household size and number of extension visits were significant, the positive signs of the coefficients mean positive effects on inefficiency.

The coefficients for farmers' age, farm size and group membership were negatively related to technical efficiency but not significant. These findings are similar to that ofBinam et al (2008) in the study of technical efficiency and productivity potential of cocoa farmers in West African countries.

The estimated coefficient of education is appropriately signed in this study and statistically significant at 1% as expected. Thus, educated farmers are technically more efficient than their illiterate counterparts (Figure 4.1). This is because educated farmers are more likely to update their beliefs about the technologies and follow the procedures relating to the use of the technology,and hencebecome more efficient than their illiterate counterparts.Also, educated farmers tend to be more knowledgeable when it comes to allocation of resources for production and are therefore more efficient than the illiterates. This results is consistent with the findings of Oyewo (2011) which observed that farmers with more years of formal education tend to be more technically efficient in maize production, presumably, due to their enhanced ability to acquire technical knowledge, which makes them closer to the frontier output.

Credit was also found to be significant and positively related to efficiency (Table 4.7). This implies that farmers who had credit access were technically efficient as shown in Figure 4.2. This is in agreement with the*a priori* expectation and the findings of *et al.,* (2011).This is because some technologiesrequire high investment at the initial stages. Farmers who have access to credit are able to adopt these technologies, and thus, become efficient. The results is are similar to that of Binam*etal.,* (2008) in which credit was found to have the greatesteffects on improving technical efficiency in Cameroon, Nigeria, and in West andCentral African countries as a whole. Thus, overcoming credit constraints is likely to enhance the productive efficiency of maize farmers in Ghana.

Distance to the market was found to be consistent with the *apriori* expectation. This is to say that farmers who are closer to the market where inputs are sold had access to an enabling environment for timely acquisition of inputs, and reduced market transactions cost. Thus acquiring inputs is easier. This makes them more technically efficient than those far away from the market. The results is consistent with that of Binam *et al.,* (2008) in which better roads result in more timely field operations and reduced transaction costs in acquiring inputs and rural credit.

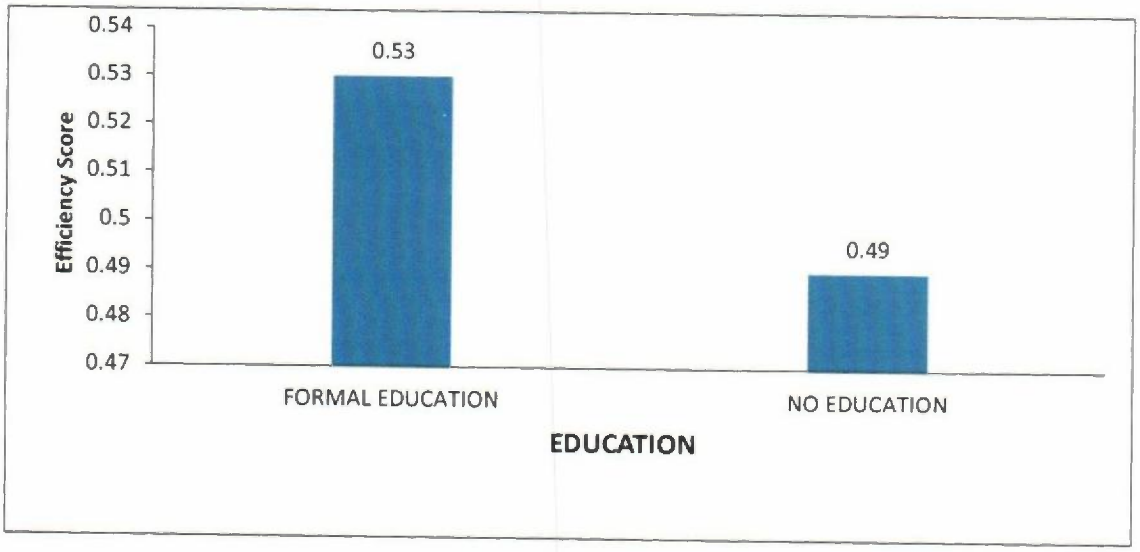

Figure 4.1: Mean Distribution of efficiency scores by level of education of maize farmers

Table 4.7: Maximum-likelihood Estimates for Parameters of the Inefficiency Effects Model

Variables	**Coefficient**	**Std. Err.**	**Z**
Constant	-0.3501	1.5901	-0.22
Gender	2.4324	0.4525	5.38***
Age	-0.0460	0.0561	-0.82
Age square	0.0007	0.0005	1.38
Education	-0.1735	0.0355	-4.88***
Farm size	-0.2272	1.3119	-0.17
Household size	0.1849	0.0369	5.01***
Group membership	-0.0015	0.0012	-1.27
Number of extension visits	0.0544	0.0203	2.68***
Credit	-1.4518	0.5230	-2.78***
Distance	-0.3477	0.0788	-4.41***
Variance parameter			
Sigma square	16.1546	1.4751	
Gamma (γ)	0.9689	0.0050	
Sigma square(σ_u^2)	15.6521	1.4732	
Sigma square (σ_v^2)	0.5025	0.0688	
Mean technical efficiency	0.5184		
Returns to scale	0.3995		
Log likelihood function	-3542.8356		

*, ** and *** are levels of significance at 10%, 5% and 1% respectively.

Source: Result from Data analysis, 2015.

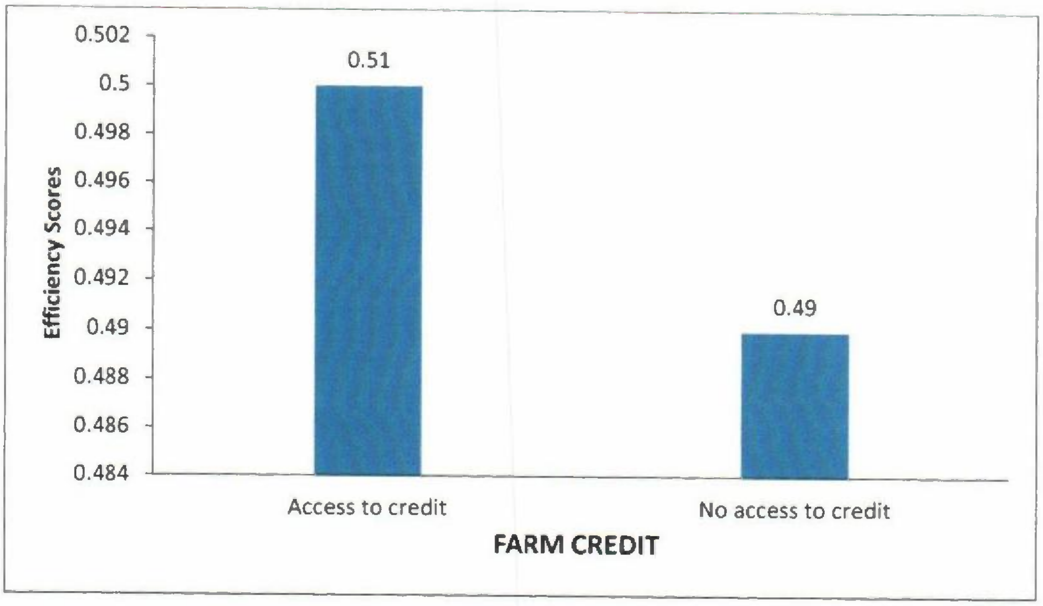

Figure 4.2: Mean distribution of efficiency scores by access to farm credit.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

INTRODUCTION

This chapter presents a summary of the researck work, the conclusions from the results and the policy recommendations arising from the conclusions of the study.

5.1 SUMMARY

The study examined the effects of adoption of Soil and Water Conservation (SWC) techniques on maize output. It employed a Poisson model to estimate the factors influencing households' adoption of SWC techniques. The effect of adoption on output of maize is assessed using the stochastic frontier production function. The data used for the study is a cross-sectional baseline survey data obtained by Ministry of Food and Agriculture (MoFA) using multi-stage sampling techniques.. The conceptual framework was based on the relationship between SWC techniques, output/productivity and economic growth and development.

The following were the major findings that emerged from the study:

- Majority of the farmers (27.5%, 26.1% and 24.8%) used row planting, fertilizer and intercropping respectively with only few using mulching, crop rotation, composting, water harvesting and zero tillage (2.7%, 11.2%, 3.9%, 0.9% and 2.8% respectively).
- The adoption of soil and water conservation techniques is significantly influenced by farmer, farm and socioeconomic/institutional factors such as gender of the farmer, farm size, household size, membership in farmer based organisation, number of extension visits access to credit and distance to market/input store. Gender of the

farmer, farm size, household size, membership in farmer based organisation access to credit positively influenced the adoption of SWC techniques while education, number of extension visits and distance to market/input store negatively influenced the adoption of SWC techniques.

- The results indicate a significant effect of adoption of SWC techniques on the output of smallholder farmers in Ghana.
- Technical efficiencies of maize farmers in Ghana ranged from 35.1% to 83.0% with a mean technical efficiency of 52%.
- The variables such as number of years in school (educational status), credit and distance to market were the variables that increased technical efficiency while gender, household size and number of extension visits caused inefficiency.

5.2 CONCLUSIONS

Based on the major findings of this study, the following conclusions are drawn.

- In general, the adoption of SWC techniques by maize farmers in Ghana is low despite their inherent capacity to increase output.
- The study confirms that farmer/household, farm and socioeconomic/institutional variables such as gender of the farmer, farm size, household size, membership in farmer based organisation and access to credit are important in increasing the probability of adopting SWC techniques
- The study also confirms the importance of SWC techniques in raising the output levels of maize farmers in Ghana.
- Maize farmers in Ghana are producing below the potential stochastic frontier output based on the present state of technologies as well as the level of input.

- The study also revealed the importance of farmer and socioeconomic/institutional variables in raising technical efficiency.

5.3 POLICY RECOMMENDATIONS

Based on the conclusions of this study, the following recommendations are made.

- Some of the SWC techniques are capital intensive especially at the initial stage and thus, causing the low adoption. Stakeholders can therefore step in to provide the necessary resources to farmers in order to facilitate the adoption of SWC techniques.
- Government and other stake holders should facilitate the promotion of eduction in Ghana
- Government should facilitate the creation of the enabling environment for the establishment of input shops in the country since distance to input store influence farmers' adoption of SWC techniques.
- Since there is limited number of extension officers in the country, the use of mass extension methods should be emphasized to facilitate the adoption of SWC techniques. For instance, mass communication through radio, TV, communication vans and dissemination through farmer groups can be used to facilitate adoption which leads to improvement in output.
- There is the need for stakeholders to streamline loan application procedures, intensify education of farmers on loan procedures and promote flexibility in types of collateral demanded by financial institutions in order to enhance access.

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LIST OF APPENDICES

APPENDIX A: SUMMARY STATISTICS OF THE VARIABLES USED IN THE ESTIMATION

Variable	Obs	Mean	Std. Dev.	Min	Max
Lnrevenue	1530	3.466588	2.943383	0	9.39
no_sct_used	1530	1.085621	1.304463	0	5
Gender	1530	.7509804	.4325866	0	1
Age	1530	50.57908	15.79303	15	90
Agesq	1530	2807.597	1696.167	1	8100
yrs_edu	1530	3.780392	5.066995	0	22
farm_size	1530	4.595346	6.69778	.1	125
hh_size	1521	6.201841	4.130362	1	30
group_mem	1530	.4065359	.4913474	0	1
no_ext_vis~s	1515	.009901	.1517217	0	4
total_credt	1530	16.77516	319.3853	0	9348
dist_sellp~t	1530	.9078431	3.934886	0	40
Laborcost	1530	2.596078	6.662684	0	86
total_cost~t	1530	11.74902	25.44263	0	270

APPENDIX B: MAXIMUM LIKELIHOOD ESTIMATION OF THE DETERMINANTS OF THE ADOPTIONOF SOIL WATER CONSERVATION TECHNIQUES (POISSON REGRESSION)

Poisson regression Number of obs = 1530
LR chi2(10) = 225.03
Prob> chi2 = 0.0000
Log likelihood = -2502.4079 Pseudo R2 = 0.0430
No_sct_used|Coef. Std. Err. z P>|z| [95% Conf. Interval]
gender | .3892 .0614 6.33 0.000 .2687 .5096
age | .0125 .0083 1.51 0.131 -.0037 .0288
agesquare |-.0001 .0000 -1.62 0.105 -.0003 .0000
yrs_edu |-.0282 .0047 -5.97 0.000 -.0375 -.0190
farm_size | .0085 .0026 3.33 0.001 .0035 .0135
hh_size | .0294 .0051 5.79 0.000 .0195 .0394
mem_ass | .3117 .1303 2.39 0.017 .0564 .5670
no_ext_vis~|-.1394 .1261 -1.11 0.269 -.3866 .1078
total_credt| .0001 .0000 2.48 0.013 .0000 .0002
dist_mkt |-.0580 .0110 -5.30 0.000 -.0795 -.0366
_cons |-.5175 .2172 -2.38 0.017 -.9432 -.09190

APPENDIX C: MAXIMUM LIKELIHOOD ESTIMATION OF THE DETERMINANTS OF THE ADOPTION OF SOIL WATER CONSERVATION TECHNIQUES (NEGATIVE BINOMIAL REGRESSION)

no_sct_used	Coef.	Std. Err.	Z	P>z	[95% Conf.	Interval]
Gender	.3962261	.0829389	4.78	0.000	.2336688	.5587834
Age	.008834	.0116227	0.76	0.447	-.0139461	.0316141
Agesq	-.0000884	.0001089	-0.81	0.417	-.0003018	.000125
yrs_edu	-.0402579	.0068042	-5.92	0.000	-.0535938	-.026922
Farmsize	-1.500853	.7122865	-2.11	0.035	-2.896909	-.1047967
hh_size	.0406068	.0072766	5.58	0.000	.0263449	.0548687
groupmembe~w	.0001215	.0000757	1.60	0.109	-.0000269	.0002698
no_extvisi~w	.0171442	.004383	3.91	0.000	.0085536	.0257348
Totalcredt~w	.3746435	.0887897	4.22	0.000	.2006188	.5486681
dist_sellp~t	-.0593093	.0129374	-4.58	0.000	-.0846661	-.0339525
_cons	-.670605	.3059853	-2.19	0.028	-1.270325	-.070885
/lnalpha	.699378	.1382962			.9704335	.4283224
Alpha	.4968943	.687186			.3789187	.6516013

APPENDIX C continued.

Number of obse	1530					
LR χ^2 (10)	291.99					
Probability χ^2	0.0000					
Pseudo R^2	0.0534					
Log likelihood	-2153.182					

APPENDIX D: MAXIMUM LIKELIHOOD ESTIMATION OF THE FRONTIER AND THE INEFFICIENCY MODEL FOR MAIZE FARMERS IN GHANA.

Stoc. frontier normal/trunc Number of obs = 1530

Wald chi2(5) = 64.94

Log likelihood = -3955.4002 Prob> chi2 = 0.0000

lnrevenue	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
No_sct_used	.2942	.0473	6.23	0.000	.2016	.3869
lnfrmsize	.0817	.0453	1.80	0.072	-.0072	.1705
lnfertcost	-.1201	.0342	-3.51	0.000	-.1872	-.0531
LNlaborcost	.1171	.0520	2.25	0.024	.0152	.2190
_cons	6.9027	.0876	78.76	0.000	6.7310	7.0745
mu						
gender	2.6698	.4851	5.50	0.000	1.7190	3.6207
age	-.0844	.0579	-1.46	0.145	-.19797	.0291
agesquare	.0011	.0005	2.13	0.033	.0001	.0022
yrs_edu	-.1931	.0375	-5.14	0.000	-.2667	-.1195
cooperativ~p	2.0397	.9799	2.08	0.037	.1192	3.9602
No_sct_used	-.3132	.1528	-4.01	0.000	-.3304	.9364
no_ext_vis~s	-.6381	.8937	-0.71	0.475	-2.3896	1.1134
total_credt	-.0022	.0014	-1.58	0.115	-.0050	.0005
dist_sellp~t	-.4120	.0939	-4.39	0.000	-.5961	-.2278
_cons	-.0208	1.6192	-0.01	0.990	-3.1943	3.1527
lnsigma2	2.9048	.0958	30.33	0.000	2.7171	3.0925

APPENDIX D Continued.

ilgtgamma	|3.7895	.1595	23.75	0.000	3.4769	4.1022
sigma2	|18.2608	1.7488			15.1356	22.0312
gamma	| .9779	.0034			.9700	.9837
sigma_u2	|17.8571	1.7445			14.4380	21.2763
sigma_v2	| .4038	.0536			.2987	.5086
ttest mean == 6.376314						

APPENDIX E:ONE-SAMPLE t-TEST FOR THE MEAN OUTPUT OF ADOPTERS

One-sample t test		
Variable Obs Mean Std. Err. Std. Dev.		[95% Conf. Interval]
mean 746 5.993887 .0095456 .2607195		5.975148 6.012627
mean = mean(mean)	t = -40.0630	
Ho: mean = 6.376314	degrees	of freedom = 745
Ha: mean < 6.376314	Ha: mean != 6.376314	Ha: mean > 6.376314
Pr(T < t) = 0.0000	Pr(T > t) = 0.0000	Pr(T > t) = 1.0000
Ho: mean = 5.99389 764		degrees of freedom =
Ha: mean < 5.99389 mean > 5.99389	Ha:	mean != 5.99389 Ha:
Pr(T < t) = 1.0000	Pr(T > t) = 0.0000	Pr(T > t) = 0.0000

APPENDIX F:ONE-SAMPLE t-TEST FOR THE MEAN OUTPUT OF NON-ADOPTERS

ttest mean == 5.99389				
One-sample t test				
Variable	Obs	Mean [95% Conf. Interval]	Std. Err.	Std. Dev.
mean	765	6.376314 6.352633 6.399994	.0120629	.3336445
mean = mean(mean)			t = 31.7024	