EFFECT OF *ZAI* PIT AND HALF-MOON TECHNOLOGIES ON HOUSEHOLD INCOME AMONG SMALL-SCALE FARMERS IN KITA *CERCLE*, MALI

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A Thesis Submitted to Graduate School in Partial Fulfilment for the Requirements of the Master of Science Degree in Agricultural Economics of Egerton University

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DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not been presented for an award of a degree, diploma or certificate in Egerton University or any other University.

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Recommendation

This thesis has been submitted for examination with my approval as the Egerton University supervisors.

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DEDICATION

This research work is dedicated to my father Boubacar Bréhima Coulibaly and my mother Aminata Ballo for their full support.

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ABSTRACT

Rain water harvesting technologies (RWHTs) known as *Zai* pit and Half-moon have been embraced by small-scale farmers as a solution to climate related shocks. However, little is known on the socio-economic, institutional and technological aspects affecting farmers demand for the technologies as well their effects on farmers' income. This study was meant to fill this knowledge gap. The general objective was to contribute towards improved food security through enhanced use of *Zai* pit and Half-moon among small-scale farmers. The specific objectives were to: determine the socio-economic, institutional and technological aspects of small-scale farmers; assess the demand for *Zai* pit and Half-moon technologies among small-scale farmers; and to determine the effects of *Zai* pit and Half-moon technologies on small-scale farmers' income. Multistage sampling technique was used to interview 280 small-scale farmers using semi-structured questionnaires. Descriptive and inferential statistics were used to determine small-scale farmers' socio-economic and institutional characteristics. Confirmatory Factors Analysis (CFA), Negative Binominal Regression (NBR) and Multinomial Switching Regression (MSR) were used to determine farmers' perception, demand and the effects of the technologies on their income, respectively. Compared to non-users, the users of *Zai* pit and Half-moon were younger (49 old years), earning less off-income (333.841.00 FCFA), owning less Tropical Livestock Unit (2 TLU), having more contact with extension services providers (3 time) and had more training. CFA also revealed that users had a higher risk attitude (4.23), higher level of compatibility (4.27), higher perception on ease of use (3.87), higher perception on resources availability (2.03) and higher level of innovativeness (4.39) compared to non-users. The NBR results showed that demand was negatively influenced by the gender status, risk attitude, farm size, soil fertility, off-farm income and production farm assets value. Conversely, demand was positively influenced by the level of education, risk attitude, number of contact of extension service providers, farm size, soil erosion, slope of soil, compatibility, ease of use, innovativeness, usefulness and perception on timeless. The MSR analysis on the average treatment effect indicated that users of *Zai* pit, Half-moon and *Zai*-Half-moon earn (42.286 FCFA, 16.073 FCFA and 110.976 FCFA respectively) more income from the main crop and (158.040 FCFA, 45.448 FCFA and 431.714 FCFA) more from the general household income than non-users. To improve *Zai* pit and Half-moon use, the study recommends policy makers to improve farmers' access to market, diversification of income, quality information and sensitizing farmers' perception on technologies.

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LIST OF ABBREVIATIONS AND ACRONYMS

ACF-E	Action Against Hunger *(Action Contre la Faim Espagne)*
ATT	Average Treatment Effect on Treated
ATU	Average Treatment Effect on Untreated
FAO	Food and Agriculture Organisation
FCFA	African Financial Community *(Franc de la Communauté Financière Africaine)*
GDP	Gross Domestic Product
MPDL	Mouvement for peace, disarmament and Freedom *(Mouvement pour la Paix, le Désarmement et la Liberté)*
MESR	Multinomial Endogenous Switching Regression
NAPA	National Adaptation Program of Action
NAP-CD	National Action Plan to Combat Desertification
NBSAP	National Biodiversity Strategy and Action Plan
NGO	Non-Governmental Organization
OCHA	Office for Coordination of Humanitarian Affairs
RWHTs	Rain Water Harvesting Technologies
RGPH	General Census of Population and Housing *(Recensement Général de la Population et de l'Habitat)*
SWCT	Soil and Water Conservation Technologies
SSA	Sub- Saharan Africa
SPSS	Statistical Package for Social Scientists
UNOCHA	United Nation Office for Coordination of Humanitarian Affairs

CHAPTER ONE

INTRODUCTION

1.1. Background information

Agriculture is the engine of the economy of Mali. It constitutes the principal source of income for around 75% of the population, mainly in rural areas (Bélières, 2014). The annual average agriculture Gross Domestic Product (GDP) growth rate was 5.2 % in January 2018, making the sector the most dynamic over that period (Trading Economics, 2018). Although most of the small-scale farmers in Mali practice subsistence farming, agriculture has great potential as a driver for economic growth as it contributes 41% to the GDP of Mali (World Bank, 2014).

In spite of the role played by the agricultural sector in the country's economy, the sector is faced with a myriad of challenges such as unpredictable weather, soil degradation, low productivity and post-harvest losses among others. In addition, inadequate rainwater conservation poses one of the greatest threats to agricultural productivity and production leading to low yields. This is emphasized by Webber *et al.* (2014) who noted that, these challenges have led to increased food insecurity and poverty among the small-scale farmers' communities and the most vulnerable people are the poor farmers. The findings are further supported by the United Nation Office for Coordination of Humanitarian Affairs (UNOCHA) which reported that, there are 4.1 million people suffering from food insecurity in the country (UNOCHA, 2018).

Land degradation, which is defined as the loss of production capacity as a result of loss of soil fertility, soil biodiversity and degradation of natural resources (Blaikie and Brookfield, 2015) remains one of the key environmental problems and poses a threat to the well-being of many households. This is due to many factors: drought, loss of vegetation, soil erosion, low or erratic rainfall patterns, inappropriate use and poor management of land. According to Duncan (2016), the effect of soil degradation, combined with mismanagement of ecosystem and extreme climatic conditions, have resulted in bare soils that have become sealed and encrusted. These phenomena in turn reduce the agricultural potential of the land. It is on the foregoing that adaptation actions are essential to the survival of farming systems.

Regarding adaptation actions, significant investments have been made in semi-arid regions to develop and promote a range of soil and water conservation technologies. These aim at improving food productivity, food security and farmers' income in the face of extreme variability of rainfall and severe drought (Ayande, 2018). The practices commonly known today as Soil and Water Conservation Technologies (SWCTs) were introduced in farming systems in Burkina Faso, Niger and Mali (Abdulai and Huffman, 2014). The most common SWC technology used is Rainwater Water Harvesting Technologies (RWHT). They are massively promoted by Non-Government Organizations (NGOs) and national agricultural extension.

Studies in Sub-Saharan Africa (SSA) indicate that RWHTs stabilized landscapes. Jat *et al.* (2012) reported that, RWHTs provides an opportunity to stabilize agricultural landscape in semi-arid regions and to make them more productive and more resilient towards climate change. As noted by Zougmore *et al*. (2010), substantial experimental evidence of RWHT has shown their high potential to increase crop production and productivity. A report by Yosef and Asmamaw (2015), noted that RWHTs in rain-fed agriculture has the potential of reducing the negative impact of mid-season dry spells in semi-arid environments. Thereby, they contribute effectively to the rehabilitation of degraded lands and maintain soil fertility. Sawadogo (2011) noted that, RWHTs such as *Zai* pits and Half-moon help to secure agricultural output in unpredictable climates.

The *Zai* pit (as shown in Plate 1a and 1b) is a traditional technique used for the rehabilitation of degraded and crusted soils. It involves creating pockets or shallow pits in the soil, mostly excavated 25-35 cm in diameter, 10-15 cm deep and 3 m apart, which are designed to capture surface runoff water and maximize water infiltration into, otherwise, encrusted soils. They are often accompanied by the application of compost, usually manure (300g of manure or compost) in each pit (Sawadogo, 2011). Despite of *Zai* pit and Half-moon are traditional technique, they were introduced in Kita *Cercle* as new agricultural technologies.

(a) (b)

Plate 1: Preparation of *Zai* pit and millet growing in the *Zai* pit

Source: Coulibaly (2013) for a and (Motis *et al.*, 2013) for b.

The Half-moon technology (as shown in plate 2a and b) is a physical structure composed of half circle (semi open) depression in the soil that allows for the collection of surface runoff water by the excavation of hollows on bare and crusted soils with gentle slopes favouring its infiltration (Bayala *et al*., 2012). Each hollow is around 10 to 15 cm in depth, dug with a hoe or a pick with the excavated earth returned to form a mound in the shape of a half-circle. It differs from *Zai* pit in that the Half-moon is larger, creating a larger surface for planting and water collection. The recommended diameter of Half-moon is 2 m, spaced 2 m apart in rows approximately 3 m apart.

(a) (b)

Plate 2: Preparation of Half-moon and maize growing in the Half-moon

Source: Coulibaly (2013) for a and Bayala *et al.*(2011) for b

1.2. Statement of the problem

The weather variability and land degradation has affected agricultural production in Mali. Rain water harvesting technologies such as *Zai* pit and Half-moon have been promoted by extension service providers and many NGOs as one of adaptations to the challenges. This can contribute to creating nutrient rich soils and availability of water for sustainable agricultural production leading to improved farms productivity, which leads to higher income. However, not all small-scale farmers are using the technologies. The socio-economics, institutional and technological aspect of the demand for the technologies are still unclear. In addition, the effect of *Zai* pit and Half-moon on small-scale farmers' income is still not well documented. It is on the forgoing that this study was aimed at filling these knowledge gaps.

1.3. Objectives of the study

1.3.1. General objective

The general objective of this study is to contribute towards improved food security through enhanced use of *Zai* pit and Half-moon among small-scale farmers in Kita Cercle, Mali.

1.3.2. Specific objectives

(i) To determine the socio-economic and institutional characteristics of small-scale farmers in Kita Cercle, Mali.

(ii) To determine the perceived technology attributes and climate characteristics of small-scale farmers in Kita Cercle, Mali.

(iii) To determine the demand for *Zai* pit and Half-moon technologies among small-scale farmers in Kita Cercle, Mali.

(iv) To determine the effects of *Zai* pit and Half-moon technologies on small-scale farmers' income in Kita Cercle, Mali.

1.4. Research questions

(i) What are the socio-economic and institutional characteristics of small-scale farmers in Kita Cercle, Mali?

(ii) What are the perceived technology attribute and climate characteristics of small-scale farmers in Kita Cercle, Mali.

(iii) What is the small-scale farmer's demand for *Zai* pit and Half-moon technologies in Kita Cercle, Mali?

(iv) What are the effect of *Zai* pit and Half-moon technologies on small-scale farmers' income in Kita Cercle, Mali?

1.5. Justification of the study

Small-scale farmers in Mali grow their crops primarily on marginal lands, which have limited agricultural potential because they are located in hillside and dry land areas. These conditions make this type of land more susceptible to soil degradation and erosion leading to low soil fertility. Consequently, farmers are more likely to experience decreased crop productivity.

To address these challenges, the government of Mali and its technical and financial partners have considered RWH technologies as crucial in any development initiatives and stimulation of rural economy. This is also aligned with Mali National Adaption Program of Action (NAPA, 2007) of enhancement of the adaptive capacity of the agricultural sector, National Action Plan to Combat Desertification (NAP-CD, 2013) and the National Biodiversity Strategy and Action Plan (NBSAP, 2014), which pursue parallel aims towards climate resilience of ecosystems services for agriculture and food production.

Although some measures have been undertaken by the government and its partners, small-scale farmers are still poor, particularly in the rural areas. To alleviate this challenge, *Zai* pit and Half-moon technologies were introduced through cash for work activities in Kita. The aim was to support vulnerable farmers facing climate change calamities to increase their resilience and livelihood by ACF-E (*Action Contre la Faim Espagne*) in collaboration with Stop-Sahel. The beneficiaries of the support were the small-scale farmers. There is need to determine the effects of *Zai* pit and Half-moon technologies on small-scale farmer's income since the impact of the different technologies on targeted population still remain not clearly determined in literature.

1.6. Scope and limitation of the study

The study focused on the effects of *Zai* pit and Half-moon technologies on small-scale farmers' income in South-West Kita Cercle. This study was also restricted to users and non-users of *Zai* pit and Half-moon technologies in seven (7) villages of Kita Cercle.

Illiteracy and inadequacy of properly kept records was predicted to affect the accuracy of the estimates since the study heavily relied on farmer's ability to recall information. However, thorough investigation was employed to ensure that data collected was enhanced in accuracy.

1.7. Operational definition of terms

Demand for *Zai* pit and Half-moon- refer to how much of pit of *Zai* or Half-moon a famer need to dig in his or her plot.

Household- is a group of people, who live together most of the time and contribute to a common economy and share common food and income.

Half-moon- is a physical structure composed of a Half-circle (semi-open) depression in the soil that allows for the collection of surface run-off water.

Land degradation- refers to the loss of production capacity in terms of soil fertility, soil biodiversity and degradation of natural resources (Blaikie and Brookfield, 2015).

Livelihoods- are defined as the capabilities, assets, and activities required for a means of living. They are how people use what they have to meet their needs and work towards their life objectives.

Small-scale farmers- refer to farmers with limited resources endowment and own a maximum land size of 3 hectares.

Users- refers to small-scale farmer who uses at least one of the technologies.

Non-Users- refers to small-scale farmer who did not uses any of the technologies.

Zai pit- consist of digging rounded or rectangular pits in order to capture surface run-off water and increase water infiltration into the soil.

CHAPTER TWO
LITERATURE REVIEW

2.1. History of soil and water conservation technologies

Repetitive droughts of the 1970s and 1980s affected agricultural productivity heavily by causing huge losses to crop and livestock production. As a consequence, hunger and malnutrition were aggravated leading to massive migration of most vulnerable population. The resultant situation left the economy severely crippled. In addition, weather instability caused soil degradation thus increasing soil erosion (Kassie *et al.*, 2009). Despite great efforts of foreign and government aids through community development programme, soil restoration did not reach the level of satisfaction.

Since drought was prevalent in different countries of Sub-Sahara Africa from 1983 to 1984, substantial investments were made in soil and water conservation technology known as Rain Water Harvest (RWH) (Shiferaw *et al.*, 2014). The objective of these investments targeted the improvement of agricultural production and farmers' livelihood through their resilience to climate calamities (Douxchamps *et al.*, 2014). In addition, soil and water conservation technologies (SWC) were introduced on cultivated fields in countries such as Burkina Faso, Niger and Mali where the majority of farmers embraced these soil and water conservation technologies.

Soil and water conservation technologies are a set of items whose selection and application depend on the socio-economic and geographical conditions of the region. The topography and the annual rainfall are determinants of the choice of a particular method. Soil and water conservation technologies that have acquired extensive attention and investment in the country are composting, anti-erosive digs, stone-bands, live-fencing, mulch and bio-intensive garden (Vohland and Barry, 2009).

''Zai'' word comes from *Moore* language, which means *''*get up early and hurry to prepare the earth'' which is based on indigenous farming as adaptation methods mostly in arid climate conditions or particular agro-ecology ones (Bayala *et al.*, 2011). Moreover, *Zai* pit and Hallf-moon technologies used for rainfall water collection were applied in Mali, Burkina Faso and Niger (Nyamadzawo *et al.*, 2013). The two (2) technologies had been rapidly spread due to their relative immediate effects on crop production and productivity. These two technologies combined with other technologies of SWC, induce their higher efficiency not only in soil restoration but also production sustainability (Sawadogo, 2011).

The *Zai* pit technology consists of digging rounded or rectangular pits in order to capture surface runoff water and increase water infiltration into the encrusted soil. The pit has a diameter of 20 to 40 cm, depth of 10 to 15 cm with 60 to 100 cm between sequential pits (Nyamadzawo *et al.,* 2013). The pits are preferably done during dry season manually using the hoes or mechanized using tillage tools. Half-moon technology differs from *Zai* by the size and the shape of the pits. The former is half-circle shape and dug perpendicular to the slope, thus creating a larger surface for planting and water collection. It can have a dimension up to 2 m in diameter, 15 to 25 cm deep and 2 m between two sequential Half-moons. According to Motis *et al.* (2013), the application of both techniques should be supplemented by the application of a handful of manure or compost of around 300g per pit at the beginning of the rain. The manure is mixed with the soil at the bottom of the hole allowing good development of beneficial microorganisms to the crops (Bayala *et al.*, 2012). Two weeks after the first rain, this pocket that acts as a catchment of microorganisms is ready for planting.

Zai pit and Half-moon are considered among simple agricultural technologies which do not require either sophisticated equipment or advanced knowledge and yet they can result in yield ranging from 300 kg of maize per hectare in low rainfall season and up to 1200kg of maize per hectare in good rainfall season (Motis *et al.,* 2012). In addition, the application of *Zai* pit and Half-moon go beyond the crops as its application has been revealed to be beneficial to trees and even the integrated crop-tree system (Sawadogo, 2011). Another advantage of *Zai* pit and Half-moon technologies is the reduction of manure losses as nutrients are abundant and readily available for plant roots. This gives the plants a competitive advantage over the weeds, thus increases the yield (Lahmar *et al*., 2012). Moreover, the *Zai* pit and Half-moon can reduce water shortages on the crops in an interval of 2 to 3 weeks.

On the contrary, their applications are more demanding in labour force since one hectare can contain 10,000-15,000 *Zai* pit, which necessitates 200 to 300 hours depending on the type of soil (Motis *et al*., 2013) and 315 hours in the case of Half-moon. Additionally, both techniques are limited by the availability and accessibility of manure or compost which are the key elements. The required amount of compost is higher in the application of Half-moon than *Zai* pit. To overcome these challenges, farmers undertake these techniques through collective action and the work is usually done by adult men. After three consecutive years of applying compost in the same pits, farmers are highly advised to alternate its application through the community work.

Recently, scientists made some progress towards mechanization of making holes using animal-drawn tool. This reduces the amount of time required to make the pits by more than 90%, which takes only 11 to 22 hours per hectare with oxen. This labour-saving strategy gave rise to an economic benefit of 165,000 CFA/ha compared to only 17,000 CFA/ha with the annually dug *Zai* (Zougmore *et al.,* 2014). Nonetheless, the use of mechanization is constrained by relatively expensive costs of animal-drawn equipment and tools for the majority of the farmers.

2.2 Challenges of soil and water conservation technologies

The introduction of many agricultural technologies has not always been met with success. Studies show that there are many factors that influence farmers' decisions to use technologies and assist in explaining heterogeneity and differences among farmers to help further explain their use behaviour. Understanding these factors may boost rates of use and facilitate the diffusion of RWH technologies.

Kassie *et al*. (2015) found risk as an important factor that determined use. The study found empirical evidence which indicated that farmers exhibited decreasing absolute risk aversion, implying that farmers were averse to downside risk, especially to unexpected low yields. Knowler and Bradshaw (2007) affirmed that a non-economic factor also plays an important role in determining whether farmers will adopt an agricultural technology. Abdulai and Huffman (2014) noted that low rates of use could be explained by constraints such as risk aversion, environmental and institutional factors. For instance, if the technology was labour intensive like *Zai* pits and Half-moons, farmers facing labour or liquidity constraints may decide not to adopt the technology.

Nierras (2016) suggested that the efficacy of development programs depend on how extension educators and technical assistants involved in agricultural development understood and addressed the factors that affect technology use. Additionally, the effective involvement of farmers could help to determine appropriate criteria for cropping system valuation, farmers' needs and preferences, improved methods of dissemination and extension, and feedback (Adebayo and Oladele, 2013).

2.3 Factors influencing agricultural technologies

Enhancing farm production through application of rain water harvest technologies (RWHT) to the extent of farm system is relevant for improving the lives of farmers in rural areas. The aim of the *Zai* pit and Half-moon technologies is to improve the lives of rural farmers in Mali. However, the decision to use is not straightforward. This decision-making process is complicated and involves many factors such as farmers' goals, socio-economic, institutional, social network and social capital leading to a wide range of use behaviour (Roussy *et al.*, 2014).

Farmers' perception of technology is subjective and varies according to the agro-ecological conditions of their living areas. For instance, their perception of the characteristics of the technology has been found to be an important determining factor of its use (Dandedjrohoun *et al.*, 2012). In the Malian context, it was found that farmers' perception is positively affecting the use of an agricultural technology innovation (Kante *et al.,* 2016). A positive attitude of farmers in a given technology might hasten the use of a particular technology. Amsalu and De Graaff (2006) noted that farmers' decision of applying RWT technology was largely determined by the knowledge of problems associated with the technology. Moreover, the perception of the marginal net benefit must be greater than the marginal cost of RWHT investment in order to undertake and maintain the RWHT investment (Amsalu and De Graaff, 2007).

Deressa *et al*. (2009) stated that the gender of the household head had an influence on the decision to use technology. The study reported that male headed households were more likely to use RWHT faster than female households since traditionally, they have more access to resources compared to women. Turinawe *et al.* (2015) found that both farmers' farming experience and age are positively related to the use of RWHT. Farmers who are involved in farming for long periods have a great probability of using a technology. This was reasonable since such farmers must have used trial and error method to acquire techniques that best suit them (Donkoh and Awuni, 2011). Nmadu *et al*. (2015) also noted that more farming experience provides better knowledge about the environment in which decisions are made. Kidanu *et al.* (2016) concluded that, farmers' training through their participation in on-farm demonstration test and workshop improve the performance, knowledge, skills or attitudes thus a higher probability of agricultural technology use. This assists them to differentiate the technology into which one is easy to use and provides maximum profit. On the other hand, some people may argue that farmers who have been in operation for long periods are conservative and are normally not willing to be innovative.

Labour availability is important in agricultural technology use. Some researchers have shown that the lack of labour might dishearten farmers from deciding to use agricultural technologies (Bayala *et al.*, 2011; Rehman *et al*., 2016). The idea was that where the technologies required a lot of hard work like RWHT uses, farmers needed to supply more labour for farm activities by hiring from the local labour market or farmer group members. Otherwise, they may choose not to use such technologies (Adeoti, 2009).

The size of the farm affects use both in a positive and negative way. Schimmelpfennig (2006) reported that, farmers with a big farm size are considered wealthy, therefore are likely to use agricultural technologies. The rate of RWHT uses increases with an increase in farm size (Mugwe *et al*., 2009). However, some researchers may argue that farmers with small farm lands are better off in terms of farm operation management since most of the SWC uses are onerous.

Ngo (2016) reported that farmers who are well endowed with financial assets or have high income are more likely to be more risk averse with more information and socio-economic advantages. Consequently, these classes of farmers are open to new ideas. In the same line, off-farm income favours farmers decision to use RWHTs positively as it overcomes the farmers` credit constraints and consequently reduces the cost of agricultural technology (Adekemi, 2016). In addition, off-farm income provides farmers with enough funds to purchase resources for productive enhancement (Babatunde, 2015). The access to credit and farm inputs as well as the market access favours farmers' decision to use RWHTs, thus the nearer a farmers' farm is to input markets, the higher the likelihood of use (Pan *et al.,* 2016)

Ownership of the land is often considered as a condition for getting credit. Abdulla (2009) found that land tenants had a low rate in terms of decision making which favours technology use. In the same line, Kitamura (2016) confirms that, farm owners were more willing to use agricultural technology than the tenants. On the other hand, some analysts had observed that tenants were innovative thus adopted the necessary technology for profit maximization in order to pay their debts.

The extension services play an important role in a farmer's decision towards a technology use. As noted by Abay *et al.* (2016), the more farmers received advice from extension agencies, the more likely they were tending to adopt the technology. This was noted by Donkoh and Awuni (2011) who found a significant rate of technology use with farmers' visit to extension officers.

Some study showed that access to information about agricultural technology was a key determinant in farmers' decisions to use (Kiyingi *et al.*, 2016). Barungi *et al*. (2013) found that the features of technology influenced the proportion and the intensive use. On the other hand, Lambrecht *et al*., (2014) argued the fact that technology was not well known by the farmers led to low potential use. Farmer's group membership or association favours the access to information about the technology through other members of the same group or association (Lambrecht *et al*., 2014).

Moreover, the social capitals of farmers, relatives, institutions, social network, positively affect the decision to use agricultural technology as shown by Maertens and Barrett (2012). In addition to that, a great proportion of group members easily undertake a collective action to overcome the higher labour demands for soil preparation and manure application. A study conducted by Ginkel *et al*. (2013) showed that, the interaction among group members increased the level of agricultural technology use. Cattle ownership reduces considerably the cash constraints and increases the availability of manure which is crucial to subsistence farming (Odendo *et al.*, 2010)

Nevertheless, some studies found contrasting results regarding the aforementioned factors that influence the use of technologies among small-scale farmers (Kinyangi, 2014). Amsalu and De Graaff (2007) mentioned in their study that livestock ownership has a negative influence on RWHT use such as stone bands. The idea is that, more specialization in livestock leads to desertion of crop farming hence the decision not to use the technologies.

The size of the land can influence negatively the farmers' use of RWHTs when the opportunity cost is higher than the benefit. Therefore, large farm sizes need an important measure of soil conservation technique to overcome soil erosion which is a constraint especially for small-scale farmers (Kinyangi, 2014). In addition, the tenure security influences the probability of use. Farmers are not willing to take a risk of losing land after investing on that land, thus lack of ownership reduces the level of agricultural technology use (Kassie *et al*., 2013).

However, a shortcoming of most of the previous studies on agricultural technology uses is that they do not consider the possible inter-relationships between the various uses and the interaction among factors (Odame *et al*., 2011). These are key factors influencing farmers' decision to use technology which might positively or negatively influence farmers' income.

2.4. Theoretical and conceptual framework

2.4.1 Theoretical framework

There exist several theories explaining the decision of farmers practicing technologies and the subsequent effects of such technologies on households' income (Rogers, 1995). Morris and Adelman (1988) have argued that there is no single theory of causation that can embrace all aspects of use or practicing and explain the traditional attitude of small-scale farmers towards technologies in developing countries. However, it is possible to distinguish four main theoretical approaches, the economic constraints approaches: the innovation-diffusion approaches; the technology characteristics-user's context approaches and the use behaviour approaches.

The economic constraints theory known as factors endowment theory is based on the assumption, where the distribution of resource endowment among the potential users in a country or region determines the pattern of use of technological innovation. The model assumes that market prices (surrogate prices induced by policy and institutional interventions) reflect the relative scarcity of the factors, implying the existence of (or need for) well-performing markets and the importance of price policies (Ruttan and Hayami, 1984).

The innovation-diffusion model, also called transfer-of-technology (TOT), follows from the initial work of Rogers (1962). According to this model, technology is transferred from its source to final users through agent medium (extension services) and its diffusion in potential user-communities depends mainly on the personal characteristics of the potential individual user. This model assumed that technology is appropriate for use unless hindered by the lack of effective communication.

The technology characteristics user's context theory, which assumes that characteristics of a technology underlying user's agro-ecological, socio-economic and institutional contexts play the central role in the use decision and diffusion process (Thompson and Scoones, 1994). This theory considers the perception of potential adopters regarding the characteristics of a technology as a component affecting adoption decisions hence the diffusion of the technology (Gould *et al.,* 1989). The model implies the importance of the involvement of farmers in the technology development process with the aim of generating technologies with appropriate and acceptable characteristics. The model also implies the importance of institutionalization of research policies and strategies that facilitate the participation of farmers and other relevant stakeholders in the technology development process.

The adoption behaviour model explains that, the behaviour of an individual is a function of socio-economic and environmental factors and the decision to use is endogenous to the sum of the interacting forces of farmers' situation (Msuya, 2007). As such the behaviour to use a technology is assumed to be intentional in this model. The model explains that use behaviour is governed by a set of intervening variables on individual needs, knowledge about the technology, and individual perceptions about methods used in meeting those needs in a specific environment. However, these intervening variables are dependent on a set of socio-economic, institutional variables such as age, level of awareness, extension contact, and income, size of the land and the size of the family (Habtemariam, 2003). The continuation of technology use is largely dependent on perceived or realized advantages of that technology among other technologies in meeting users' needs. This research will be generally based on the last two assumption theories.

2.4.2. Conceptual Framework

The conceptual framework adopted in this study is represented in figure 1 below. The diagram represents a conceptual framework which provides a link between the factors influencing *Zai* pit and Half-moon technologies, increased small-scale farmer's income and improvement of their food security.

The *Zai* pit and Half-moon technologies use by the small-scale farmers is influenced by socio-economic and institutional aspects such as household size, farming experience, household income level and access to extension services. These factors may encourage or limits farmers to use *Zai* pit and Half-moon technologies. If farmers decide to use *Zai* pit and Half-moon technologies, this study expects an improvement of their technical efficiency hence high yields. This will eventually lead to an increase of small-scale farmer's income, and ultimately, improved food security. Thus, the profitability of the farm is influenced by the type of crops, output levels of the different crops, the prices of produce as well as the cost of production.

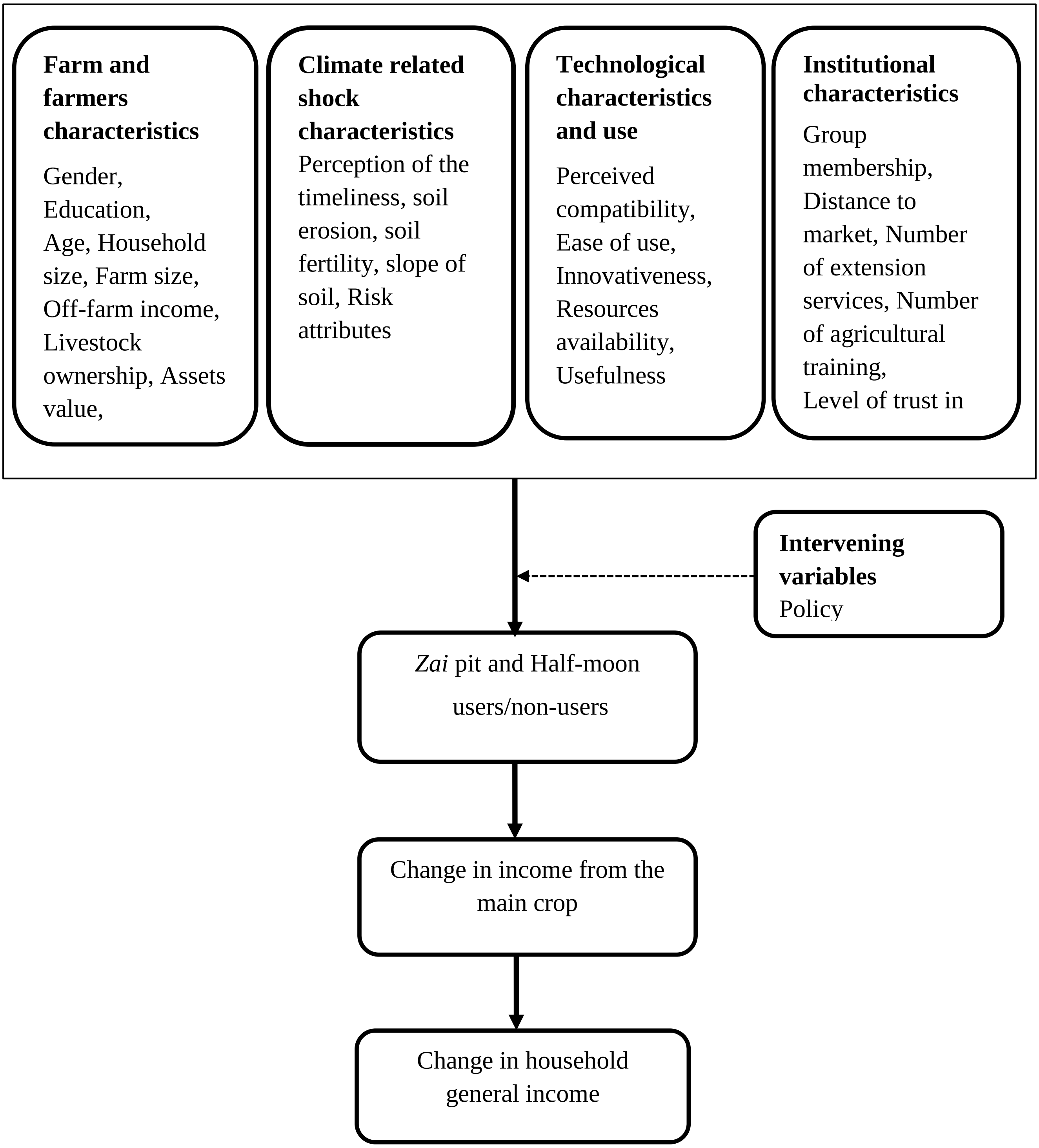

Figure 1: Conceptual framework on effect of *Zai* pit and Half-moon on household income

CHAPTER THREE

METHODOLOGY

3.1. Study area

The study was conducted in the Cercle of Kita, Kayes Region which is located in the South-western part of the Republic of Mali. This area was chosen because it has the most active participation in *Zai* pit and Half-moon activities. Its geographical coordinates are 13° 15' North, 9° 20 West and covers an area of 35.250 km^2 with a total population estimated in 2012 at 4,565,763 and 33 communes (Sangho *et al.*, 2015). The Kita Cercle lies on the North by the Cercle of Djema and Nioro, South by the Republic of Guinea, East by Kati and Kolokani Cercle (Koulikoro region) and to the West by Bafoulabé and Kéniéba Cercle. This area represents 3% of the country’s agricultural territory and 29% of the regional territory (*Action Contre la Faim Espagne*- ACF-E, 2013). The study area has a tropical climate and is characterized by two different seasons. The dry season with scattered rainfall lasting 3 to 4 months followed by an often-prolonged drought with an average rainfall of 500 to 700 mm. On the other hand, the long rainy season lasts 5 to 6 months with an average rainfall of 1000 to 1200 mm.

Agriculture is the main economic activity in the area particularly crop production which plays an important role in the region. It constitutes 85% of food sources for small-scale farmers (ACF-E, 2013). The main crops grown in the area are maize, sorghum and groundnuts while livestock is dominated by cattle, sheep, and goats. Kita Cercle has experienced environmental degradation including soil erosion and flooding which poses threat to its food production potential. The study was conducted in ACF-E intervention zone which are the following rural commune of Kita Cercle: Sefeto-north, Sefeto-west, Djougoun, Didanko and Guemoukouraba. The map of the study area is shown in Figure 2.

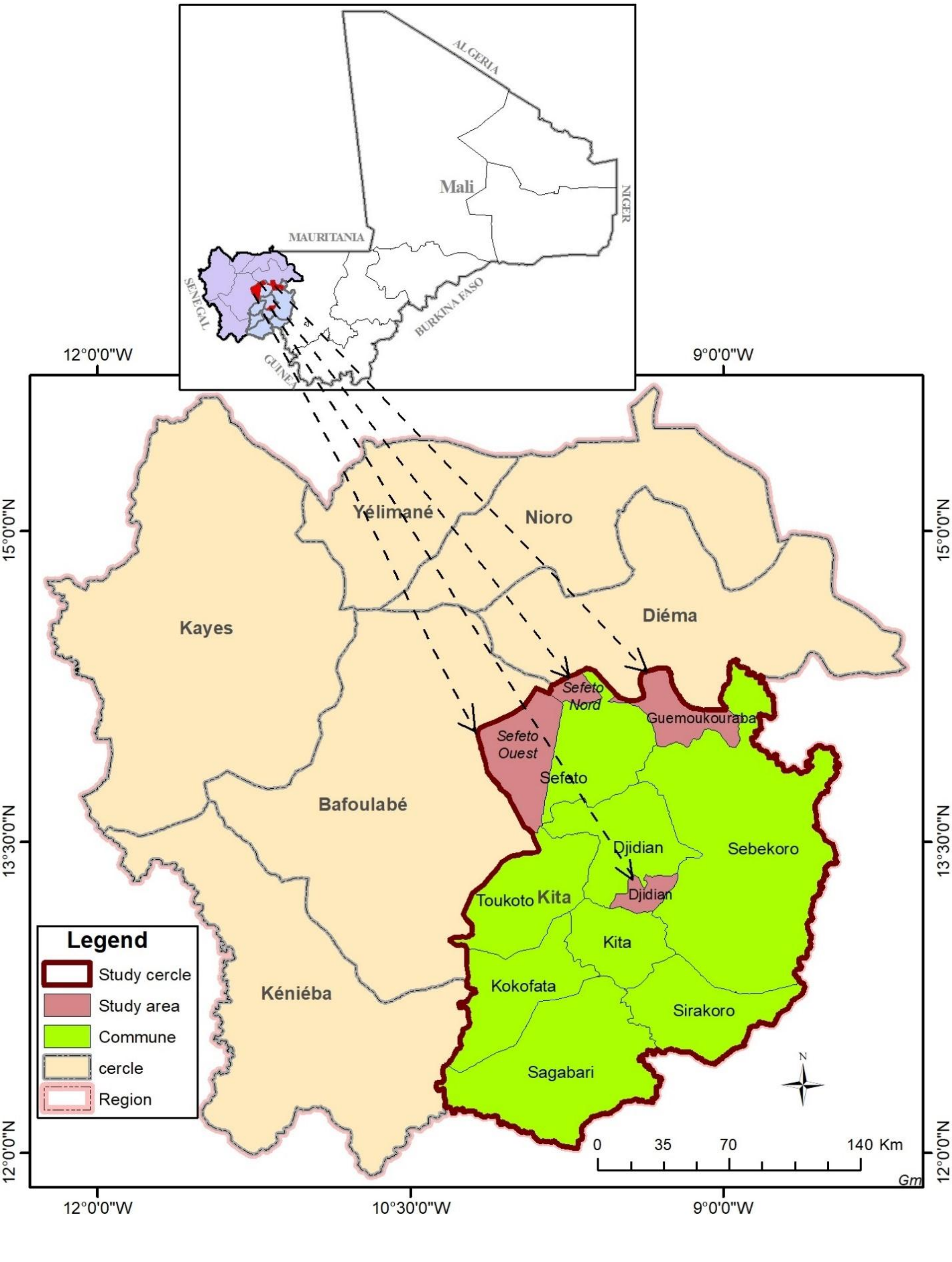

Figure 2: Map of the study area

Source: GIS Diva website download and map prepared by Geoffry maina Environmental science department Egerton university

3.2. Sampling procedure

The target population was small-scale farmers (users and non-users of *Zai* pit and Half-moon). The research employed a multistage sampling technique to select the following sampling clusters: Cercle, commune and villages. First, four (4) communes were purposively selected based on their *Zai* pit and Half-moon development potential from Kita Cercle. Secondly, seven villages from the four communes were purposively selected among the other villages because they have the most active participation in *Zai* pit and Half-moon activities. Thus, the seven villages namely Mansala, Djougounté, Kakoromoutan, Sakora, Kabé, Doumbadjila and Marena were selected. According to ACF-E (2013), the number of small-scale farmers in Mansala, Djougounté, Kakoromoutan, Sakora, Kabé, Doumbadjila and Marena are 68; 200; 135; 64; 268; 65; 130 respectively (Table 1). Villages' sample size was determined proportionally from the already defined sample from which users and non-users were identified. Finally, respondents were selected randomly from the list of small-scale farmers from each targeted village provided by the local extension officer (mayor of the commune); where its details is described as shown below:

$$\frac{P}{N} \times S_{total} \tag{1}$$

Where; P = number of small-scale farmers in a village (users and non-users)

N = total number of small-scale farmers in the seven villages,

S_{total} = Total sample size

3.3. Sample size determination

The sample size determination followed a proportionate to size sampling methodology as specified by Yamane (1967) and was calculated as follows;

$$S_{total} = \frac{N}{1 + N(e)^2} \quad (2)$$

Where;

S_{total} = the sample size; N= total number of small-scale farmers in the seven villages which is **930** (ACF-E, 2013).

1= a constant value; e= is the level of significance (confidence interval of 95%; level of error 0.05)

Therefore, with replacement of the value into the formula gives:

$$S_{total} = \frac{930}{1 + 930(0.05)^2} = 279.69 \approx \mathbf{280}$$

By applying the probability proportional (equation 1) which is $\frac{P}{N} \times S_{total}$ to each village, we get respectively the number of the sample size for each village as show below (Table 1)

$$\text{Mansala} = \frac{68 * 280}{930} = 20.47 \approx 20$$

$$\text{Djougounté} = \frac{200 * 280}{930} = 60.21 \approx 60$$

$$\text{Kakoromoutan} = \frac{135 * 280}{930} = 40.64 \approx 41$$

$$\text{Sakora} = \frac{64 * 280}{930} = 19.26 \approx 19$$

$$\text{Kabé} = \frac{268 * 280}{930} = 80.68 \approx 81$$

$$\text{Doumbadjila} = \frac{65 * 280}{930} = 19.56 \approx 20$$

$$\text{Marena} = \frac{130 * 280}{930} = 39.13 \approx 39$$

The total sample size = **280** small-scale farmers where 208 were users and 72 non-users

Table 1: Sample size per selected village

Villages	Mansala	Djougounté	Kakoro-Moutan	Sakora	Kabé	Doumb-Djiala	Marena
Number of small-scale farmers	68	200	135	64	268	65	130
Sample Size	20	60	41	19	81	20	39

3.4. Data collection and analysis

Primary data was collected from sampled small-scale farmers through face-to-face interviews using semi-structured questionnaires, which were administered by trained enumerators. A pre-test of the questionnaire was first carried out to determine the validity of the data collection instrument and the pertinence of the data for the study.

Data based on farm and farmers' characteristics such as sex and age, level of education, marital status, and occupation, access to credit, income, and distance of farm to market, experience in crop, family size, agricultural extension services, and use of manure on crops production were collected. The data collection considered the socio-economic, institutional and technological factors that affect the farmers' income (yields, productivity, quantity of output sold, and sale price and off-farm activities). This included the amount of time allocated to *Zai* pit and Half-moon work and other costs of production such as land, equipment, compost. The data was collected during the period of 2016/2017 production season.

Secondary data such as the list of small-scale farmers was obtained from respective offices of agriculture, mayor of commune, NGO's such as Stop-Sahel Kita, *Action Contre la Faim* (ACF-E, Kita; a French NGO), MPDL-Kita, and some written literature. The analyses were done by using Statistical Package for Social Scientists (SPSS) version 20.0 and STATA version 13.0 software to generate econometric results.

3.5. Analytical framework

3.5.1. Objective one

To determine small-scale farmers' socio-economic and institutional characteristics, both descriptive and inferential statistics were used such as means, frequencies, percentage and standard deviation. The inferential statistic included *t-test* and *chi-square* test.

3.5.2. Objective Two

The Confirmatory Factors Analysis (CFA) was conducted for perceived technology attributes and climate characteristics since they are psychometric tools. The CFA as a method of Principal Component Analysis (PCA) was applied for variable reduction purposes in order to ensure the internal consistency reliability, the convergent validity and the discriminant validity of the selected constructs. In using this method, multiple items are recommended for latent or unobservable construct (Olsen *et al*., 2017). For each construct used to measure farmers' perception, available measures were identified from relevant literature such as Kassie *et al*. (2012); Aubert *et al*. (2012); Recha (2015) and adapted to the study. However, the measures have a lower limit of three items since constructs with two (2) items or less tend to be problematic and do not give the flexibility to remove an item to improve reliability. They have an upper limit of six (6) items to minimize the number of question (Compeau *et al*., 2007). Additionally, each construct was subjected to the Relevancy Weightage (RW), using the following formula:

$$RW_{PTCA} = \sum_{i}^{n} \frac{FScore_i * item_i}{TScore} \quad \text{……} (3)$$

Where: *PTCA* is the relevancy weight of farmers' perception on technological characteristics and attitudes; $FSCcores_i$ is ith factor score; $item_i$ is ith item of the statement; $TScore$ is the total factor score.

The Weighted Mean of a constructs as suggested by Moralista *et al*. (2014) should be included between 1 and 5. Bartlett's test of sphericity was used to confirm the fitness of CFA to the data. In the same line, the Kaiser-Meyer-Oklin measure for sampling adequacy was applied to ensure that the sample size is adequate for CFA. Based on KMO values between 0-1 can be qualified Marvellous, Meritorious, Middling, Mediocre, Miserable and Unacceptable (Friel, 2018). In the present study, a total of 24 self-estimation items were used to rate the perception of small-scale farmers about technology attributes and climate related factors. The latent constructs used were: perception of timeliness, risk taking attribute, ease of use, compatibility, level of trust in institution, perceive resources and users' innovativeness. All measured were reflective construct with items measured by using 5-point Likert-type scales ranking from "strongly agree" to strongly disagree".

Cronbach's alpha, Composite Reliability (CR) and Average Variance Extracted (AVE) were calculated to estimate both constructs' reliability and validity. The factor loadings estimate the direct effects of constructs on indicators (variables). It measures the factors reliability which is considered attained if all the items loading recorded a value of 0.7 or higher and statistically significant at $p< 0.05$ (Garson, 2012). The acceptable internal consistency reliability for a measurement of the construct is achieved once the composite reliability (CR) of every construct is above the recommended value of 0.7 (Garson 2016). The average variance extracted (AVE) value is used to measure the convergent validity. The AVE measures the percentage of variance captured by a construct showing the ratio of the sum of the variance captured by the construct and measurement variance (Gefen *et al*, 2000).

3.5.2. Objective three

To assess the demand for *Zai* pit and Half-moon technologies among small-scale farmers, the Bivariate Negative Binomial Regression model was used. The BNBR model allows for specification of two correlated count outcomes with either two outcome-specific covariate lists or one common covariate list and fits models. The model specifies each marginal distribution as Poisson, negative binomial or bivariate zero-inflated Poisson of the demand from each outcome. Thus, the likely demand for each technology is expressed as a count of pit (Edmeads *et al*., 2006). *Zai* pit and Half-moon are characterized by the number of pits which can be counted in a given plot or land by the farmers since they were aware of the number of pits for each of the technology. Despite the recommended number of pit, some farmers may choose to dig many or few pits of *Zai* pit or Half-moon based on their attributes and farmer needs and preferences.

The BNBR approach has an advantage for understanding the likely demand for RWHT. The decision to use is associated with problems of choosing whether to use a logit variable or a censored variable that represents the extent of use (Tobit). The count outcomes approach is more general, thus allows combining the categorical data such as use, non-use with the count data (number of *Zai* pit or Half-moon). When the decision to use which is the dependent variable is measured as the number of *Zai* pit or Half-moon dug by farmers, observations on the dependent variable are represented by non-negative integer quantities, and failure to account for the integer nature of the data can bias results (Isgin *et al*., 2008). Therefore, any measure based on continuous demand models such as OLS or Tobit was inaccurate and misleading since the variable is a non-negative integer (Ganguly *et al*., 2010). For this reason, the BNBR regression model was applied in this study. Following Long *et al.* (2015), the detailed model of BNBR distribution for bivariate events (Y_1, Y_2) is defined as follows:

$$P(Y_1 = 0, Y_2 = 0) = \varphi + (1 \quad \varphi)\exp(\quad \lambda) \quad \ldots\ldots(4)$$

$$P(Y_1 = y_1, Y_2 = y_2)$$

$$= (1 - \varphi) \sum_{j=0}^{\min(y_1, y_2)} \frac{\lambda_1^{y_1 - j} \lambda_2^{y_2 - j} \lambda_0^j}{(y_1 - j)!(y_2 - j)!\, j!} \exp(-\lambda),$$

$y_1 \neq 0$ or $y_2 \neq 0$

$0 \prec \phi \prec 1$ and $\lambda = \lambda_1 + \lambda_2 + \lambda_0$

Where Y_1 and Y_2 can be expressed by

$$Y_1 = U_1 + U_0 \text{ and } Y_2 = U_2 + U_0 \quad \ldots\ldots(5)$$

Where U_1, U_2 and U_0 are independent univariate Poisson random variables with mean λ_1, λ_2 and λ_0, respectively.

The marginal distributions of BNB are univariate ZIPs:

$$P(Y_k = 0) = \phi + (1 - \phi)\exp(-\lambda_k - \lambda_0) \quad (6)$$

$$P(Y_k = y_k) = (1 - \phi) \frac{(\lambda_k + \lambda_0)^{y_k}}{y_k!} \exp(-\lambda) \quad \ldots\ldots(7)$$

With $y_k \neq 0, k = 1, \; 2$

For the *Zai* pit and Half-moon use, we can write as follow:

$$Y(ZP) = \text{Exp}\left(\beta_0 + \sum_{k=1}^{2} \beta_k X_i\right) \quad \ldots\ldots(8)$$

$$Y(HM) = \text{Exp}\left(\beta_0 + \sum_{k=1}^{2} \beta_k X_i\right) \quad \ldots\ldots(9)$$

Where $Y(ZP)$ and $Y(HM)$ refer respectively to the number of *Zai* pit, Half-moon dug by i farmers, and X_i is a vector of covariates. The model variables, explanations and hypothesized relationships are shown in Table 2.

Table 2: Description of variables used in Bivariate Negative Binomial regression model

Variable	Description	Measurement	Expected sign
Dependent Variables			
Zai pit	Number of *Zai* pit dug by farmer	Number of pit	
Half-moon	Number Half-moon dug by farmer	Number of pit	
Independent Variables			
Gender	Gender of the household head	1=Male, 0=Female	+
Education	Years of schooling of household head	Number of years spent in school	+/-
Age	Age of the household head	Number of years	+
Household size	Number of household members	Number of members	+
Off-farm income	Revenue from non-farming activities	Currency (FCFA)	+
Risk attitude	Household head risk attitude toward technologies	5-point Likert-scale	+
Farmers' group membership	Household head's being member of a farmer group	1=Yes 0=No	+
Distance to market	Distance from household home to nearest output market	minutes walking	+
Number of extension service	Household head's access of extension services	Number	+
Number of agricultural training	Household head's attendance of agricultural training	Number	+
Trust in institution	Household level of trust in available institutions	5-point Likert-scale	+/-
Livestock ownership	Livestock owned by household head	Tropical Livestock Unit (TLU)	+
Farm asset value	Monetary value of farm properties	Currency (FCFA)	+
Farm size	Total land owned by household head	Hectare	+

Table 2: Continuous

Variable	Description	Measurement	Expected sign
Independent Variables			
Perception of timeliness	Household head's perception on timeliness of rainfall	5-point Likert-scale	+
Soil erosion	Household head's perception on soil erosion	1=less eroded; 2=eroded; 3=very eroded	+/-
Soil slope	Household head's perception on slope of soil	1=flat; 2=moderate slope; 3=steep slope	+/-
Soil fertility	Household head's perception on soil fertility	1= less fertile;2= fertile; 3= very fertile	+/-
Compatibility of technology	Household head's perception on technology compatibility	5-point Likert-scale	+
Ease of use of technology	Household head's perception on the ease of use of technology	5-point Likert-scale	+
Innovativeness	Household head level of Innovativeness	5-point Likert-scale	+
Resource availability	Resources availability	5-point Likert-scale	+/-
Usefulness of technology	Usefulness of *Zai* pit, Half-moon	5-point Likert-scale	+

3.5.2. Objective four:

Objective four was analysed using multinomial endogenous switching regression model proposed by Deb and Trivedi, (2004). The first stage of this model (multinomial logit selection model) was used to determine the choice of socio-economic, institutional, perceived technology attributes and climate characteristics influencing small-scale farmers decisions of *Zai* pit and Half-moon technologies uses. The estimation of Average Treatment Effect on the Treated (ATT) was used in the second stage to determine the effects of *Zai* pit and Half-moon technologies on small-scale farmers' income.

The basic problems faced by farmers when it comes to agricultural technology use are choices and trade-offs. Farmers often self-select into different use status due to the fact that they have different resource endowments, objectives, preferences, culture, educational and socio-economic backgrounds. As such, some may decide to use the technologies while others may not (Abdulai and Huffman, 2014) and failure to account for this may understate the true effect of the technologies. To achieve the above scenario, a selection correction estimation method is required. A multinomial endogenous switching regression (MESR) approach following Bourguignon *et al*. (2004) model to correct selection bias was used. This framework offers several advantages over the multivariate probit model: it has the benefit of evaluating alternative combinations of uses as well as individual uses, it also addresses both problems of self-selection bias and the interactions between choices of alternative uses (Mansur *et al.,* 2007). In contrast to MESR models, the multivariate probit model is limited by the difficulties in model calibration. In addition, there is no guarantee for a global maximum in the likelihood function and the computation of probit probabilities for K choice alternatives requires the evaluation of a (K-1) variant cumulative normal (Kamakura, 1989). Modelling the effect of practicing *Zai* pit and Half-moon technologies on the income under the MESR framework proceeds in two stages.

In the first stage, farmers' motivation of individual and a combination of technologies and the role of socio-economic, institutional, the perceived technology attributes and climate characteristics influencing the choices are modelled using a multinomial logit selection model. This approach allows us to get both consistent and efficient estimates of the selection process and a reasonable correction for the outcome equations, even when the assumption of the independence of irrelevant alternatives (IIA) is not achieved (Bourguignon *et al*., 2007). This framework has the advantage of evaluating both individual and combined uses, while capturing the interactions between the choices of alternative uses (Mansur *et al*., 2008).

In addition, the model recognizes the inter-relationships among the factors. For this study, a farmer is considered as a user if he or she uses *Zai* pit, Half-moon or the combination of both and non-user otherwise. The dependent variable which is technology use has a multinomial nature. Therefore, the study analyses the factors motivating the uses of combinations of RWHT and their effect on income in the MESR framework, a relatively new selection-bias correction methodology based on the multinomial logit selection model (Bourguignon *et al*., 2004). It is assumed that a farmer *i* makes a decision to use RWH technologies $\mathbf{J}$ to maximize his expected profit if the RWH technologies $\mathbf{J}$ provide higher expected profit (Vij) than any other alternative RWHTs combination (Vim). Hence, in this model there are latent or unobservable variables that captures the expected net incomes from implementing strategy j (j = 1...3) with respect to implementing any other strategy m with ($m \neq j$).

According to Koop (2003), these different alternatives and respective profits can be quantified as:

$$V_t = V_{ij} - V_{im} \quad \text{..........(10)}$$

The econometric specification of the model is given in its latent as:

$$V^*_{ij} = X'_{ij} + n_{ij} = X_i\,\beta_j + n_{ij} \;;\; j=1, 2, 3, 4 \quad \text{..........(11)}$$

Where X_i is the observed exogenous variable, j denotes the choices of use available (non-, of *Zai* pit, use of Half-moon and their combination in this case), β is the parameters that are estimated by maximum likelihood, n_{ij} is the unobserved characteristic, X' is a vector of independent variables that explain the use of a combination of technologies such as age of household head, sex of the household head, education, farm group membership and access to credit.

Let Y be the farmer's choice of the technology, hence:

$$Y_i = \begin{cases} 1 \;\text{ iff }\; Y^*_{i1} \succ \max_{m\neq j} (Y^*_{im}) \text{ or } n_{i1} \prec 0 & \\ j \;\text{ iff }\; Y^*_{ij} \succ \max_{m\neq j} (Y^*_{im}) \text{ or } n_{ij} \prec 0 & \end{cases} \quad \text{for all } m\neq j \quad \text{..........(12)}$$

Where $n_{ij} = \max_{m\neq j} (Y^*_{im} - Y^*_{ij}) \prec 0$; Y_i denotes use of $\mathbf{j}$ technologies by a i^{th} farmers.

From equation (12), it can be suggested that a farmer *i* makes a decision to adopt RWH technologies $\mathbf{J}$ to maximize his expected income if the RWH technologies $\mathbf{J}$ provide higher expected income than any other alternative RWH technologies combination $\text{with } m \neq j$ and $n_{ij} = \max_{m \neq j}(Y^{*}_{ij} - Y^{*}_{im}) > 0$.

The probability of i farmers with characteristics X to choose j technologies is specified by a multinomial logit model (McFadden, 1973) which can be express as thus:

$$P_{ij} = \Pr(n_{ij} \prec 0 \ / X_i) \ \frac{\exp(X_i \beta_j)}{\sum_{m=1}^{j} \exp(X_i \beta_m)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)$$

In the second stage of MESTR as mentioned previously, the effect of each strategy on net income was evaluated using the Average Treatment on Treated (ATT). This examines the relationship between the outcome variables and a set of explanatory variables conditional on the use decision (Mansur *et al*., 2007). The model implies that a farmer faces a total of M regimes in the case of this study one regime per strategy. The reference category here is the non-use denoted by N_0A_0 where j=1 and the rest of the alternative choices are respectively j=2; j=3; j=4 for *Zai* pit, Half-moon and their combination. The net income equation for each possible regime j defined as:

(14a) Regime1: $Z_{1i} = Q_{1i}\alpha_1 + u_{1i}$ if P=1 ……………………………..……….……(14a)

(14j) Regime j: $Z_{ji} = Q_{ji}\alpha_j + u_{ji}$ if P= j ……………………………………………(14j)

Where Z_i is the net income from acre of a farmer *i* in regime j, (j = 1, 2, 3, 4); Q_{1i} , Q_{ji} are vectors of exogenous covariates of inputs such as fertilizers, manure, labour, farmers' characteristics and soils' characteristics; α_1, α_2 are vectors of parameters; u_{1i}, u_{ji} are random disturbance terms that capture the uncertainty faced by farmers, satisfies E(u) = 0. But if the error terms n_{ij} of the selection model (equation 11) and the error terms u_{ij} of the net income functions (equation 14a-14j) are not independent or correlate, the equation (14) was biased because the expected values of u_{ij} conditional on the sample selection was non-zero. To avoid that scenario, the inclusions of the selection correction terms of the alternative choices in equation (14) are required. Therefore, Bourguignon *et al*. (2004) model was used to consider that correlation between the error terms n_{ij} from the multinomial logit model estimated in the first stage and the error terms from each net income equation u_{ij}.

The assumption of Bourguignon *et al*. (2004) shows that consistent estimates of α_j in the outcome equations (14a)-(14j) can be obtained by estimating the following selection bias-corrected net income equation:

(15a) Regime1: $Z_{1i} = Q_{1i}\alpha_1 + \delta_1 \hat{\lambda}_{1i} + \theta_{1i}$ if P=1……………………………………(15a)

(15j) Regime j: $Z_{ji} = Q_{ji}\alpha_j + \delta_j \hat{\lambda}_{ji} + \theta_{ji}$ if P= j…………………………………..(15j)

Where δ_j the covariance between the error's terms $(u_{ij}$ and $n_{ij})$ λ_j is the inverse Mills ratio from the estimated probabilities equation (equation 12) which can be expressed as:

$$\lambda_{ji} = \sum_{m \neq j}^{j} \rho_j \left[\frac{\hat{P}_{mi} \ln(\hat{P}_{mi})}{1 - \hat{P}_{mi}} + \ln(\hat{P}_{ji}) \right] \qquad (16)$$

Where ρ is the correlation coefficient between the errors terms u_{ji} ; n_{ji} and Θ_{ji} with zero value of expectation. In the multinomial choice setting, there are $j-1$ selection corrections terms include in the income function, one of each alternative combination. To account the heteroskedasticity of λ_{ji} regressor, the standard error in equation (16) was boot strap.

These MESR frameworks was used to compute the counterfactual and average treatment effect by comparing the expected income of the adopters with and without use. The counterfactual is defined here as the income of the users they could have earned if the returns (coefficients) on their characteristics had been the same as the returns (coefficients) on the characteristics of the non-users. Following Di Falco *et al.* (2011) and Teklewold *et al.* (2013), the ATT in the actual and counterfactual can be computed from equation (14) as follow:

Users with use characteristics (actual)

$$E(Z_{i2} \;/ I = 2) = Q_i\alpha_2 + \delta_2 \lambda_2 \qquad (17a)$$

$$E(Z_{ij} \;/ I = J) = Q_i\alpha_j + \delta_j \lambda_j \qquad (17b)$$

From equation (14), we can derive the expected net income of farmers who use strategy j in the counterfactual hypothetical case that they did not use (j = 1) as:

Users, had they decided not to use (counterfactual):

$$E(Z_{i1} \; / I = 2) = Q_i \alpha_1 + \delta_1 \lambda_2 \quad \text{...(18a)}$$

$$E(Z_{i1} \; / I = J) = Q_i \alpha_1 + \delta_1 \lambda_j \quad \text{...(18b)}$$

Equations (17a, b) represent the actual expected income actually observed in the sample for users and non-users respectively, while equations (18a, b) are their respective counterfactual expected income.

These expected values can be used to derive unbiased estimates of the ATT. Therefore, it allows for calculating the Average Treatment effects (ATT) as the difference between equations (17*a*) and (18*a*) or (17b) and (18b).

$$ATT = E(Z_{i2} / I = 2) - E(Z_{i1} / I = 2) = Q_i \alpha_2 + \delta_2 \lambda_2 - Q_i \alpha_1 - \delta_1 \lambda_2 = Q_i(\alpha_2 - \alpha_1) + \lambda_2 (\delta_2 - \delta_1) \text{......(19)}$$

The first term on the right-hand side of equations (19) represents the expected change in farmers' income, if the characteristics and resources of users had the same returns (coefficients) as the returns on the characteristics and resources of non-users. The second term on the right-hand side (λ_j) is the selection term that corrects all potential effects of the difference in the selection bias from unobserved characteristics. The model variables, explanations and hypothesized relationships are shown in Table 3.

Table 3: Description of variables used in Multinomial Endogenous Switching regression model

Variable	Description	Measurement	Expected sign
Dependent Variables			
Income from the main crop	Income of household head from the main crop production	Currency (FCFA)	
General household Income	Household head general income	Currency (FCFA)	
Independent Variables			
Gender	Gender of the household head	1=Male, 0=Female	+
Education	Years of schooling of household head	Number of years spent in school	+/-
Age	Age of the household head	Number of years	+
Household size	Number of household members	Number of members	+
Off-farm income	Revenue from non-farming activities	Currency (FCFA)	+
Risk attitude	Household head risk attitude toward technologies	5-point Likert-scale	+
Farmers' group membership	Household head's being member of a farmer group	1=Yes 0=No	+
Distance to market	Distance from household home to nearest output market	minutes walking	+
Number of extension service	Household head's access of extension services	Number	+
Number of agricultural training	Household head's attendance of agricultural training	Number	+

Table 3: continued

Variable	Description	Measurement	Expected sign
Independent Variables			
Trust in institution	Household level of trust in available institutions	5-point Likert-scale	+/-
Livestock ownership	Livestock owned by Household head	Tropical Livestock Unit (TLU)	+
Farm asset value	Monetary value of farm properties	Currency (FCFA)	+
Farm size	Total land owned by household head	Hectare	+
Perception of timeliness	Household head's perception on timeliness of rainfall	5-point Likert-scale	+
Soil erosion	Household head's perception on soil erosion	1=less eroded; 2=eroded; 3=very eroded	+/-
Soil slope	Household head's perception on slope of soil	1=flat; 2=moderate slope; 3=steep slope	+/-
Soil fertility	Household head's perception on soil fertility	1= less fertile;2= fertile; 3= very fertile	+/-
Compatibility of technology	Household head's perception on technology compatibility	5-point Likert-scale	+
Ease of use of technology	Household head's perception on the ease of use of technology	5-point Likert-scale	+
Innovativeness	Household head level of Innovativeness	5-point Likert-scale	+
Resource availability	Resources availability	5-point Likert-scale	+/-
Usefulness of technology	Usefulness of *Zai* pit, Half-moon	5-point Likert-scale	+

CHAPTER FOUR
RESULTS AND DISCUSSION

This chapter is organized into four sections. The first sub-section describes the socio-economic and institutional characteristics of the sampled farmers. In the second sub-section, the results of the confirmatory factors analysis (CFA) for technology attributes and climate characteristics are discussed. Sub-section tree presents the results on demand for *Zai* pit and Half-moon technologies and the final sub-section discusses the effect of *Zai* pit and Half-moon technologies on small-scale farmers' income.

4.1. Small-scale farmers characteristics

4.1.1. Socio-economic and institutional characteristics of small-scale farmers

The socio-economic and institutional characteristics of small-scale farmers sampled in Kita Cercle are presented in Table 4. Farmers' characteristics are shown by farmer status (users versus non-users). Users were significantly younger than non-users at 10% level of significance. This imply that younger farmers are explorative and innovative and they may seek to try new and improved agricultural technologies compared to older farmers who might be more conservative. Factors associated with old age such as a shorter-term planning horizon as well as loss of energy associated with less innovation affects negatively agricultural technology adoption (Shongwe *et al.* 2014). Contrary to this, Donkoh and Awuni (2011) found that older farmers were more likely to use RWHTs because such farmers must have used trial and error method to acquire techniques that best suit them.

There was a significant difference at 5% level in off-farm income earned by non-users and users. Households with more off-farm income are less likely to use technologies, suggesting that income could cause households to invest in other activities such as commerce rather than in agricultural production. Wollni *et al*. (2010) reported that participation in off-farm activities places a constraint on the time and labour available for agriculture technologies use. In contrast, Knowler and Bradshaw (2007) found that participation of household head in agricultural technology use requires substantial financial investment. Therefore, household's engagement in off-farm activities is likely to be an important driver for agricultural technology use as it improves farm liquidity through supplementary income for purchase of farm inputs and payment of labour requirements associated with RWHT uses.

Table 4: Summary statistics of selected socio-economic characteristics of small-scale farmers

Variable	Non-Users (N=72)	Users (N=208)	*t*/*chi*-square value
Mean of farmer and farm characteristics			
Age of household head (Years)	52.35	48.97	1.77*
Education level (Years)	1.65	1.29	0.84
Household size (Number)	12.88	11.81	-0.15
Asset value (Franc CFA)	350, 941.00	333, 841.00	0.58
Off-farm income (Franc CFA)	69, 431.00	42, 861.00	2.57**
Farm size (ha)	2.23	2.25	-0.17
Livestock (TLU)	2.57	1.86	1.97**
Mean of institutional characteristics			
Extension contact (Number)	1.85	3.10	-4.38***
Agricultural training (Number)	0.72	1.23	-4.31***
Distance to nearest market (walking minutes)	75.88	128.86	-3.39***
Percentage of gender, group membership of household head and ownership of security to land			
% of male headed households	96	99	3.13*
% of female headed households	4	1	
% of household belonging to a group	24	30	1.17
% of household not belonging to a group	76	70	
% of households owning land by title	99	98	0.09
% of households not owning land by title	1	2	

Note: ***, **, * significant at 1%, 5% and 10% levels, respectively.

The tropical livestock unit (TLU) was significantly different at 5% level of significance between non-users and users. On average, users owned 2 TLU while their counterpart owned 3. Livestock ownership is considered as vital factor influencing the use of RWHTs in the region as it is the main supplier of animal draught and manure important for enhancing soil quality. Moreover, the difference could be attributed to the fact that livestock holding may act as a supplier for organic fertilizer as livestock contributes to manure applied by users. This result is in contrast with the finding of Knowler and Bradshaw (2007) which highlighted the importance of livestock ownership in SWC technology practice.

There was a significant difference in the number of contact with extension service providers between non-users and users at 1% significance level. Agricultural extension is a source of information for farmers to learn about innovations. The uses of *Zai* pit and Half-moon requires technical information such as the diameter, deep-set and spreading between the pits leading to higher frequent advice from extension services by users. Kariyasa *et al.* (2013) reported that access to extension service is the driving force for agricultural technologies diffusion as it provides necessary information to farmers, thus improving their skills and performance.

Regarding the number of agricultural training, users had more training than their counterpart at 1% significance level. The importance of training among users is plausible due to the nature of the technologies which require some technical knowledge. These finding supports the importance of agricultural training in agricultural technology uses. Agricultural training does not only provide information and advisory to farmers but also strengthens their capacity by supporting the dissemination of knowledge among them and plot demonstration experiences gained from SWC technologies (Christoplos, 2010; Gido *et al*., 2015).

Users had a longer distance to the nearest market compared to non-users with a significance difference at 1% level. Distant farmers with a limited access to the markets often rely on agricultural activities which require less inputs such as *Zai* and Half-moon uses while those who did not use were engaged in commerce in the market. Contrary, Wollni and Anderson (2014) indicated that longer distance to the market discourages farmers from adopting agricultural technology due to limited access to information and involved high transaction costs.

Majority of the farming households were male-headed (98%). The difference between female-headed and male-headed households was significant at 10%. There usually exists gender-specific constraints faced by female-headed households such as dominant culture that males still have exclusive rights to make farm decisions. Further, security of land tenure in Kita Cercle for women is not guaranteed which could deny them access to important facilities like credit. Ndiritu *et al*. (2014) found inadequate access to information and resources such as land, productive assets and livestock results in less use of agricultural technology among female-headed households. Male-headed households in developing countries have higher access to the required resources and information that increase their likelihood to adopt agricultural technologies (Odendo *et al*., 2009).

The results show that group membership was less common among users and non-users. Group membership plays an important role during the exchange of information, experiences and knowledge among the group members and influences farmer decision to adopt agricultural technologies (Tambo and Abdoulaye, 2012).

Households owning land by title was the most common form of land ownership in the area of study compared to other type of land ownership. Security of the tenure in land guarantees farmers access to credit and motivates them to make long-term investment decision, hence the greater percentage of users. Kassie *et al*. (2009) found security to land an important variable influencing farmers' decision in adopting technology in semi-arid regions of Ethiopia.

4.1.2. Small-scale farmers' perceptions of the soil fertility, soil erosion and the usefulness of the technologies

Table 5 presents the results of farmers' perception of the usefulness of the technologies, soil fertility and soil erosion. The difference in perception of soil fertility between users and non-users was significant at 1%. These results suggest that farmers who perceived their soil being poor fertile favourably dispose them to use *Zai* pit and Half-moon technologies. Farmer perception of soil fertility indicates the level of soil degradation and depletion of soil nutrients which drive farmers to invest in soil and land conservation uses (Adimassu *et al*., 2013). The more farmers perceive the soil to be less fertile the more likely they are to adopt agricultural technologies to improve productivity.

Table 5: Farmers' perceptions of the slope, fertility, erosion and perceived usefulness

Variable	Categories	Non-users (%)	Users (%)	*Chi*-square
Perception of the slope	Flat	67	72	1.86
	Moderate	32	25	
	Steep	1	3	
Perception of the soil fertility	Low	35	56	15.82***
	Medium	51	41	
	Fertile	14	3	
Perception of the soil erosion	Less eroded	69	15	80.14***
	Eroded	21	68	
	Very eroded	10	17	
Perceived usefulness	Not important	19	2	27.52***
	Important	42	54	
	Very important	39	44	

Note: *** significant at 1% a level

There was a significant difference in farmer perception of soil erosion between non-users and users at 1% level of significance. Perception of the severity of soil erosion influences farmers' decision to use appropriate soil and water conservation technologies because it negatively affect farm production. Therefore, users were quite responsive in countering the effects of severe soil erosion by implementing RWHTs. Soil degradation caused by soil erosion leads to decrease in agricultural productivity, threat to food security and rural household livelihood in Sub Saharan Countries (Tully *et al*., 2015).

In terms of usefulness of *Zai* pit and Half-moon technologies, there was a significant difference at 1% level between users and non-users. Perceived usefulness of agricultural technology probably influences its uses because it identifies famers' perception of the extent to which the use of that technology can improve their farming operations. Farmers' perception of usefulness of agricultural technology was more negative for non-users than users. Perceived usefulness influences behaviour and intentions, which in turn influence technology adoption decisions (Verma and Sinha, 2016).

4.2. Confirmatory factor analysis for technology attributes and climate related factors

A total of 24 self-estimation items were used to measure the latent constructs such are perception of timeliness, risk taking attribute, ease of use, compatibility, level of trust in institution, users' innovativeness and perceived resources availability (Table 6). Post-estimation tests were carried out to ensure the Internal Consistency Reliability, Indicator Reliability and Convergent Validity of the selected constructs.

The results of the Confirmatory Factor Analysis indicate a good fit with the data $\left[\chi^2 = 2975.672; DF = 276; p = 0.000\right]$. The Kaiser-Meyer-Olkin measures the sample adequacy $\left[KMO = 0.79\right]$ which was qualified as "Middling", indicating as well that the sample size is adequate for the CFA (Tee and Wang (2017).

Table 6: Bartlett test of sphericity

Chi-square	2975.67
Degrees of freedom	276
p-value	0.000
KMO	0.79

The factor loadings recorded values between 0.452 and 0.931 at significance level of p=0.001. The CR for the constructs recorded values between 0.614 and 0.898. Therefore, both convergent validity and CR demonstrated satisfactory indicators for convergent validity and reliability of the constructs (Garson, 2012). All the latent variables of the study registered an AVE values of between 0.565 and 0.832 except for the variables ease of use which has an AVE = 0.483. This weak AVE value on the ease of use variable is remedied by its high CR of 0.614 which surpass the recommended threshold of 0.5. These results are presented in Table 7.

Table 7: Factor analysis of attitudinal, perception constructs and technological attribute

Variables	Items	Factors loadings	CR	AVE
Attitudinal and perception constructs				
Perception of timeliness [Kassie *et al*., 2013]	Rainfall comes and stops on time	0.868	0.646	0.592
	There was adequate rain for the crops during the last five years	0.452		
	Throughout the growth period of the crops, the rain was well distributed in the last three years	0.906		
Risk-taking attribute [Kassie *et al*., 2013]	I like to devote my assets and my time to agricultural technology with high profitability	0.788	0.687	0.621
	I prefer agricultural technology with less risky outcomes	0.876		
	If the technology is highly risky and high profitable, I would go for profit but with insight into the risk	0.690		
Level of trust in institution [Kassam *et al.*, 2009]	I trust the agricultural associations as they work for the welfare of the farmers and the sectors	0.892	0.737	0.565
	I trust the local agricultural officer	0.899		
	I trust the public institution (local government)	0.662		
	I trust the NGO' officers	0.466		
Perceived technological attributes				
Compatibility [Rogers, 2010]	Using the RWH technologies is compatible with most aspects of my work	0.906	0.898	0.832
	Using RWH technologies fits my work style	0.931		
	Using RWH technologies fits as well with the way I like to work	0.899		

Table 7: continued

Perceived technological attributes				
Ease of use [Aubert *et al*., 2012]	I clearly understand how to use RWH technologies	0.679	0.614	0.483
	Learning to operate RWH technologies system is easy for me	0.857		
	I find RWH technologies inflexible to interact with	0.462		
	It is easy to perform work using RWH technologies	0.722		
Users' innovativeness [Aubert *et al*., 2012]	I am very curious about how things work	0.786	0.797	0.626
	I like to experiment with new ways of doing things	0.841		
	I like to take a chance	0.884		
	I like to be around unconventional people who dare to try new things	0.631		
Ressources availability [Aubert *et al*., 2012]	I have the resources, opportunities and knowledge for using RWH technologies	0.852	0.716	0.641
	I will be able to use RWH technologies if I wanted	0.805		
	There are no barriers to me using RWH technology	0.741		

Note: CR and AVE denote Composite Reliability and Average Variance Extracted, respectively.

The Weighted Mean (WM) was used to generate the scores for technology attributes and climate characteristics among user and non-users. Considering the work of Moralist *et al.* (2014), the technology attributes and climate related factors based on the Weighted Mean can be scaled as follows: “Extremely Strong” (ES) has a mean score of 4.21-5.00, “Very Strong” (VS) has 3.41-4.20, “Strong” (S) has 2.61-3.40, “Somewhat Strong” (SS) has 1.81-2.60, and “Not Strong” (NS) has 1.00-1.80. The t-test statistic was used to compare the Weighted Mean of the two (2) groups of farmers, users and non-users. The results of these analyses are presented in Table 8.

Table 8: Mean scores of farmers’ perceptions of the technology attributes and climate related factors

Variable	**Non-Users (N=72)**	**Users (N=208)**	***t-test value***
Perception of timeliness of rainfall	3.02	3.33	-2.11**
Farmer risk-taking attribute	3.62	4.23	-5.65***
Level of trust in institution	3.99	4.06	-0.66
Perception on compatibility of technology	3.53	4.27	-5.62***
Perception on ease of use of technology	3.12	3.87	-6.79***
Perception on innovativeness	3.97	4.39	-4.99***
Perception of resource availability	1.68	2.03	-2.65***

Note: ***, **, significant at 1% and 5% levels respectively

As indicated in Table 8, farmers’ perception of timeliness of rainfall was significant different between users and non-users at 5% significance level. This implies that users had relatively “strong” perception than non-users vis-à-vis the timeliness, adequacy and distribution of rainfall. In the presence of such unpredictability of rainfall patterns and inadequate distribution, users tend to implement strategies that involve low risk technologies such as *Zai* pit and Half-moon that reduce such shocks. Thus, favourable perception of timeliness of rainfall outcome positively impacts decisions to use RWHTs. Singh *et al*. (2016) found contrary findings that rainfall-related risks and uncertainty affects negatively the agricultural technology adoption decisions and the ability of farmers to adapt to rainfall shocks.

Farmers’ risk attitude towards technology attributes was found to be very strong and extremely strong for non-users and users, respectively. This indicates that users had higher risk attitude compared non-users. The adventure in new technology is considered as risky, thus demanding high risk-taking attitude for its use. This implies that users undertake various adaptive strategies that are in line with their perceptions of rainfall-related production risks. Farmers' perceptions of the level of risk posed by rainfall increases the possibility of using land management practices in order to mitigate possible effects of rainfall variability (Slegers, 2008).

Perception of compatibility of technology was statistically different at 1% between non-users and users. In other words, users are categorized at higher level of perception of "extremely strong" and non-users at lower perception of "very strong". This implies that users were more positive towards the perception of *Zai* pit and Half-moon compatibility as consistent with the existing values and norms of their practices, past experiences, and needs of potential users. Theoretical and empirical evidence suggest that higher the positive compatibility's perception of farmers towards a technology the higher the adoption of that technology as perceived lack of compatibility limits farmers' demand and ultimately constitutes an obstacle to RWHTs uses (Reimer *et al*., 2012).

Regarding the ease of use characteristics, there was a statistical difference between the users and non-users at 1% significance level. Users had a favourable perception of the ease of use of *Zai* pit and Half-moon technology, hence their demand. Similarly, Compeau *et al.* (2007) found that the introduction of new agricultural technologies which is not compatible with the existing use and infrastructure is likely perceived by farmer as difficult thus there is low probability to use a particular technology. Positive perception on the ease of use about technology serves as a basis for judging the level of adoption of that technology (Compeau *et al.*, 2007).

A comparison of farmers' innovativeness revealed significant difference between non-users and users at 1% significance level. The innovative farmers are more open to new ideas and seeking information, hence more willing to try out newly introduced technologies. Szabo *et al.* (2013) stated that innovativeness is considered to be one of the priorities in technical changes as it plays an important role in development.

There was significant difference in the perception of resource availability between users and non-users at 1% significance level. This suggests that the users saw resources at their disposal not only as opportunities but also sufficient for venturing in technology uses. Available resources (internal and external) are particularly relevant in the use of soil and water conservation technologies (Adekemi *et al.*, 2016). Beshir *et al.* (2012) highlighted that households with higher perception of adequate available resources are more likely to adopt agricultural technologies than the ones with lower perception.

4.3. Factors influencing the demand for *Zai* pit and Half-moon uses by small-scale farmers

4.3.1. Preliminary diagnostics of the variables to be used in the econometric analysis

Preliminary diagnostics for statistical problems of multicollinearity and heteroskedasticity were conducted on the variables for socio-economic, institutional, technology attributes and climate characteristics. Table 9 presents the results of VIF tests.

Table 9: Variance inflation factor test results

Variable	VIF	1/VIF
Age of the household Head	4.51	0.22
Household size	2.80	0.36
Number of people in economics activities	2.50	0.40
Distance to the nearest market	2.09	0.48
Education level of household head	1.17	0.85
Number of training	1.29	0.77
Number of extension	1.82	0.55
Land size	1.55	0.64
Value of assets	1.15	0.87
Value of off farm income	1.17	0.85
Value of credit Amount	1.35	0.74
Farmers’ risk-taking attitude	1.96	0.51
Livestock ownership in tropical livestock Unit	1.34	0.75
Farmers’ perceptions of timeliness	1.86	0.54
Perception of ease of use of technology	1.88	0.53
Perception of compatibility of technology	1.72	0.58
Perception of farmers innovativeness	1.47	0.68
Perception of resource availability	1.20	0.84
Level of trust in institution	1.07	0.93
Mean VIF	1.89	

Multicollinearity, a state of very high inter-correlations or the inter-associations among the proposed independent variables, was tested using variance inflation factor (VIF) for all continuous variables as well the pair-wise correlation for all categorical variables. The white test was used to detect heteroskedasticity for all hypothesized explanatory variables

By the rule of thumb, a value of VIF between 5 and 10 indicates high correlation amongst the explanatory variables in a regression model (Akinwande *et al*., 2015). The variance inflation factor results presented in Table 9 confirm that there was no strong linear relationship among the explanatory continuous variables tested since all VIF values were less than 5.

Similarly, pair-wise correlation results presented in Table 10 confirmed that there was no strong linear relationship amongst the categorical explanatory variables tested because the pair-wise coefficients were less than 0.5 in all cases.

Table 10: Pair-Wise Correlation test results for categorical explanatory variables

	Gender	Group	Land tenure	Slope	fertility	Erosion	Usefulness	Village
Gender	1.00							
Group	0.03	1.00						
Land tenure	-0.02	-0.09	1.00					
Slope	-0.08	0.14	-0.08	1.0				
Fertility	-0.01	0.03	-0.01	-0.01	1.00			
Erosion	0.02	0.10	0.10	0.01	0.11	1.00		
Usefulness	0.00	0.07	0.01	0.05	-0.23	0.28	1.00	
Village	0.13	0.08	0.01	-0.03	-0.07	-0.06	0.04	1.00

Unlike the Breusch-Pagan test which would only detected linear forms of heteroskedasticity, the white test was preferably applied as it incorporates both the magnitude as well as the direction of the change for non-linear form of heteroskedasticity (Williams, 2015). These results are shown in Table 11.

Table 11: Test for Heteroskedasticity

Source	**chi^2**	**df**	**P-value**
Heteroskedasticity	273.79	220	0.0079
Skewness	48.41	20	0.0004
Kurtosis	0.89	1	0.3468
Total	323.08	241	0.0003
Chi^2 (220) = **273.79**			
Prob $>$ chi^2 = **0.0079**			

White' general test is a special case of the Breusch-Pagan test, where the assumption of normally distributed errors has been relaxed. The results in table 11 indicated the presence of heteroskedasticity evidenced by a chi^2 value of 273.79 which was significantly large. To solve this problem, robust standard errors were reported in the subsequent analyses. Therefore, all of the proposed potential explanatory variables were used in regression analysis.

4.3.2 Factors influencing demand for *Za*i pit and Half-moon technologies

Factors influencing the demand for *Zai* pit and Half-moon technologies were determined using bivariate negative binomial (BNB) regression analysis with normal copula function. The results of BNB regression are presented in Table 12. The standard Poisson model was first estimated for confirmation purpose. Negative binomial marginal distributions allow for over-dispersion relative to the standard Poisson models (SP). The Wald test $\left[\chi^2(52) = 527.950; p = 0.000; \ \log pseudo \ \ likelihood = -2595.460\right]$ implied that the model fits the data well. Therefore, the null hypothesis that the coefficients of all variables are jointly equal to zero was rejected. Additionally, the null hypothesis that the covariance of the error terms across the two equations is zero is also rejected. The alpha1 and alpha2 are dispersion parameters. The larger values for the alpha1 and alpha2, 11 and 16 respectively, with a P-value < 0.0001 indicates that over-dispersion is present and leads to the rejection of independence assumption of a marginal Poisson distribution while indicating the appropriateness of BNB model relative to the SP model. Hence, the BNB model is a suitable model to estimate the determinants of demand for *Zai* pit and Half-moon uses. Regarding the determinants of *Zai* pit and Half-moon uses, the results suggest that the socio-economic, plot and technological characteristics are significant in conditioning the small-scale farmers' decision to use RWHTs.

Gender of the household head negatively influenced the demand for *Zai* pit use at 5% while positively influencing demand for Half-moon use at 1% level of significance. Male-headed households were twice less likely to demand for *Zai* pit compared to female-headed households. On the other hand, male-headed households were 15 times more likely to demand for Half-moon than their female counterparts. This could be attributed to socioeconomic inequality and barriers that disadvantage women in accessing resources that are necessary for technology use.

Table 12: Bivariate Negative Binomial Regression model results

Explanatory variables	Number of *Zai* pit		Number of Half-moon pit	
	Coef.	**Robust Std. Err.**	**Coef.**	**Robust Std. Err.**
Farmers characteristics				
Gender (Male =1)	-2.006**	0.862	15.295***	1.629
Household head's years of schooling	0.135*	0.069	-0.459**	0.134
Age of household head	-0.001	0.012	-0.001	0.018
Household size	0.016	0.020	-0.016	0.046
Log value of off-farm income	-0.042	0.027	-0.106	0.057
Risk attitude	-0.385	0.272	2.685***	0.567
Institutional characteristics				
Group membership (Yes =1)	-0.391	0.311	-0.316	0.718
Distance to nearest market	0.004*	0.002	0.001	0.003
Number of extension services	0.086	0.075	0.282*	0.154
Number of training	0.284*	0.149	-0.338	0.253
Trust in institution of farmers	-0.098	0.178	0.445	0.380
Farm characteristics				
Tropical livestock Unit-TLU	0.026	0.091	-0.135	0.105
Log value of assets	0.074	0.056	-0.827***	0.306
Farm size under *Zai* and Half-moon	-0.450**	0.184	0.460*	0.274
Perception characteristics				
Perceptions of timeliness	-0.136	0.178	0.599	0.354
Eroded Plot[1]	2.009***	0.467	3.744***	0.581
Very eroded Plot[1]	2.052***	0.623	2.274**	1.070
Medium Slope Plot[2]	-0.158	0.299	1.482***	0.565
Steep Slope Plot[2]	-1.278	1.563	1.399	1.692
Perception characteristics				
Medium Fertile Plot[3]	-0.387	0.331	-0.557	0.602
Fertile Plot[3]	-1.237	0.842	-5.650**	2.444
Technological characteristics and attribute				
Compatibility of technology	0.468**	0.212	0.489	0.398
Ease of use of technology	0.962***	0.306	-0.046	0.477
Innovativeness of farmers	1.192***	0.337	-1.680***	0.647
Resource availability	-0.231	0.157	0.737	0.326
Usefulness of the technology	0.654***	0.220	1.615***	0.367
Constant	1.630	0.942	-21.253***	5.108
alpha1	11.359	1.395		
alpha2	16.481	2.81		
Number of observation	280			
Log pseudo likelihood	-2595.460			
Wald chi2 (52)	527.950***			
Prob > chi2	0.0000			

Notes: ***, **, *, indicates significance level at 1%, 5% and 10% respectively; 1= base category: less eroded; 2= base category: flat slope; 3= base category: low fertility.

In addition, women have comparatively smaller land size than men, and *Zai* pit technology is the most convenient technology in this case. On the other hand, Half-moon requires relatively large space, thus leading to its higher demands among male-headed household. Previous studies (Ndiritu *et al*., 2014; Theriault *et al*., 2017) noted that male headed households have a higher probability of adopting SWCTs because its construction and maintenance demands more resources. Kpadonou *et al*. (2017) found that female-headed households were more likely to adopt multiple SWCTs because most fields affected by soil degradation have been planted with annual food crops which were mainly cultivated by women.

A significant positive relationship was found between household head years of schooling and demand for *Zai* pit use at 10% while a significant negative relationship with demand for Half-moon uses at 5% level of significance. For an additional year of education of household heads, the log count of Zai pits and Half-moon are expected to increase by 0.135 and decrease by 0.459 respectively, compared to the one with less years of schooling. The possible explanation is that farmers with more years of schooling have better understanding about the consequences of soil degradation and the resulting benefits of *Zai* pit and Half-moon. The year of schooling possibly enhances knowledge leading to more demand for *Zai* pit since it is knowledge intensive than Half-moon. Because the technical knowledge required to implement this technology, farmers with less years of schooling need to be trained several times to increase their demand for RWHTs. Exposure to school attendance increases the farmer's ability to easily seek, understand the costs, benefits and constraints with the demand associated with *Zai* pit and Half-moon uses. This result is consistent with past studies (Abdulai and Huffman, 2005; Matuschke and Qaim, 2008; Turinawe *et al*., 2015), where educated farmers were able to process information and evaluate technology before engaging in its adoption.

Attitude towards risk positively influenced farmers' demand for Half-moon uses at 1% significance level. An additional unit of increase in farmers risk-taking attitude, the log count of Half-moon is expected to increase by 2.685. Risk takers are characterized by their higher willingness to venture in new technology or ideas with uncertainty about the outcome while expecting higher profit. This behaviour makes risk-takers demand more number of Half-moon technology despite of demanding relatively large land sizes. Cooper and Coe (2011) found that uncertainties discouraged farmers' decision to invest in new technologies as regarding continuous utilization of stone terraces in Ethiopian Highlands.

The distance to the nearest market was found to have a positive effect on demand for *Zai* pit uses at 10% significant level. For an additional minute of distance to nearest market, the log count of *Zai* pits is expected to increase by 0.004, on average. This is reasonable because the distance to the market reduces farmers' access to chemical inputs (fertilizer and herbicides) due to higher transaction cost, thus the increased demand for *Zai* pit uses which relies on the use of organic fertilizers like manure. Additionally, farmers closer to the market are most often engaged in other small businesses as an alternative source of incomes which limits their availability in implementing *Zai* pit technology. Asfaw *et al.* (2014) found that distance to the markets and chemical inputs constitute a barrier to the ability of farmers to demand agricultural technology in Malawi due to higher transaction costs. In contrast, Teklewold *et al.* (2013) reported that longer walking distance between market and farmers' residence had a negative effect on organic fertilizers use since it was provided locally.

Contact with extension service providers had a positive significant influence on the demand for Half-moon use at 10% significance level. For an additional contact with extension providers, the log count of Half-moon is expected to increase by 0.282, on average. Contact with extension services providers exposes farmers to more information and knowledge which favoured Half-moon use more than *Zai* pit, thus sensitizing and motivating them to demand for Half-moon technology. This result is consistent with the findings by Emmanuel *et al*. (2016) and Asfaw and Neka (2017) who established that adequate access of farmers to extension services increased the diffusion of new and improved technologies in Sub-Saharan Africa. Similarly, Mango *et al.* (2017) attributed the higher demand for a technology to an increased knowledge and information that are mainly provided by extension services.

As far as the number of agricultural trainings is concerned, it was found to positively influence the demand for *Zai* pit uses at 10% significance level. With an additional training, the log count of *Zai* pits is expected to increase by 0.284. This is due to the fact that training provides farmers with awareness of technologies, technical expertise and capacity building activities that may significantly influence the demand for *Zai* pit uses. Additionally, the *Zai* pit uses are technically intensive in terms of the knowledge needed for installation and the management. This finding is in line with the results of Bayard *et al*. (2007) who reported that training significantly influenced adoption decision of agricultural technology among smallholder farmers in Haiti. On the contrary, Mucheru-Muna *et al*. (2017) found a negative

association between training and trash line technology adoption in Tharaka South, Eastern Kenya.
Agricultural assets value negatively and significantly influenced farmers' demand for Half-moon uses at 1% significance level. For an additional unit of assets value, the log count of Half-moon is expected to decrease by 0.827. This is possibly because farmers with important asset value are oriented to intensive agriculture since they can afford the necessary inputs required. This reduces the possibility of undertaking labour intensive technology like Half-moon. The finding is in line with Johnson *et al.* (2016) who reported that relatively low value of agricultural assets limit adoption of technology. This is because farmers with few assets require technology with little requirements on the basis of affordability. Ayuya *et al.* (2015) noted that higher agricultural asset value increased the probability of participation in certified organic vegetable production and safeguards farmers against any risks and assures them liquidity during the production of organic produce in Kenya.

Farm size under RWHTs had a positive influence on demand for Half-moon while it had a negative influence on the demand for *Zai* pit uses at 10% and 5% significance level, respectively. For an additional unit of land size, the log count of Half-moon is expected to increase by 0.460 while the log count of *Zai* pits is expected to decrease by 0.450. This result was expected since Half-moon uses requires larger plot size compare to *Zai* pit uses (1 hectare can contain approximately 313 Half-moons while the same size of land can contain 10,000 *Zai* pits). This implies that farmers' demand for technologies is led by the convenience of the latter to their farm characteristics mostly the plot size. This result is consistent with those of Mango *et al.* (2017), who found that installation of SWCs is highly influenced by the size of land. According Mango *et al.* (2017), the land size can be a barrier to adoption of a particular technology among small-scale farmers depending on the respective land demands of the technologies.

With respect to soil characteristics, the analysis showed a positive and significant influence of farmers' perceptions of soil erosion on demand for the joint use of *Zai* and Half-moon at 1% level of significance. Relative to farmers who perceived their soil been less eroded, an increase on very eroded soil perception, the log count of *Zai* pits and Half-moon are expected to increase by 2.052 and 2.274, respectively. In addition, an increase on eroded soil perception, the log count of *Zai* pits and Half-moon are expected to increase by 2.009 and 3.744, respectively compared to farmers who perceived their soil been less eroded. This result corroborates with the findings of Udayakumara *et al*. (2012) who reported that farmers' perception of soil erosion problems was positively associated with their willingness to adopt soil and water conservation technologies in Sri Lanka. The uses of *Zai* pit and Half-moon are the available technologies to tackle the soil erosion issues, thus farmers' higher demands. Similarly, Haregeweyn *et al*. (2017) found farmers' perception of soil erosion being crucial in supporting planning for conservation of soil and other land resources.

Perception of slope positively influenced the demand for Half-moon uses at 1% level of significance. For an increase in farmers' perception on medium slope, the log count of Half-moon is expected to increase by 1.482. This is expected since the topography of medium slope is more prone to the effects of soil nutrient losses, thus the higher probability in soil failure. As a consequence, the higher rates of slope gradient could have probably motivated the demand of Half-moon use. The finding is consistent with previous studies (Ketema and Bauer, 2012; Nkegbe and Shankar, 2012; Teshome *et al*., 2016) who found a significantly positive influence of the slope on the intensity of adoption of soil and water conservation technologies.

Farmers' positive perception of soil fertility negatively affected the demand for Half-moon use at 5% significance level. Compared to farmers who regarded their farms as being less fertile, for an increase in farmers perception on fertile soil, the log count of Half-moon is expected to decrease by 5.650. This is because the use of Half-moon technology increases water infiltration and drain water storage while reducing soil water evaporation losses, reducing soil nutrient losses which improves soil fertility leading to increased yield. Thus, farmers were highly motivated to implement more Half-moon on less fertile farms compared to fertile farms. Bekele and Drake (2003) found a positive association between farmers who perceived their soil been poor fertile and the adoption of range of soil and water conservation technologies. Similarly, Adeola (2012); Nkegbe and Shankar (2014) noted from a sample of Ghanaian and Nigerian farmers that farmers who perceived their soils as infertile were more likely to adopt a portfolio of soil SWCTs to prevent declining of soil fertility cause by poor agricultural activities and soil degradation.

Farmers' perception of compatibility of *Zai* pit with existing values, norms of their practices and past experiences is found to positively and significantly influence the demand for *Zai* pit use at 5% significance level. For an increase in farmers' perception on compatibility, the log count of *Zai* pits is expected to increase by 0.468, on average. In other words, the more the farmer perceived the *Zai* pit use to be compatible with the existing system, the more likely farmers' demand for it. According to Rogers (2003), technology compatibility is the degree to which innovation is perceived as consistent with existing values, past experiences, and needs of potential users. Therefore, this positive perception creates harmony between the farmer and their attitude vis-à-vis the *Zai* pit, thus favours its demand. This result is in agreement with the study findings and observations by Robertson *et al*. (2012) who reported a significant positive relationship between farmers' judgment about the suitability of a given use to farming environment and the willingness of its adoption.

The results also showed that farmers' perception on the ease of use of *Zai* pit uses had a positive and significant effect on its demand at 1% level of significance. With farmers who perceived *Zai* pit technology easier to use, the log count of *Zai* pits is expected to increase by 0.962 compare with those who perceived it to be difficult and complex to use. Ease of use of *Zai* pit is the extent of the efforts needed by farmers to understand and implement an agricultural use, which in turn can influence its demand. In line to this, Sin (2003) reported that a technology perceived as complex by farmers may be difficult to use, thereby discouraging its adoption. The result contradicts findings by Sharifzadeh *et al*. (2017) who highlighted that the ease of use of agricultural technology did not support farmers' adoption decisions.

The innovativeness of a farmer had a positive influence on the use of *Zai* pit while it had a negative influence on the Half-moon uses, both at 1% significance level. With innovative farmers, the log count of *Zai* pits and Half-moon are expected to increase by 1.192 and 1.680, respectively compared to conventional farmers. Innovativeness is the farmer's ability to introduce new ideas or procedures that simplify farm operations which is characterized by their efficiency, adequacy and rationality. Since *Zai* pit use is considered more sophisticated and needing advanced technical skills than Half-moon uses, this requires some innovation. By developing innovativeness behaviour, farmers are able to improve their agricultural uses, learn and exploit new knowledge and articulate an innovative response. The benefits of such innovation output may last longer. Further, it may motivate and facilitate a new innovation effort and may contribute to a sustainable competitive advantage. Innovativeness enhances farmers' ability to explore the potential of their environment through their motivation in venturing in new ideas and spirit of rational judgement of efficiency and efficacy in decision-making (Szabo *et al.,* 2013).

Finally, the joint demand for *Zai* pit and Half-moon uses were positively and significantly influenced by farmers' perception on the usefulness of the two technologies, both at 1% level of significance. Farmers with positive perception on usefulness of the technologies, the log count of *Zai* pits and Half-moon are expected to increase by 0.654 and 1.615, respectively compare to those with negative perception. The perceived usefulness identifies farmers' perception of the extent to which *Zai* pit and Half-moon technology uses can improve the soil quality and the productivity, therefore their livelihood. This benefit or advantage that farmers expect to draw from the technologies is a key factor in their demand decision-making, thus its positive effects on both *Zai* pit and Half-moon uses. The relative usefulness of a technology motivates use by instigating the desire to achieve greater benefits from uses. The study finding is consistent with Miller and Meek (2004) who reported that farmers' perception of relative importance of integrated pest management technologies influenced adoption decisions and the intensity of use of these technologies.

4.4 Determinants of the choice of specific RWHT uses and its effect on small-scale farmers' incomes

4.4.1. Determinants of the choice of specific RWHT uses

The results in this sub-section are presented in two stages. First, the determinants of the choice of specific RWHTs uses, which is followed by quantification of the effects of using these technologies on farmers' income in the last stage. This is an important as it guides on the necessary interventions to improve the uses of RWHTs. The marginal effects from the ML model measured the expected change in the probability of a particular choice being made with respect to a unit change in an independent variable. This result is reported in Table 13. The base category is non-use upon which the results comparisons are made. The results showed three sets of parameter estimates, and one for each mutually exclusive combination of technologies. The model fits the data very well with the Wald test $\left[\chi^2(280) = 128.03; p = 0.000\right]$, implying that the null hypothesis that all regression coefficients are jointly equal to zero is rejected. Therefore, these results showed that the estimated coefficients differ substantially across the alternative uses.

Table 13: Results of Multinomial Logit and marginal effects for the choice of RWHTs

	Zp			Hm			Zp-Hm		
Variable	**Coef.**	**SE**	**dy/dx**	**Coef.**	**SE**	**dy/dx**	**Coef.**	**SE**	**dy/dx**
Gender (Male =1)	1.538	1.366	0.196	0.841	1.510	-0.053	2.272	2.024	0.101
Age of household head	-0.019	0.018	-0.003	-0.006	0.020	0.001	-0.017	0.021	-0.001
Education level of household	-0.066	0.072	-0.009	-0.077	0.092	-0.005	0.01	0.080	0.008
Household size	0.049	0.028	0.008	0.005	0.045	-0.005	0.046	0.032	0.002
Group membership	0.257	0.555	0.095	0.064	0.621	-0.004	-0.53	0.669	-0.079
Distance to nearest market	0.006	0.003	0.001*	0.005	0.003	0.001	0.002	0.004	-0.001
Number of extension service	0.088	0.150	-0.011	0.093	0.166	-0.003	0.301	0.172	0.028**
Number of training	0.816	0.412	0.060	0.876	0.439	0.031	0.68	0.458	-0.003
Log value of assets	-0.817	0.229	0.055**	-0.776	0.235	-0.011	-0.88	0.247	0.024*
Log value of off-farm income	-0.018	0.053	0.002	-0.064	0.058	-0.008	-0.005	0.060	0.003
Trust in institution of farmer	-0.051	0.308	0.020	-0.063	0.331	0.005	-0.336	0.348	-0.036
Tropical livestock Unit-TLU	0.026	0.112	0.010	-0.090	0.133	-0.009	-0.079	0.107	-0.006
Perceptions of timeliness	-0.232	0.293	0.022	-0.318	0.341	-0.008	-0.606	0.359	-0.048
Riske-taking attitude	-0.333	0.351	-0.181**	0.758	0.492	0.140**	0.283	0.455	0.041
Farm characteristics									
Farm Size	-0.256	0.231	-0.082**	-0.150	0.261	-0.008	0.427	0.255	0.076
Erosion of Plot	1.749	0.389	0.126*	1.306	0.450	0.040	2.255	0.479	0.106**
Slope of Plot	-0.403	0.484	-0.052	-0.138	0.536	0.031	-0.430	0.550	-0.018
Fertility of Plot	-1.269	0.429	-0.046	-1.228	0.476	-0.008	-1.854	0.535	-0.096**

Table 14: continuous

Variable	Zp			Hm			Zp-Hm		
	Coef.	SE	dy/dx	Coef.	SE	dy/dx	Coef.	SE	dy/dx
Technological characteristics and attribute									
Compatibility of technology	-0.082	0.281	0.045	-0.126	0.355	0.007	-0.667	0.362	-0.072
Ease of use of technology	1.075	0.395	-0.016	1.167	0.462	0.012	2.106	0.518	0.144
Innovativeness of farmers	0.732	0.461	0.234	-0.415	0.450	0.133	-0.133	0.520	-0.063
Resource availability	0.222	0.283	0.055	-0.181	0.329	0.056	0.229	0.311	0.016
Usefulness of the technology	0.943	0.293	0.047	1.238	0.390	0.071	0.787	0.390	-0.010

Regression diagnostics for ML model
Number of observations 280
Log likelihood -252.4599
Wald chi2 (69) 128.03
Prob > chi2=0.0000

Notes: ***, **, *, indicates significance level at 1%, 5% and 10% respectively; SE=standard error; Zp= Zai pit; Hm=Half-moon; Zp-Hm=Zai pit and Half-moon combined.

Distance to nearest market positively influenced usage of *Zai* pit use at 10% level of significance. A unit increase in the time taken to reach the market by one minute increased the probability of using *Zai* pit by 0.1%. Being close to the market facilitates access to inputs and market for output since it affects their transaction costs. Difficultly in accessing the market and inadequate infrastructure may make farmers more likely to participate in agricultural technology that require less inputs or focus more on local and available inputs. Therefore, the high likelihood of deciding to use *Zai* pit in their farm. Gebremariam and Tesfaye (2018) noted that distance to the nearest market had a negative effect on chemical fertilizer adoption but a positive effect on the adoption of organic fertilizers and crop rotation as presented by *Zai* pit use.

The number of contact with extension service providers had a positive and significant influence on the usage of Zai-Half-moon uses at 5% level of significance. A unit increase in the contact with extension providers increased the likelihood of joint use of *Zai* and Half-moon by 2.8%. In this respect, agricultural extension services are the basic sources of information for smallholder farmers' awareness about soil degradation and the way in which it can be tackled, thus affecting their option for use of *Zai*-Half-moon combination. This is consistent with the findings of Nyangena and Juma (2014) who reported that increased contact with extension service providers increased farmers' knowledge and awareness of SWC technologies. This affects positively the level of adoption of such technologies.

The results in Table 13 revealed a positive and significant influence of the farm production assets on usage of *Zai* pit and *Zai*-Half-moon RWHTs by 5.5% and 2.4%, respectively. This result indicated that resource endowed farmers were more likely to largely use *Zai* pits and Zai-Half-moon as opposed to non-users. This is likely because farmers with higher asset value not only prefer more capital-intensive technologies but also can afford them. In line with this, Kersting and Wollni, (2012) noted that wealthier farmers are in a better position to face production and marketing risks and increasing farm liquidity which are determinant factors in agricultural technology adoption.

With regard to farmer risk attitudes, there was a negative influence on the usage of *Zai* pit and a positive influence on the usage of Half-moon. A unit increase in the risk attitude decreased the probability of using *Zai* pit by 18.1% while it increased the likelihood of Half-moon usage by 14%, both at 5% level of significance. The risk-takers have higher expectation of gains from the technologies. The Half-moon is comparatively considered riskier than *Zai* pit since it requires more investment in terms of labour and land size. Therefore, farmers having a high-risk attitude are more likely to go for the usage of Half-moon. Previous studies (Deressa *et al*., 2008; Cooper and Coe, 2011; Muriu-Ng'ang'a, 2017) found a statically significant relationship between adoption of chemical fertilizer, improved seeds, pesticides and farmers risk-taking behaviour of farmers.

The model results revealed that the farm size had a negative and significant influence on the use of *Zai* pit at 5% level of significance. An acre increase in the land size decreased the probability of using *Zai* pit by 8.2%. This explained that farmers with a larger plot size were less likely to use *Zai* pit compared to non-users. This is probably due to *Zai* pit technology being more labour intensive but also it is the most convenient for small plots compared to other technologies. This result is supported by Mango *et al*. (2017) who reported that ownership of more pieces of land was positively associated with greater wealth and increases availability of capital resources, which increase the likelihood of farmers making investment in land, soil and water conservation measures.

Farmers' perception of soil erosion severity positively influenced use of *Zai* pit and *Zai*-Half-moon at 10% and 5% level of significance, respectively. The probability of using these two different technologies increased by 12.6% and 10.6%, respectively, for farmers who regarded their plots as severely eroded. Farmers with higher perception on soil erosion are more likely to solve the erosion issues by implementing multiple strategies, thus the use of *Zai* pit and *Zai*-Half-moon. In concordance to this, Haghou *et al.* (2014) found a positive correlation with adoption of soil conservation technology to solve soil degradation.

Farmers' perception towards soil fertility negatively and significantly influenced the joint use of *Zai*-Half-moon technologies at 5% level of significance. Those famers with good, fertile soils have less incentive to use *Zai*-Half-moon technologies by 9.6%, compared to those who have less fertile soils, because returns from using *Zai*-Half-moon technologies is high on less fertile soil. Additionally, *Zai*-Half-moon technology is primarily used as soil management strategy with the aims to reduces land degradation, improve poor soil quality thus enhance farm productivity. Manda *et al.* (2015) found that the propensity to adopt sustainable agricultural practices such as improved maize was high on fertile soils than low fertile soil, because most improved maize varieties required the application of expensive inorganic fertilizers.

4.4.2. Average treatment effects of Zai pit and Half-moon uses

After determining the drivers of the choice of RWHTs uses in the first stage, average treatment effects were determined in the second stage. Table 14 presents results of the effect of RWH uses on income from the main crop and the general household income. For comparison purposes, the outcome variables are estimated under actual and counterfactual conditions. In Table 14, X represents the treated group (the users) and Y represents untreated (non-users), α1 represents treated characteristics (use status) and α2 untreated characteristic (non-use status). The level of effect is the difference in outcome from yield of the main crop and household income as a result of usage of the specified technology. Therefore, effect on the treated characteristic (ATT) is α1(X-Y), while the one for untreated characteristic (ATU) is α2(X-Y). The treatment effect or returns effect on the treated is X(α1-α2), while the one of untreated is Y(α1-α2). The impact is considered as result of the difference between treated with treatment characteristics and the untreated with non-treatment characteristics (α1X) - (α2Y).

The ATT effects indicated that, on average, users of any RWHTs had higher income from the main crop than non-users and the results are positive and statistically significant for all the combinations. The same is true for the general income of household. Therefore, making a simple comparison is misleading because it does not account for both observed and unobserved factors that may influence outcome variables. This significant difference in income from the main crop and general household income could be attributed to unobservable characteristics such as farmers' managerial abilities or soil quality. This issue is addressed by estimating a multinomial endogenous treatment effects model. Thus, outcome variables of farmers who used the RWHTs are compared with the outcome variables if they had not used. At the same time, the outcome variables of farmers who did not use RWHTs are compared with the outcome variables if they could have used the RWHTs.

Table 15: Effects of the use and non-use of RWHTs on household income estimated by ESR

		Income from the main crop in CFA					General Household Income in CFA				
Combination		**Treated characteristic (α1)**	**SE**	**Untreated Characteristic (α1)**	**SE**	**Impact Return**	**Treated characteristic**	**SE**	**Untreated characteristic**	**SE**	**Impact Return**
Zai pit only	Treated (X)	270 564	7353.80	295 514	10152.91	-24 950	458 685	17224.02	469 503	21439.97	-10 818
	Untreated (Y)	195 244	7785.80	262 480	10918.10	-67 236	229 646	14260.10	398 504	18332.36	-168 858
	Effects (ATT)	75 320***		ATU= 33 034***		42286	229 039 ***		70 999 ***		158040
Half-moon only	Treated	311 139	11709.88	360 007	8733.91	-48 868	554 346	26186.27	695 802	17981.30	-141 456
	Untreated	179 587	10076.84	244 528	7474.74	-64 941	183 947	17478.22	370 851	12622.51	-186 904
	Effect (ATT)	131 552***		ATU=115 479***		16073	370 399***		324 951***		45448
Zai pit-Half-moon combined	Treated	319 857	15284.24	367 617	7373.21	-47 760	635 364	34573.24	593 864	17796.44	41 500
	Untreated	97 756	18344.89	256 492	6945.77	-158 736	2 095	33564.75	392 309	12526.56	-390 214
	Effect (ATT)	222 102***		ATU=111 125***		110976	633 269***		201 554***		431714

Notes: ***, indicates significance level at 1%; ATT=Average Treatment effect on the Treated; ATU= Average Treatment effect on the Untreated; CFA= Africa Francophone Community.

The results reveal that, in all cases, users of RWHTs had a significant and positive impact on income from main crop and general household income compared to the counterfactual scenario (non-use). This implied that farmers who used RWHTs actually would have earned less if they had not used. In the counterfactual case, farmers who did not use the RWHTs but considered as users would have earned more from the use of the technologies. Additionally, RWHTs use as a combination had a significant and positive effect on the main crop yield and household general income compared to those who used them separately. This is consistent with other studies on adoption of multiple agricultural technologies (Teklewold *et al*., 2013; Arslan *et al*., 2015; Manda *et al.,* 2015). Further, the average treatment effect (ATT) results indicate that RWHTs use significantly enhances the household income from main crop and household general income for users. The average treatment effect on the untreated (ATU) results indicated that the non-users' decision not to use appears to be irrational as they would have been better off in terms of yield and income if they chose to use. Farmers who did not use might be less informed about the importance of RWHTs uses as they reduced exposure to soil degradation by conserving soil moisture, increasing soil organic matter, reducing soil loss from erosion, flooding and reducing weeds.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1.Conclusion

1. The study concluded that the major differences between the farmers in use of RWHTs are that non-users had more off-farm income, more TLU, are closer to market while the users were more male-headed household, members of farmers' group, younger, had more contact with extension service and had participated in more agricultural training.
2. Regarding to farmers' perception, the users had higher perception on technology characteristics such soil erosion, timeliness, usefulness, compatibility, ease of use and higher personality traits in risk-attitude, innovativeness and resources availability for new venture.
3. The main factors influencing small-scale farmers' demand for RWHTs were found to have effects either separate or jointly. The *Zai* pit was positively affected by household head's years of schooling, distance to nearest market, agricultural, farmers' perception on soil erosion, technology compatibility, ease of use, usefulness, and innovativeness. The demand for Half-moon was also positively affected by gender of the household head, number of contact with extension service providers, farm size, farmers' perception on soil erosion, slope, technology usefulness and risk-attitude.
4. Concerning the determinants of the choice for a specific RWHT (*Zai* pit, Half-moon or combined), the study concluded that the distance to the nearest market, number of contacts with extension service providers, farm production assets, farmer's perception on soil erosion had positive effects on the choice of *Zai* pit while farm production assets, farmers' perception on soil erosion and their risk-attitude positively affected the choice for Half-moon. Using RWHTs increased both general household income and main crop income. The highest payoff is achieved when RWHTs are used jointly rather than separately.

5.2.Recommendations

1. To improve the use of RWHTs, policies should aim at promoting farmer group membership and improve access to extension service providers and agricultural training.
2. Sensitizing farmers on climate related shocks and their negative effects should also be taken into consideration for increased use of RWHTs
3. To improve the demands for RWHTs, efforts should be made to support gender equality and income diversification in farming systems since it helps towards sustainable farming and farmers' intention of new ventures and opportunities taking. Regardless of the knowledge and labour-intensive nature of RWHTs, effort should be made to improve training and mechanize the uses as one of the strategies to improve demand for RWHTs.
4. Farmers should be motivated to invest more in productive farm assets since it enhances their ability to tackle farming related risks and their ability of using RWHTs. Finally, farmers should also be sensitized to incorporate various RWHTs as much as possible to improve their livelihood. This can be realized through increased income, participation in farmers group activities and training.

5.3. Suggestions for further research

The study is limited on use of *Zai* pit and Half-moon and its effects among small-scale farmers in only Kita Cercle, further research should consider more RHWTs technologies and their effects on farmers not only in this Cercle but also countrywide. Further, the sustainability of RHWTs uses among small-scale farmers should be considered by new studies. Due to the high labour cost and timeframe of RWHTs uses, further studies should be done to analyse potential ways and actual costs of RHWTs mechanization as well as RHWTs integration with livestock production in Kita Cercle and other parts of the country.

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APPENDIX 1: Number of small-scale farmers per Cercle and per village

Commune	**Village**	**Number of SSF**
Didanko	Farena	192
	Garangou	55
	Guetala	206
	Sérémé	29
	Sagafing	46
	Bilissibougou	31
	Didanko	47
	Sub-total	**606**
Djougoun	Diallamadji	12
	Karega	183
	Sonrongolé	102
	Kobokoto	89
	Djougoun	130
	Subtotal	**516**
Guémoukouraba	Guémoucoura	166
	Sakora	64
	Dionfa	62
	Guéssébiné	101
	Kakoro-Moutan	135
	Subtotal	**528**
Djidian	Kabé	268
	Doumbadjila	65
	Subtotal	**333**
Sefeto Nord	Damina	90
	Marena	130
	Sitakoto	12
	Neguebougou	195
	Niagané	289
	Subtotal	**716**
Sefeto Ouest	Nafadji	73
	Dalaba	43
	Djougounté	200
	Mansala	68
	Guemoucourani	18
	Sonki	36
	Siramissè	72
	Keniénifè	84
	Seféto	757
	Subtotal	**1375**
	Grand total	**4074**

Source: ACF-E, 2013

APPENDIX 2: Farmers' questionnaire

My name is Ayouba COULIBALY, student from Egerton University. This study is conducted to find out the effect of *Zai* pit and Half-moon on small scale farmer's income in Kita Cercle, Mali. The information you will provide will assist in formulation of policies and programs that will help to improve the food security of small-scale farmers in the Cercle. I assure you that the information will be treated as confidential as possible.

Questionnaire number…………………………………

Enumerator name ……………………………………..

Commune……………………………………………..

Village…………………………………………………

Date of interview………………/……………/ ………

A. Section A: farm and farmers characteristics

A.1 Name of the household head: ………………………………..**(NmHed)**

A.2 Age of household head: ………………………………………(**AgHed)**

A.3 Gender of household head: *1=Male; 0=Female*……………….....**(GdHed)**

A.4 Years of schooling of the household head............ …………….**(YrdSchlH)**

A.5 How many people are you living and eating together in your household?.**(NPlHd)**

From the number of household members mentioned above how many are involved in economic activities in the household?... **(EcAct)**

A.6 What is your current total land size for farming in hectare? ……….......(**LdSize**)

A.7 What is the nature of land ownership of the main plot? 1=Title; 2= others ..(**NtLdOw**)

A.8 Are you practicing SWCT as *Zai* pit or Half-moon? …………………………. (**Prct**)

1=yes; 0=no

If yes, please, indicate the size of the plot and number allocated to *Zai* pit, to Half-moons in the last season

	Size of land (hectare)	Number of pit/Half-moon
Zai pits		
Half-moon		

Codes: 1=Zai pit; 2=half-moon;

A.9 Do you participate in any off-farm income? *1=Yes; 0=No* ……………….(**OffrnInc)**

If yes, please fill in the table

Type of off-farm activity	Number of months they earned income in the last one year	Average monthly Income FCFA
Typacvty	**Nmbacvty**	**AvMntInc**

Codes: *1= Salaried employment; 2= Casual employment; 3= Pension, 4= Trading business; 5=Man-day work; 6= others (specify) …………………………………..*

A.10 Did you receive any remittance in the last one year? 1=yes, 0=No

If yes, how much?...(**AmtOfRmtce)**

Please, indicate the value of family farm assets …………………..……(**FamAssets)**

Assets		Number of item	Unit value of item	Total value of item
		Itnum	**Untval**	**Totval**
Hoes	1			
Tillage tools	2			
Tractor	3			
Plough	4			
Sower	5			
Disc harrow	6			
Cart	7			
Pulveriser	8			
Threshing machine	9			
Milling machine	10			
Weighing machine	11			
Farm store	12			
Lorry	13			
Motorbike	14			
Others(specify)	15			
Others(specify)	16			
Others(specify)	17			

A.11 Do you possess any domestic animal? *1= Yes; 0= No*……………………(**NnbLvstck)**

If yes fill the table below

Type of livestock	Number of livestock	Number sold in the last one year	Average unit price
TypLvk	**NberLvk**	**NLvkSld**	**AvPrLvk**

Code for livestock**:** *1=bull 2=other cow; 3=donkey; 4=horse; 5=goats; 6=sheep; 7=poultry; 8=other (specify)……………….*

A.12 Crop Inputs supply for the last season

No.	inputs	Quantity and purchase value			
		unit	quantity	price	Total value
cdinp	**inptnam**	**untinp**	**inptqty**	**inptprice**	**inptval**
2	Manure				
4	Other fertilizer (specify)……….				
5	Seed1…………..,				
6	Seed2……………				
7	Seed3……………,				
8	Insecticides				
9	Herbicide………,				
11	Fungicide				

A.13 Production and post-harvest losses for the last Season

Crops or by products (*see codes below*)	Land size (*ha*)	Amount produced	Unit (*see codes below*)	Unit price in (FCFA)
Crp/pd	**LdSz**	**AmPd**	**Unprd**	**Upr**

Codes for crops*: 1=Maize; 2=Sorghum; 3=Millet; 4=Groundnut; 5=others (specify)...........*
Codes for unit*:* 1*=Kg; 2=Liter; Bag; 4=Basket; 5=Others (specify)…………………*

Which type of labor did you use? *1=Family; 2=Hired;* 3*=Both…………..* **(TpLabr)**

A.14 Please fill the table below regarding the labor used in your main crop production

Crop	Activity	Family labor in man-day	Hired labor in man-day
TypCrp	**TypActy**	**MandS1**	**MandS1**

Codes for crops*: 1=Maize; 2=Sorghum; 3=Millet; 4=Groundnut; 5=others (specify)...........*
Codes for activities*: 1=Land preparation; 2=pickaxe; 3=Seeding; 4=Harvesting; 5=Removing the cover; 6=Transport 7=others (specify)……………………………………*

A.15 What is the average cost in CFA of a man-day in this area……………… **(Mnday)**

B.Section B: Climate related chock characteristics

B.1 Please indicate your perception about the slope, the slope, the fertility and the erosion of your main plot cultivated for the last season?

Perception of the slop (Code for slope)	Perception of the soil fertility (Code for fertility)	Perception of the soil erosion (Code for erosion)
(**PerLanSlop**)	(**PerLanFert**)	(**PerLanErod**)

Code for slope**:** *1= Flat slope; 2= Medium slope*; *3= Steep slope*
Code for fertility**:** *1=Low; 2=Medium*; *3=Fertile*
Code for erosion**:** *1=Less eroded*; *2= Eroded*; *3= Very eroded*

B.2 Farmer's perception of the timeliness

The timeliness is the variability in the timing and the levels of rainfall, and the increase in the temperatures.
What is your farm-specific experience related to rainfall in the preceding 3 seasons?

Statement	Agreement				
	1	2	3	4	5
1. Rainfall comes and stops in time **(RanTime)**					
2. There was adequate rain for the crops during the last five years **(RanAdeq)**					
3. Throughout the growth period of the crops, the rain was well distributed in the last five years (**RanDist)**					

Code for agreement: 1= Disagree; 2= Strongly disagree; 3=Neutral; 4= Agree; 5= Strongly agree

B.3 Risk-taking attribute

A risk-taking attribute is defined as willingness of an individual farmer to invest in agricultural technology although uncertain outcome and high cost of failure.

Statement	Agreement				
	1	2	3	4	5
1. I like to devote my assets and my time to agricultural technology of high profitability **(RiskTak1)**					
2. I prefer agricultural technology with less risky outcomes **(RiskTak2)**					
3. I don't like to newly venture if there is uncertainty about outcome **(RiskTak3)**					
4. If the technology is highly risky and high profitable, I would go for profit but with insight into the risk **(RiskTak4)**					

Code for agreement: 1= Disagree; 2= Strongly disagree; 3=Neutral; 4= Agree; 5= Strongly agree

Section C: Technological characteristics and use

Statement	Agreement				
	1	2	3	4	5
Compatibility (T.Com)					
1. Using the RWH technologies is compatible with most aspects of my work					
2. Using RWH technologies fits my work style					
3. Using RWH technologies fits as well with the way I like to work					
Ease of use (T.EsUs)					
1. I Cleary understand how to use RWH technologies					
2. Learning to operate RWH technologies system sis easy for me					
3. I find RWH technologies inflexible to interact with					
4. It is easy to perform work using RWH technologies					
5. It is not easy for me to become skilful in using RWH technologies					
6. I find RWH technologies easy to use					
Level of trust in institution (T.LTIns)					
1. I trust the agricultural associations as they work for the welfare of the farmers and the sectors					
2. I trust the local agricultural officer					
3. I trust the public institution (local government)					
4. I trust the NGO' officers					
Users' innovativeness (P.PrtIn)					
1. I am very curious about how things work					
2. I like to experiment with new ways of doing things.					
3. I like to take a chance					
4. I like to be around unconventional people who dare to try new things					
5. I often seek out information about new agricultural technologies					
Perceive resources availability (P.Resce)					
1. I have the resources, opportunities and knowledge for using RWH technologies					
2. I am able to use RWH technologies if I want to					
3. I have access to the resources I would need for using RWH technologies					
4. There are no barriers to me using RWH technologies					

Code for agreement: 1= Disagree; 2= Strongly disagree; 3=Neutral; 4= Agree; 5= Strongly agree

Perceived usefulness (PrUsf)

In general way, when performing my work, RWH technology are:

1. Not important	
2. Important	
3. Very important	

Section D: Institutional factors

D.1 Did you receive any advice from extension services agent about agricultural technologies use in the last season? *1=Yes 0= No*………………… **(AdExAg)**

If yes, how many contacts did you ever had with the extension services agent?.. (**NnbContExtAget**)

D.2 Did you access to formal/informal credit for your farm activities last 3 seasons*?* *1=Yes 0=No*

If yes, please, indicate the amount that was obtained in *S1………………* (**AmCredOb**)

D.3 Did you attend any training on agricultural technologies use in the 3 seasons? *1=Yes; 0=No* ……………………………………………………….. (**AgtecTr**)

If yes, indicate the number of trainings attended? ……………….……... **(NbAgTr)**

D.4 Do you have access to market information? *1=Yes; 0=No*……................**(AcMtIf)**

D.5 What is the distance to the nearest market (minutes walking)? .... (**DstMt**)

D.6 What is the distance to the nearest extension services (minutes walking)? ………………………………………………………………………...(**DstExtSvc**)

D.7 Are you a member of any agricultural related group? *1=Yes; 0= No*………(**Grp)**

D.8 What is the nature of land ownership of the main plot? *1=Title; 2= others*……………………………………………………………. (**NatLdOwnp**)

Thank you for your patience and responses.