Contribution of agroforestry practices to reducing farmers' vulnerability to climate variability in Rakai district, Uganda

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Declaration of authorship

I, Mabel Nabunya declare that this thesis titled, “Contribution of agroforestry practices to reducing farmers’ vulnerability to climate variability in Rakai district of Uganda” is my own. I have fully referenced the ideas and work of others, whether published or unpublished. Literal or analogous citations are clearly marked as such.

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Abstract

Agroforestry has been used widely in developing world as a strategy to manage effects of climate variability. However, its contribution to the welfare of farmers in rural communities is not well researched. This study aimed at assessing the contribution of agroforestry practices (AFPs) to reducing the effects that climate variability has on farmers' welfare, specifically evaluating the impacts of implementation of VI agroforestry project on farmers in Rakai district. Five specific objectives were developed to achieve this and these included; i) assessing climate variability in Rakai over the last 15 years, ii) description of agroforestry practices, iii) Determining farmers' sensitivity to climate variability, iv) evaluating the roles of AFPs in increasing resilience of farmers to climate variability , and v) assessing the perception of farmers to climate variability in relation to AFPs. To conceptualize the study, literature on vulnerability, agroforestry and climate variability was used. Indicators for measurement were built based on these theories and they included; erosion intensity, fuelwood stock, income, Household (HH) assets, crop yield and diversification of income. Data was collected from VI agroforestry project participants households (VI households) in three parishes of Kirumba in Rakai district and also from a control consisting of non-VI agroforestry project participant households (Non-VI households) with similar socioeconomic background. Assessment of climate data shows that there has been an increase and decrease in rainfall amount and mean annual temperature respectively over the last 15years. Four agroforestry systems notably; home gardens, pastoral live fences, coffee plantation crop and woodlots, were identified in Kirumba. VI HH had more land and significantly higher number of trees per hectare (P=0.000). They also had significantly higher agroforestry income (0.0016) and assets such as crop yield per hectare (p=0.0018) and livestock (p=0.0004) and also showed higher fuel-wood sustainability (p=0.003) than their counterparts. Non-VI households, on the other hand, were more diversified in terms of the number of income sources. The soil erosion intensity on the farms of the two farmer groups didn't differ. Farmers agree that AFPs help in soil erosion control, enhance fuel-wood production and in managing hazards through timber and fruit sales. With the physical attributes that VI households generally possess, they stand a better chance to cope with climate-related hazards such as drought and floods than the non-VI households. It was concluded that agroforestry plays a role in reducing the vulnerability of farmers to climate variability. However, the extent to which this is true is very difficult to determine as both farmer groups have generally low levels of assets such as land and income which restricts tree planting to obtain optimal benefits from agroforestry. Other factors such as tree products' market dynamics that determine farmers' decision to plant tree have to be carefully considered by project implementing agencies.

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Acronyms

AFPs	Agroforestry practices
AFS	Agroforestry system
cm	Centimeter
DBH	Diameter at Breast Height
DFID	Department for International Development
DOI	Diversification of income sources
E	East
GDP	Gross Domestic Product
GOU	Government of Uganda
FAO	Food and Agricultural Organization
ha	Hectare
HIV/AIDS	Human Immune Virus/ Acquired Immune Deficiency syndrome
HH	Household
ibid	*ibidem* (Latin) meaning "in the same place"
IPCC	Inter-government Panel on Climate Change
IRIN	Integrated Regional Information Networks

km	kilometer
m	Meter
mm	millimeters
MAI	Mean Annual Increment
MADDO	Masaka Diocesan Development Organization
N	Sample size
NEMA	National Environment Management Authority
Non-VI household	Non- Vi Planterar Träd household
NPHC	National Population and Housing Census
OCHA	Office for the Coordination of Humanitarian Affairs
S	South
SIDA	Swedish Development Cooperation Agency
TLU	Tropical Livestock Unit
VI household	Vi Planterar Träd household
UGX	Uganda Shillings
USD	United States Dollar

1. CHAPTER ONE: INTRODUCTION

1.1 Background

People all over the world are being confronted with the reality of climate variability. Although in some in places it's perceived as a change in weather patterns, it's indeed a matter of survival in other places (Daze, 2011). The latter is especially true in poor countries where the majority of the population depends on rain-fed agriculture for their livelihood (Morton, 2007). Among livelihood sources, agriculture is the most prone to impacts of climate variability and yet, it's the backbone of survival for many households (World Bank, 2008). This implies that communities who depend on it are vulnerable to climate variability. Acknowledging this dilemma and seeking for strategies that reduce farmers' vulnerability to climate variability is of critical importance. Given the fact that agriculture is rain-fed, a fundamental approach lies within agricultural or land use related practices that can reduce or adapt to the risks brought about by changes in climate (Verchot et al., 2007).

Thus, climate-smart agriculture, that, "sustainably increases productivity, resilience (adaptation), reduces/removes greenhouse gases (mitigation) while enhancing the achievement of national food security and development goals" (FAO, 2012; cited in Kapp and Manning, 2014 p.94) has been proposed as a fundamental approach. This umbrella term, however, consists of or covers many agricultural related practices such as soil management, livestock management, forestry, and Agroforestry. The latter particularly was proposed by FAO and is defined as "a farming system where woody perennials like trees and shrubs are integrated with crops and/or livestock in the same management unit" (Nair, 1993 p.14). The sustainability attributes of agroforestry like diversified niches, flexibility, and income generation among others are strong assets to farmers for resilience against climate variability (Lipper et al., 2014). Thus, many international organizations working in developing countries on agriculture issues related, have encouraged implementation of agroforestry practices (AFPs) in many vulnerable communities who depend on agriculture (Oelbermann and Smith, 2011). The philosophy is that agroforestry improves production and financial stability, and at the same time provides many benefits for smallholder farmers who are vulnerable to the effects of climate change (Lin, 2014). This is particularly in rural and agriculturally based economies with few other livelihood options.

Uganda, like other developing countries has the majority of its population living in rural areas and deriving their livelihood mainly from rain-fed agriculture. Several initiatives have been put in place in these areas to boost farmers' incomes and improve their wellbeing. Among other initiatives, agroforestry has been widely adopted widely adopted and continues to be implemented in many districts of Uganda under the banner of improving farmers' livelihood thus increasing their resilience against climate hazards such as drought. For instance, in the Southwestern Uganda, AFPs have been adopted through the VI agroforestry program, a Swedish government-funded project through SIDA. Although agroforestry is not an entirely new practice in Uganda, the wellbeing of a number of farmers has purportedly been increased through this program. Therefore, this research focuses on addressing the impacts that resulted due to farmers' involvement in the project.

1.2 Problem statement and justification

The impacts of increasing climate variability such as crop failure and livestock mortality are becoming apparent in many vulnerable communities of Uganda (Mwaura et al., 2014). Many studies have indicated agroforestry system as a strategy to addressing this problem (Verchot et al., 2007; Morton, 2007). This is because agroforestry not only improves household food security, but also reduces vulnerability for seasonal food and fodder shortages. This strategy has been greatly supported by many organizations and funding agencies (Oelbermann and Smith, 2011). One of such organizations is VI-agroforestry under the Swedish Development Cooperation Agency (SIDA).

VI agroforestry project has been operating in Uganda since 1992 with an initial aim of halting desertification and soil erosion through tree planting. The Lake Victoria watershed region and the southwestern districts of Uganda were its first target areas. These areas were prone to erosion and occasional flooding, and were also poor after the HIV/AIDS disease outbreak which left most households vulnerable to different shocks. By 2015, VI Agroforestry was working with over 18000 households who were involved in one or more of the project activities. Project activities included training on the effects of climate change, efficient use of energy, diversification of income, and erosion control among other things (VI Agroforestry 2013-2015). These activities were expected to increase farmers' knowledge, diversify their income and reduce their vulnerability. Despite these interventions, there has been no evaluation of the extent to which these activities have achieved their intended objectives.

Despite a large number of households involved in the project activities, little documentation is available on the impact of agroforestry activities to the target communities. Most of the available documentation is annual publications from the organization featuring few individual household case studies of agroforestry impacts. However, with a large household involvement such as this, more studies are required to assess the contribution of agroforestry to reducing the vulnerability of these farmers basing on larger sample size. Using a large sample size for evaluating impacts captures more details than when based on a small sample size. Moreover, comparing results with a control group gives a better picture of the impacts of the agroforestry implementation to farmer households. Often, internal evaluations tend to be biased and are usually deemed successful because negative results can cause projects to lose funding. This study would act as an independent evaluation of the project thus offering more concrete evidence on these impacts.

Information obtained is not only useful for existing project evaluation but also would contribute a great deal to the field of vulnerability studies. Scholarship on vulnerability is seeking better interdisciplinary evaluations that highlight practices like agroforestry that can improve farmers' ability to cope with climate-related hazards (Morton, 2007). Additionally, the results will be used as a baseline for forthcoming project work by other project developers. Furthermore, through this study, factors that contribute to the success or failure of implemented activities will be highlighted.

1.3 Objectives

1.3.1 Overall objective

To assess the role of agroforestry in reducing farmers' vulnerability to the effects of climate variability by comparing VI agroforestry beneficiary households with non-VI agroforestry beneficiary households in Kirumba, Rakai district Uganda

1.3.2 Specific objectives and research questions

1) To assess climate variability in Kirumba sub county over the last 15 years
   i. Has there been significant change in the rainfall amount received in Rakai in Kirumba over the last 15 years?
   ii. Has there been change in the mean annual temperature of Kirumba over the last 15 years?
2) To identify and describe the existing Agroforestry Practices (AFPs) in Kirumba sub county
   i. What are the characteristics of agroforestry systems and their components in the different households in the area?
   ii. Do farmers have a preference to plant some specific trees species than others?
3) To determine farmers' sensitivity to climate variability with AFPs
   i. Do land and tree resources among VI households differ from that among non-VI households?
   ii. Does the erosion intensity on VI and non-VI farms differ?

iii. Do VI households have more standing wood volume to sustain future fuel-wood needs than non-VI farms?

4) To examine the contribution of AFPs towards increasing resilience of farmers to climate variability

   i. Do VI households have a higher resilience index than non-VI households?

5) To assess farmers' perception of AFPs as a strategy to reduce impacts of climate variability

   i. Are farmers in Kirumba aware of the changes in climate as well what is causing them?

   ii. Do farmers recognize that AFPs contribute to reducing the effects of climate variability?

1.4 Scope of research

This research focuses on the roles of agroforestry to the farmers in Kirumba sub-county of Rakai district, Uganda. Emphasis is put on those agroforestry roles that relate to improving the well-being of farmers amidst variability in climate. The theoretical framework for this research is constructed focusing on the existing theories on vulnerability, climate variability and agroforestry roles with the empirical evidence conducted in other parts of the world. Based on the theoretical framework, a conceptual framework for the empirical analysis is developed together with the identification of indicators for the research questions. Comparative analysis is done between two groups of farmers; those who implemented agroforestry and those who did not, to obtain information from different perspectives. Due to the constraints of time, access, funds and personnel, three parishes are selected as case study areas for this study.

The study is significant in terms of its contribution to both theory and practice. It provides insights into the contribution of agroforestry to the livelihoods of large and marginal households. The results of this study can be useful in redirecting, improving and strengthening the existing agroforestry program. Since this is a case study of Rakai district, the results of the study may not hold true for other agroforestry projects.

2. CHAPTER TWO: THEORETICAL REVIEW

2.1 Vulnerability

In this research, vulnerability is defined as “the degree, to which a system is susceptible to or unable to cope with, adverse effects of climate change, including climate variability and extremes” (IPCC 2001). Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity. Reducing a system’s vulnerability to hazards related to climate variability means a reduction in both exposure and sensitivity, and increase in resilience (Nguyen et al., 2013). Vulnerability and its components have been explained in details with the help of a framework by Turner et al (2003) who assess how vulnerable people are affected by shocks and stresses. According to this framework, a system’s vulnerability is divided into three major components which include exposure, sensitivity and resilience and this is illustrated in the figure 1 below;

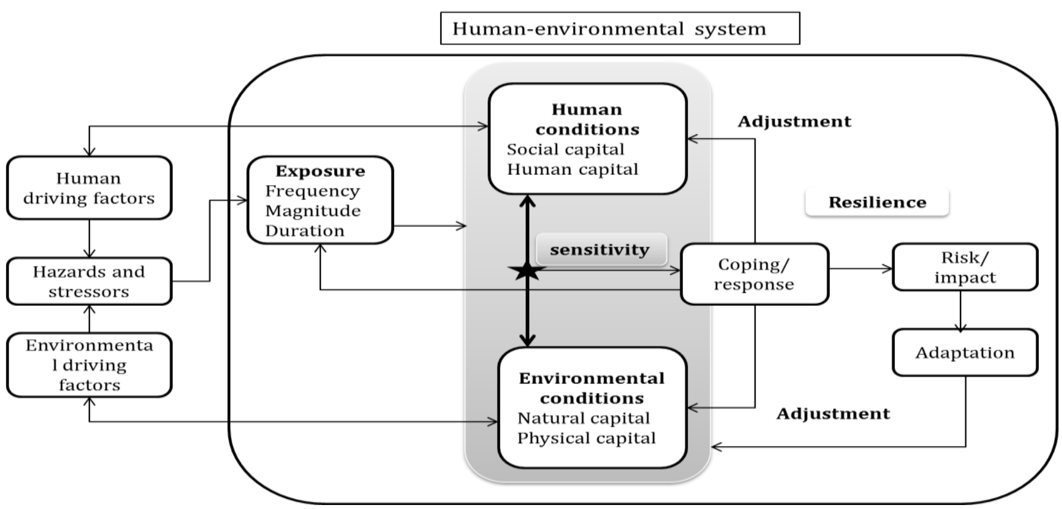

Figure 1: Vulnerability Framework

(Source: Turner et al., 2003)

Exposure to hazard is the first component of vulnerability and it is defined as “the degree of climate variability that a system experiences” (IPCC). A system can be a community, household, individual or farm depending on the context. Exposure considers the frequency, magnitude and duration of the hazard the system encounters. Hazards include any threats to the system, both sudden shocks (like floods and droughts) and slow increases in stress on the system (due to soil degradation, increased variation of rainfall patterns, etc.) (Turner et al., 2003).

Second, there is the sensitivity of a system's condition to these hazards which is "an assessment of the amount of impact the climate factors have on the system" (IPCC). It is determined by both the environmental and human characteristics that contribute to how a system responds to exposure to hazards. These mechanisms influence and feedback to affect each other, so that a response in the human subsystem could make the biophysical subsystem more or less able to cope, and vice versa and their outcomes collectively determine the resilience of the coupled system (Turner et al., 2003). Characteristics of the human- environment system include social, human, natural and physical capitals that influence the existing coping mechanisms of a given system. DFID (2001) defines these capitals as;

Physical capital: this represents the basic infrastructure and producer goods needed to support livelihoods and reduce vulnerability e.g. secure shelter and building, safe water, affordable energy. Without adequate access to services such as energy, human health deteriorates and long periods are spent in some activities such as the collection of water and fuelwood.

Natural capital: this represents natural resource stocks from which resource flows and services useful for livelihoods are derived such as trees, land, biodiversity, nutrient cycling or erosion protection. Sustainable use of natural resources has a direct impact on stocks of natural capital and this mainly affects those who derive their livelihood from them

Human capital; this represents the skills, knowledge, ability to work and good health that together enable people to pursue different livelihood strategies

The last component of vulnerability is resilience which is "the ability of the system to manage the negative impacts and take advantage of any opportunity that arises" (IPCC, 2001). It refers to future actions that can improve its ability to cope with outside hazards. These actions or processes help improve farmers' resilience to hazards and can include governmental policies, NGO programs and autonomous decisions made by individuals or communities (Turner et al., 2003). The FAO resilience index tool comprehensively analyses household resilience. In algebraic terms, the resilience index for household *i* is expressed as follows:

$$R_i = f\left(IFA_i, ABS_i, A_i, SSN_i, S_i, AC_i\right)$$

Where; R = resilience; *S* = stability; *SSN* = social safety nets; *ABS* = access to basic services; *A* = assets; *IFA* = income and food access; and *AC* = adaptive capacity (Alinovi et al., 2009).

In the model, at time *T0*, each component is estimated separately to generate a composite index of household resilience. The different components observed at time *T1* reflect how changes in these factors influence household resilience to endogenous and exogenous shocks. Resilience depends on these components and therefore increasing any components of the resilience model makes the system more resilient than before (Alinovi et al., 2009).

2.2 Well-being

In the study of vulnerability, it is very important to discuss well-being because vulnerability is not just about human mortality rates but also people's way of life. Achieving well-being or a similarly acceptable quality of life is a fundamental goal in most development projects focused on reducing vulnerability (Costanza et al 2007).) Human well-being is defined using a three-dimensional holistic approach as "a state of being with others, where human needs are met, where one can act meaningfully to pursue one's goals, and where one enjoys a satisfactory quality of life" (Copestake, 2008; Pg. 3). Under this approach well-being is not only income or material well-being but also relational and subjective well-being (Sumner and Mallet, 2011). Several authors also distinguish between *determinants* and *constituents* of well-being (Costanza et al., 2007).

"Constituents" are generally the components that define well-being such as happiness, health and positive relationships with others whereas "*determinants"* are factors that produce or cause improvements in well-being (Costanza et al., 2007). Examples of determinants include clean water, access to knowledge and capital, and wealth. Whereas *determinants* are relatively easy to identify and measure, some *constituents* of well-being are still challenging to estimate. The following indicators are usually used as *determinants* of social well-being: income/consumption/ wealth; health; education; political voice; social connectivity; environmental conditions and insecurities (Stiglitz et al., 2009). More and more indices including environmental components especially land to their list of well-being *determinants*, and they recognize the importance of environmental health for long-term sustainability. In order to improve the *determinants* of well-being, it is important to enhance security especially through income diversification of different livelihoods (*ibid*)

2.3 Climate variability

Different regions in the world have experienced, and are expected to experience different effects due to variability in climate. In this paper, climate variability is defined as "the way climate fluctuates yearly above or below a long-term average value" (Dinse, 2009). In the case of climate variability, climate/weather varies over season or years instead of day to day like weather for example when one rainy season is heavier or longer than others. Climate variability also differs from climate change which is the long-term continuous change (increase or decrease) to average weather conditions or the range of weather. Climate change is slow and gradual, and unlike year-to-year variability, is very difficult to perceive without scientific records (ibid).

Over the past 100 years, changes in mean surface temperatures and precipitation have been less in the tropics than the global average (Zhao et al., 2005). Based on climate change projections made by IPCC, there is a potential increase in the occurrence of droughts, floods and extreme rainfall events in most humid and sub-humid tropics which generally depicts increased variability of precipitation. Agriculture, particularly in the sub-humid areas, is vulnerable to many environmental hazards including frequent floods, droughts, tropical cyclones, storm surges and high temperatures (ibid). Climate variations will have a disproportionately large effect on developing countries that still rely heavily on rain-fed agriculture and other ecosystem resources (World Bank, 2008). Agricultural productivity in the developing world is expected to reduce by 10-20% by 2050 because of changing rainfall patterns, warming temperatures, increases in the frequency of extreme weather events, and more prevalent crop pests and diseases (ibid).

Rainfall and temperature variability in Uganda

Historic trends show that the climate is changing in Uganda (Zinyengere et al., 2016). Average annual temperatures increased noticeably by 1.3°C between 1960 and 2010, with the largest increase occurring during January and February. The warming trend is projected to continue in Uganda, with some projections suggesting an increase of up to 1.5°C as early as 2030. Similarly, temperatures could rise between 0.9°C and 3.3°C by the 2060s (ibid). There are no clear changes in annual rainfall trends across the whole country over the past 60 years. A modest decline has however been detected in some northern districts e.g. Gulu, Kitgum, and Kotido (Zinyengere et al., 2016). The climate of Uganda may become wetter on average and the increase in rainfall may be unevenly distributed and occur as more extreme or more frequent periods of intense rainfall (GOU, 2007; Hepworth, 2008). Predicting regional rainfall changes in the tropics is a major challenge for climate scientists, and rainfall projections are therefore more uncertain. On average, the projections for Uganda show a slight increase in mean rainfall (Zinyengere et al., 2016). There are likely changes in the frequency or severity of extreme climate events, such as heat waves, droughts, floods and storms (Hepworth, 2008).

Drought

Droughts are defined differently depending on the source and context but are generally characterized by lack of rainfall. Meteorological drought indicates deficit rain of different quantum which occurs whenever rainfall is below the long-term average in an area (National Drought Mitigation Center: Types of droughts). Frequent rainfall deficits recorded in many parts of Uganda coupled with their effects on productivity of both crops and livestock are evidence of the occurrence of agricultural droughts (GOU, 2012). Although Uganda has experienced relatively less severe droughts compared to other countries in the sub-Saharan Africa, there have been adverse effects on the well-being of rural communities (ibid). According to the ministry of water and environment (2007), droughts are on the rise in Uganda. The western, northern and north-eastern regions experienced more frequent and longer-lasting droughts between 1987 and 2007 than had been seen historically (Zinyengere et al., 2016).

Floods

In the last decades, the worst floods on the African continent have been caused by heavy rainfall (IRIN, 2012). The IPCC predicts that climate change is likely to intensify flooding in many areas of the world (Parry et al., 2007). Although models cannot definitively determine where, when, or by how much flood hazards will change, specialists suggest that existing flood-prone locations and some coastal and river-basin areas will become more vulnerable to severe flooding (ibid). Uganda's climate is naturally variable and susceptible to flood which have had negative socio-economic impacts in the past (Hepworth et al., 2008). Owing to increasing heavy rain events predicted, runoff is also projected to increase (Zinyengere et al., 2016).

2.4 Effect of climate variability on farmers' well-being

Generally, extensive studies in the literature report negative effects of climate variability on farmers' well-being (Mwaura et al., 2014; Hepworth, 2008; Zuazo et al., 2008). Rainfall variability either causes floods or drought depending on the nature of variation from the long-term normal. Rainfall variation always has effects on water resources, food security, natural resource management, human health, settlements and infrastructure (Hepworth, 2008).

Increasingly, erratic rainfall patterns create difficulties for farmers who rely on seasonal cues to plant their crops (Mwaura et al., 2014). The decrease in rainfall means delays in planting which has a huge impact on farm yields. For example, maize production in Zambia decreased by an average of 1.5% each day that planting was delayed. When rainfall comes earlier than expected, some crops are significantly affected. Farmers attribute some crop diseases like blight disease to unexpected rainfall which comes late in the growing season and lower the expected seasonal income of farmers (Mwaura et al., 2014). Recent studies also indicate that climatic variability will result in greater frequency and intensity of extreme weather events, which will inevitably intensify soil erosion (Zuazo et al., 2008).

Droughts have major economic and social implications, especially in the developing world where national GDPs rely heavily on agricultural production. The value of damage and losses caused by rainfall deficit conditions in Uganda in years of 2010 and 2011 was estimated at 2.8 trillion Shillings (US$ 1.2 billion) which was equivalent to 7.5% of the GDP in 2010. Three types of effects were identified and these included; death of livestock, low productivity and higher production costs (GOU, 2012). These losses directly impact on the well-being of people especially the rural communities where the main livelihood asset is livestock. Droughts also put higher pressure on natural resources especially forests as deforestation increases substantially during drought periods due to increased charcoal production, agricultural expansion, logging and forest grazing (Zhao et al., 2005).

Floods are the most frequent and have a rapid impact on human well-being compared to droughts and rainfall variability (Hepworth et al., 2008). Floods have both short term and long term impacts on communities. Short-term impacts include loss of livestock and human life, increased risk of disease, reduced mobility, increased prices of goods, contaminated water, difficulty in finding cooking material, damage to houses and increased food insecurity. Long-term effects of floods include fertility and soil loss on agricultural land, damage to infrastructure and housing, migration, and devaluing of agricultural land. Damage associated with floods has also been increasing over the last century due to intensified land use, loss of forest cover, human encroachment onto floodplains and higher population densities in flood-prone areas. (IRIN, 2012)

2.5 Agroforestry systems

According to Nair (1993), agroforestry is the deliberate growing of woody perennials on the same unit of land as agricultural crops and/or animals, either in some form of spatial mixture or sequence so that there must be a significant interaction (positive and/or negative ecological and/or economic) between the woody and non-woody components of the system. Nair (1993) and the National Research Council (1993), describes agroforestry systems based on their structure, function, socioeconomic nature level of management and environmental spread (Figure 2). However, the broad basis of classification is by no means independent or mutually exclusive

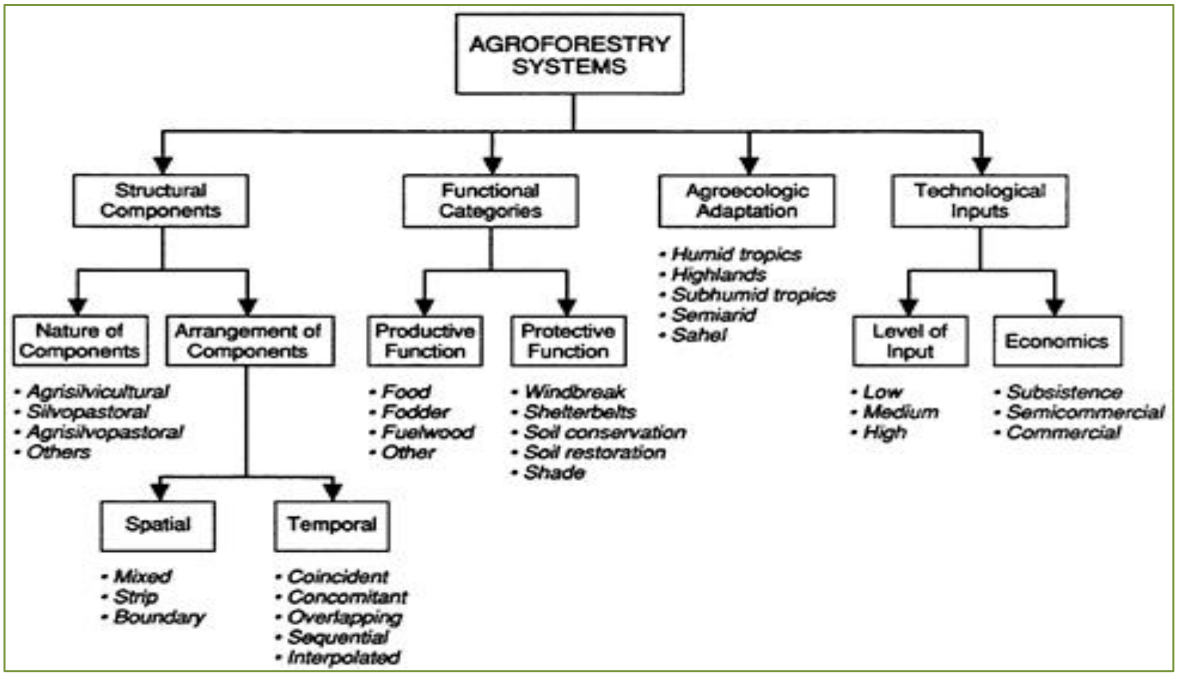

Figure 2: Characteristics of traditional agroforestry systems used in the tropics

(Source: National Research Council, 1993)

In this study, the structural classification is used to best define agroforestry systems. The structure of a system can be defined based on the nature and arrangement of its components. There are three basic components of any agroforestry system that is woody perennials, livestock and herbs/crops (Nair, 1993). Basing on the nature of agroforestry systems, four broad categories are described based on the combination generated on a piece of land. These categories include Agri-silviculture - crops (including shrubs/vines) and trees; silvopastoral- pasture/animals and trees; Agrosilvopastoral - crops, pasture/animals and trees and also woody perennials (ibid).

2.6 Role of agroforestry in improving farmer's well-being

Interest in using agroforestry techniques to improve farmer well-being has recently increased because of their joint role in climate change mitigation through carbon sequestration and supporting farmers' adaptation to these changes (Verchot et al 2007). Studies on agroforestry have generally shown that it can improve farmer well-being and environmental health (Scherr et al., 2002a).

Agroforestry involves intentional use of trees in the cropping systems to increase farm productivity, diversify income sources and provide environmental services. For example, nitrogen-fixing trees are usually intercropped between rows of food crops to provide limited nutrients to crops so as to improve farm productivity. Agroforestry techniques also include the use and sale of tree crops such as fuelwood, fruit, and timber (Nair, 1993).

Trees help to mitigate soil erosion generated by water and wind thereby sustaining the productivity of the soils. Additionally, reduction of erosion minimizes impairment of the quality of water in catchments. Trees provide wood products for the farm; they provide raw materials for rural industries that generate employment for rural communities. Besides that, trees provide environmental benefits such as wildlife habitats, water retention capacity, or shade for dwellings (Current et al., 1995). Also, agroforestry meets almost half of the demand of for both commercial and domestic wood requirements. For example, they satisfy about 80% of fuelwood, 70–80% wood for plywood, 60% of raw material for paper pulp. As for fodder, trees constitute 9–11% of the green fodder requirement of livestock. (Mbow et al., 2014)

Although it's evident that agroforestry systems have positive effects on farms, it's worth noting that trade-offs do exist. For instance, Agroforestry systems which involve practices such as shifting cultivation, pasture maintenance by burning, nitrogen fertilization and animal production may lead to a rise in GHG emissions (Mbow et al., 2014). Just like any other crop, cultivating trees also has some risks. Unusual drought conditions or poor planting materials could mean failure to establish the trees. Uncertain market prospects that most projects are unable to develop or improve can make agroforestry also a bad investment (Current et al., 1995). To be successful, it is essential that these systems be specifically designed and managed to suit the site so that the positive effects are optimized and the potentially negative effects kept to a minimum (Kapp and Manning, 2014). Management options in agroforestry include tree pruning and measures to reduce below-ground competition, particularly for water, such that trees tap into deep groundwater rather than topsoil moisture that annual crops rely on. Failure to properly manage the AFPs can impact on crop growth and performance. This makes AFPs very complex and difficult to manage, requiring a lot of labor (Mbow et al., 2014).

2.7 Agroforestry and vulnerability

Agroforestry has been proposed as a potential strategy for helping subsistence farmers to reduce their vulnerability to climate change (Verchot et al., 2007). In sub- Saharan Africa, 15% of farms have tree cover of at least 30% which indicates a high potential in Africa for sequestering carbon and reducing other agriculture-related GHG emissions (Mbow et al., 2014). Agroforestry systems have 3–4 times more biomass than traditional treeless cropping systems and in Africa, they constitute the third largest carbon sink after primary forests and long-term fallow land (ibid).

Agroforestry systems comprise a long list of land management practices, including crop diversification, long rotation systems for soil conservation, home-gardens, boundary plantings, perennial crops, hedgerow intercropping, live fences, improved fallows or mixed strata agro-forestry. If well managed, agroforestry can play a crucial role in improving resilience to uncertain climates through microclimate buffering and regulation of water flow (Mbow et al., 2014).

Trees are considered to be less sensitive to climate-related hazards such as floods and droughts due to their deep root systems (World Bank, 2005; Smith, 2010; Pandey et al., 2015). The sensitivity of a system is determined by the characteristics of the human- environment system which are the human, social, physical and natural capital. When leguminous trees are planted with food crops, they provide limiting nutrients to crops and can also be used or sold as timber, fruit and fuelwood (Sanchez et al., 1997). Agroforestry helps to conserve and protect natural resources by, for example, mitigating non-point source pollution (e.g. dust), controlling soil erosion and creating wildlife habitats. It facilitates flexible responses to rapid shifts in ecological conditions, while at the same time maintaining or restoring soil and water resources. (Mbow et al., 2014)

Agroforestry allows for optimal use of family labor as the labor needs normally reduce during the off-season (Current et al., 1995). Development of agroforestry for sustainable fuelwood can contribute to energy substitution and can become an important carbon offset option (Mbow et al., 2014). By implementing agroforestry, time and energy spent in fuelwood collection are reduced tremendously (Tharlakson et al., 2012). Agroforestry improves household's general standard of living via improvements in farm productivity, off-farm incomes, wealth and the environmental conditions of their farm. Trees on the farm are also physical assets which are used for insurance and also increase land value (Chavan et al., 2016).

The final outcomes of agroforestry contribute directly to increase in resilience. Final outcomes which include, the realization of rights or improvement in well-being are a good measure of resilience (Fuller et al., 2015). These outcomes can be evaluated by looking at food security, asset ownership, school attendance, nutrition and so on. Agroforestry is a direct source of food and fruits and is an additional source of income from timber and firewood trade (Current et al., 1995). Also, the presence of trees on the farm is the best form of insurance in asset terms and as a strategy for coping with different climate change scenarios (Chavan et al., 2016).

2.8 VI Agroforestry

VI agroforestry is a non-profit organization and has no party-political or religious affiliations. In Sweden, VI Agroforestry is registered as a foundation under the name VI plantar träd. The offices in Kenya, Uganda, Tanzania, and Rwanda are branch offices and are registered in the respective country under the name VI Agroforestry. Vi Agroforestry works with smallholder farmer families living in poverty especially women, youth and children, who are members or potential members of democratic farmers' organizations in areas vulnerable to climate change in Sub-Saharan Africa (VI strategy 2017-2021).

VI agroforestry started in 1983 in Kenya with an aim of halting desertification and soil erosion by planting trees (VI history). In light of new challenges in the target area, VI expanded its objectives to include other working areas. In the mid-1990s the approach of the Vi-Program underwent a radical transformation. Consequently, by 1997/98 the Vi-Program abandoned its tree planting strategy based on tree seedling distribution from central nurseries and embarked on the promotion of a wider range of agroforestry techniques to small-scale farmers supported by intensive extension activities (Haldin et al., 2000). Currently, VI agroforestry has six main working areas with a major objective to "Sustainably improved livelihoods for smallholder farmer families in Sub-Saharan Africa through increased climate change resilience, food security, higher incomes and greater equality between women and men". Although VI strategies have changed over years, the major basis for all its work is still tree planting (VI agroforestry strategy 2017-2017). The agroforestry approaches enable farmers to increase and diversify their production so that agriculture not only covers the families' food needs but also to generate a surplus that can be sold. Vi Agroforestry supports market-oriented production through capacity building and advisory services, and the farmers are also helped to set up their own savings and credit associations (VI Agroforestry Strategy 2013-2015).

In Uganda, VI Agroforestry started in 1992 in the central and western region in the districts of Masaka, Rakai, and Bukomansimbi. It has since extended its operations to include districts of Mubende, Kabale, Mityana and many others in these regions. Since 2008, VI agroforestry, Uganda stopped active implementation on ground and is working through District Farmer Associations (DFAs). Through a VI agroforestry funded program called Farmer of Agroforestry (FoA), farmers receive advisory service and other services through their respective DFAs (VI Agroforestry, 2013).

3. CHAPTER THREE: METHODOLOGY

3.1 Description of the study area

3.1.1 Geographical Location and Size

The study was conducted in Kirumba sub-county, one of the 19 sub-counties of Rakai district in Uganda. Rakai District is located in the South Western region of Uganda, west of Lake Victoria, lying between longitudes 31^{o}E, 32^{o}E and latitude 0^{o}S. Its southern boundaries are part of the international boundary between Uganda and Tanzania. It is bordered by Lyantonde District in the North-west, Masaka District in the North, Kalangala District in the East, and Kiruhura and Isingiro districts in the West. The District has an area of about 4012 square kilometers. Kirumba is located in the Northeast of Rakai district (Figure 3). It has 6 parishes and 35 villages. There are approximately 5860 households in Kirumba sub-county (Rakai district development plan 2010-2013).

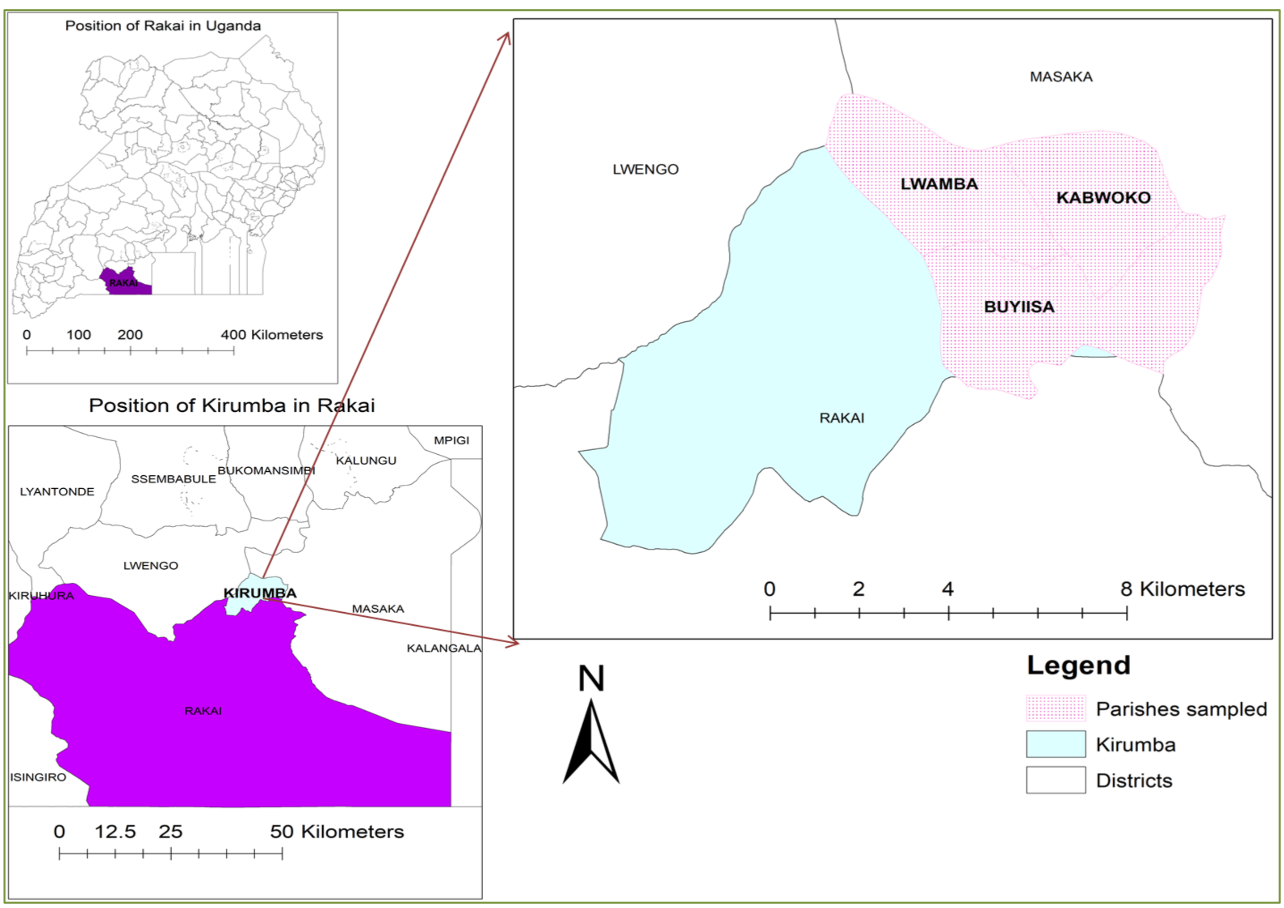

Figure 3: Map of the study area

Climate

Rainfall patterns in the district are bimodal and are fairly distributed with mean annual rainfall range between 1,350mm and 2,125mm. There is a relatively dry season from January to February and from June to August. However, these dry periods are occasionally mitigated by a few light falls. A principal peak is due around March to May, whereas the minor peak is around October and November (Okoria, 2006)

The temperatures are generally high in the District throughout the year. The eastern parts of the district record a mean annual minimum of 17.5^{o}C while in the western part, it's around 15^{o}C. The District generally records around 25^{o}C mean annual maximum temperatures and occasionally between 26^{o}C and 27^{o}C (Okoria, 2006).

Relative humidity in the area varies with time. It ranges between 80-90% in the morning and decreases to between 61% and 66% in the afternoons during the months of January and May. From June to August, the morning recordings decrease to around 77% and so, are the afternoon recordings that decrease to around 56% and 57% (Okoria, 2006).

Soils and topography

Over 75% of Rakai soils are ferralitic representing an almost final stage of weathering with little or no mineral reserve left. Other soil types include lithosols, alluvial and lacustrine sands, and alluvial clays. Generally, lithosols and humus loams are the dominant upland components while the grey sandy soils are derived from hill wash or river alluvium, grey clays of the valley bottoms and lacustrine sands dominate the lowland component (Rakai district development plan 2010-2013).

Generally, the soils of Rakai District can be classified into four soil catenas, four soil series, and peat soils. Kooki catena is the dominant soil type accounting for over 40% of the soils in the district. However, this soil catena is loose and collapses easily making some land use like construction and agriculture very difficult (Radwinski, 1960).

The landscape of Rakai District corresponds to Wetland Peneplain. It is part of the mid-tertiary or Buganda surface, which is essentially a plateau land. The same landscape is represented in large parts of East, Central, and Southern Africa. The landscape is the result of a long period of quiescence from the end of the Karoo era to early tertiary, during which sub-aerial erosion reduced the plateau land to a very low relief. This almost perfect pene planation was followed by slow uplift, which commenced in the early tertiary period and the consequent dissection by the rejuvenated drainage system. As a result, an elevated and dissected plateau consisting of flat-topped hills or their remnants and intervening valleys was formed (Rakai district development plan 2010-2013).

Socio-economic characteristics and land use

The population of Rakai as per year, 2014 Population and Households Census was 516,309(257,565 Male and 208,744 Female), with an average annual growth rate of 2% per year. 93.4% of the population is rural. The average family size of the district is 4.4 people per household. 47% of the population in Rakai district is self-employed while 40% are unpaid family workers (Nation population and housing census-NPHC, 2002). Firewood is the major source of energy with 3,226 households using it for lighting while 82.3% of the population in Rakai uses it for cooking (UBOS, 2016)

The vegetation in Rakai can be classified into three categories namely; swamps, Savannah, and forests (Rakai development plan 2010-2013). The main land-use type in Rakai is rain-fed agriculture comprising of over 70% of all the land characterized by rain-fed small herbaceous fields mixed with isolated small shrub and tree fields. Rain-fed agriculture includes coffee production, maize, paddy, legumes, banana, fruits, agroforestry as well as livestock. A large portion of about 20% of the land is covered by swamps or wetlands. By mid-2000s, the number of people farming in wetland had started increasing (Okoria, 2006).

The forests of Rakai District cover about 363.8km^2. The major forests (total of 151km^2) are found in the Sango Bay area in the southern part of the district. They occupy part of the Kagera River floodplain and are surrounded by swamp and seasonally flooded grasslands (Okoria, 2006).

VI agroforestry project operations in Rakai district

VI agroforestry started operating in Rakai district in 1995. VI agroforestry operations in Rakai were under seven zones, each managed by a zone manager. Kirumba was under Kalisizo zone which consisted of Kalisizo, Kirumba and Lwankoni sub-counties (VI strategy, 2006). Part of Kalisizo sub-county is peri-urban and therefore, most farmers in this zone were from Kirumba sub-county. The zones consisted of "Areas of Concentration (AoC)", where an extension officer worked directly with farmers. Altogether, there were 15 extension workers per zone each working with about 250-300 farmers. In addition to the extension staff, the Training and Community Empowerment Unit supported the project development and improvement by identifying and responding to training needs among the project staff, extension workers and also farmers (Haldin, 2000).

All households with a total land area between of 0.5 to 5acres were eligible to join the program. Altogether, 44,000 households in Masaka and Rakai were equipped with agroforestry knowledge (VI agroforestry). Another training that VI agroforestry program gave farmers in Rakai was on the creation of saving scheme, silviculture activities such as, spacing and weeding, maintenance, soil and water conservation techniques. VI agroforestry supported community nurseries by giving them tree seedlings, polythene tubes, seed collection and also management fees in cases where big nurseries were established (Key informant interview).

The project phased out of Rakai district to other districts in 2000. Some communities that it worked with continued planting trees for mainly fuelwood and fruit benefits. Fruit trees especially were easier to plant than other trees in rural communities of Rakai, since communities could quickly see the direct benefits (Kyazze et al., 2011).

3.2 Conceptual framework

The conceptual framework of this research (Figure 4) was developed on the theories and frameworks defined in chapter 2 above. The framework highlights that the vulnerability of a farmer household to effects of climate variability is determined by its exposure, sensitivity and resilience components (Figure 1). Climate variability has a direct effect on the household components such as livestock, crops and human well-being and therefore increases farm sensitivity and reduces farm resilience. Adopting agroforestry as a coping strategy to effects of climate variability is expected to improve human and environmental components of the households which reduce household sensitivity by increasing natural and physical capital and also increase household resilience. The framework, therefore, emphasizes on sensitivity and resilience components as the main variables for analysis in this research and it relates them to two main areas of interest notably climate variability and agroforestry.

In analyzing climate variability, the framework focused on two climate components which are temperature and rainfall. Agroforestry was defined by agroforestry components which included tree characteristics (size, species, stocking, and arrangement), livestock and crops. To analyze the sensitivity of households to climate variability, natural and physical capital components were used. Variables for analysis included soil erosion intensity, tree and land resources for natural capital components and fuel-wood energy for physical capital components. The resilience of households was analyzed using agroforestry assets (crop yield per hectare, land, trees, livestock), income and households adaptive capacity (diversification of income).

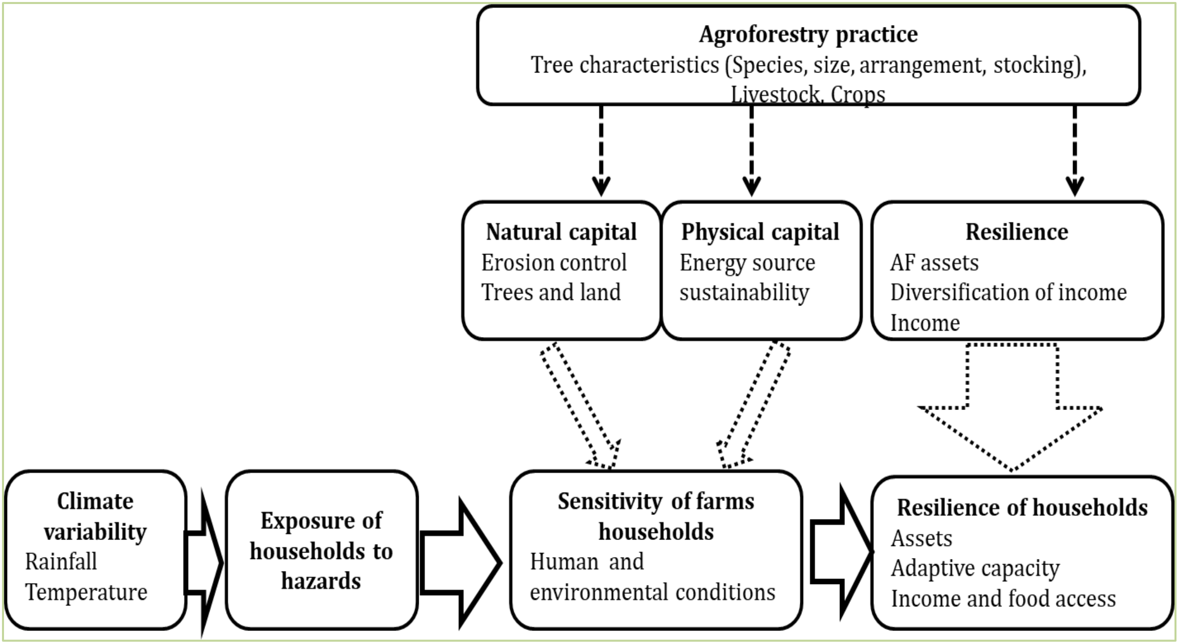

Figure 4: Conceptual framework of the research explaining vulnerability of farmers to effects of climate variability

(Source: Turner et al, 2003, Modified and Illustrated by Author)

3.3 Research process

The research process followed nine different steps namely; development of objectives, theoretical review, conceptual framework, identification of variables and indicators, case study selection, data collection and analysis and finally report writing. The study area was selected basing on the objectives of the study. The variables and indicators to measure, described in detail in Table 1, were built following the components of the developed conceptual framework (Figure 4).

A holistic case study approach was used because it offers unique richness in details rather than generalizations, and understanding instead of explanations. Case studies lend themselves to study complex issues while retaining the holistic characteristics of real-life events (Yin, 2003). Both qualitative and quantitative data were collected using both primary and secondary sources to create a rich picture of the situation and to enhance the validity and reliability of the results.

Data was collected from two farmer groups which included; farmer households that worked with the VI agroforestry project (VI households) and a control group consisting of farmer households who didn't work with VI agroforestry project (non-VI households). This was done as a comparison to provide a better picture of the impact of AFPs. Different research techniques were used and these included primary sources using household interview, key informant interview, field measurements and observations as well as secondary sources using meteorological data and literature. The analysis built on interpretations and processing of data collected.

Table 1: Data requirements and variable measurements

Variable name	Definition of indicators	Data collection techniques
Climate data		
1. Rainfall variability	– Rainfall trend and shifts or changes in rainy seasons	– Meteorological data – Climate database – interviews – Secondary data
2. Temperature variability	– Changes in mean monthly temperature	
Agroforestry Practices		
1. Tree characteristics	– Tree number, species and size	– Field observation and measurement – Interviews and informal discussion and observation
2. Arrangement	– Arrangement of tree components	
3. Livestock characteristic	– Livestock types and number	
4. Crop characteristics	– Crop types	
Household Sensitivity data		
1. HH demographics	– Household size, age, gender	– Household interviews – Expert interview – Field observation and measurements
2. Soil erosion analysis	– Soil erosion intensity of farms	
3. Energy-Fuel wood analysis	– Wood supply for energy from AFPs	
4. AFPs products	– Products from agroforestry	
Resilience data		
1. AFPs Income	– HH income from AFPs products	– Questionnaires – Informal discussions – Field observation – Resilience index
2. Diversification of income	– Number of HH income sources	
3. AFPs assets	– Trees, landholding, TLU and Crop production/ha	
Attitude and perception	– Indicators, effects and causes of climate variability – AFPs in managing effects of climate variability	– Interviews – Expert interviews – Likert scale – Informal discussions

(Illustrated by author)

3.4 Data collection

3.4.1 Secondary data collection

Assessment of climate variability over the last 15years

Rainfall data was obtained from the NEMA offices in Uganda. This data was in form of GIS images taken on a monthly basis from 2001 to 2016 for all parts of Uganda. For each month, three decadal (every 10 days) readings were taken. Because the year 2016 had data for only 3 months, it was not considered therefore only rainfall data from 2001 to 2015 was used in this research. Arc-GIS software was used in data processing to obtain rainfall readings for the study area. The study area delineated and later rainfall reading of that area were clipped for each decadal of each month of the year. To obtain a reading for the monthly rainfall amount, the three decadal readings of that month were added. Thus, the rainfall amount of each month was obtained in millimeters. Temperature data of Uganda over the last 15 years was also obtained in its raw form from the World Bank global climate database.

3.4.2 Primary data collection

Selection of study area and sample households

Prior to the main data collection, a reconnaissance survey was made in the sub-county of Kirumba. This survey aimed at collecting information on the boundary of the study area, the number of households in the study area and self-introduction to the sub-county headquarters. Would-be participants in the study were also identified and notified. Three parishes namely Buyiisa, Lwamba, and Kabwoko, in Kirumba sub-county were selected as case studies in this study (Figure 2). From three parishes, samples households including both VI agroforestry project beneficiary households and non-VI agroforestry project beneficiary households were selected.

VI households were purposively selected with the help of records from VI and a local expert. Generally, the target was to sample at-least 10% of the VI beneficiary households. In total, there were 51 VI households in the three parishes and they were all included in the study. Additionally, 51 non-VI agroforestry beneficiary households with similar socio-economic characteristics were selected to act as a counterfactual for estimating the impact of the project activities. To ensure that an unbiased sample is used, all non-VI farmer households in the three parishes were allocated numbers with the help of local extension worker and were randomly selected. In total, 102 households were considered in this study and the distribution in the three parishes is summarized in Table 2. Although this is a small sample compared to the total number of household in the area, this number was considered appropriate because according to Mbeyale (2007), a sample size of at least 30 units (households) is sufficient irrespective of population size. Also, the major target of sampling 10% of VI households in Kirumba was successfully met.

Table 2: Distributions of households in the three selected parishes of Kirumba sub-county

Parish	Total No. of households	VI samples	Non-VI samples	Samples taken
Buyiisa	1387	20	30	50
Lwamba	714	15	7	22
Kabwoko	612	16	14	30
Total	**2713**	**51**	**51**	**102**

(Source: Field survey)

Key informant interviews

Five key informant interviews were conducted in this study. According to Yin (2003: p.90) "key informants or experts are those who can provide the researcher with insights into a matter, suggest the source of corroboratory and contrary evidence and also initiate the access to such sources". Key informants and experts in this research included a VI agroforestry officer, a community leader, an extension officer and two elderly farmers. The main advantages of such interviews are that researcher can ask not only about the facts of the matter but also their opinions about events (Yin, 2003). Opinions, especially on climate events were very important to this study. Key informant interviews also provided invaluable information that was used for triangulating the outcomes from household surveys and observations made.

Household interviews

Household face to face interviews were conducted with farmers using semi-structured questionnaires in each household. They captured information on some sensitivity variables, resilience to climate variability and perception. Question aimed to collect information on socio-economic variables such as household demographics, education, skills and knowledge. Farmers were also asked about their income, assets, and uses of trees. The contents of questionnaires were first developed based on the literature reviews and conceptual framework of the research. However, before conducting surveys in the selected sub-counties, the questionnaires were pretested in one village and later revised to fit into the context of the local socio-economic situations (Questionnaire template in Annex 2).

Field observations and measurements

Field observations were done to obtain information on agroforestry practices in the study are and soil erosion intensity. The main emphasis was to get information on tree density/ stocking on farm, tree size measurement and identifying different tree species and their distribution on the farmlands. In order to obtain this information, the following procedures were used.

Tree characteristics: To know the tree density on the farm, all trees were counted with the help of household members present at the time of interviews. Household members helped in locating the farm boundary and in the counting of the trees. All species on the farm were identified by their local names with the help of household members. Trees that couldn't be identified on the farm were taken to the VI agroforestry expert for identification.

Tree size: Tree height and diameter were measured using the Sunnto clinometer and vernier caliper respectively. Because of the differences in the farm area of different households, a procedure for tree measurement for firewood estimation described by Gevorkiantz and Olsen (1955) was used. An area on the farm that is representative of where most firewood is collected was identified and a point was picked randomly. A circle of radius 11cm (37 feet) was measured from the point to represent 10% of an acre. The diameter at breast height (DBH) and height of all harvestable trees for firewood within the circle were measured. These values were later used in the estimation of the volume of trees on the farm.

Soil erosion: Soil erosion was classified using two on-farm observations, type of erosion present and intensity of observed erosion. In order to classify household erosion intensity, the type of erosion and strong indicators of erosion as identified by Okoba and Graaf, (2005) were used. An erosion intensity class was assigned to a household using an erosion classification tree developed by Vigiak et al. (2005) (Details in questionnaire in Annex 2). The observations for soil erosion intensity of a household were done in home-gardens and crop field excluding Coffee plantation and woodlots.

Farmers' perceptions: Farmers' perception of agroforestry practices and climate variability was measured using a five-level perception scale. In this scale, each item is scored from 5 to 1, with 5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, and lowest score 1 = strongly disagree.

3.5 Data analysis

The data were coded, categorized and analyzed using computer software packages MS Excel (2010) and R (RStudio.Ink). Quantitative data was analyzed by simple statistical tools such as frequencies, means and percentages and qualitative data information and attitudes were analyzed by ordering, and ranking with descriptive manner.

3.5.1 Climate variability

Rainfall variability was analyzed using time series regression analysis with R-software (RStudio.Ink). The trends and patterns of rainfall were depicted on a time series graph and regression analysis was performed to analyze the general trend. This approach is similar to the one described by Tesso et al. (2012). Since there was no sufficient literature about normal rainfall monthly amount or long-term average rainfall of Rakai district, five-year periodic rainfall average amounts from the available data were compared to analyze the shifts in dry and rainy seasons in the area. Line graphs were plotted using Excel to show the seasonal variability in average monthly rainfall amount received in the area over a period of five years. In fact, a similar procedure was used to analyze variability in rainfall in a study by Kashaigili et al. (2013). A similar procedure was followed to analyze changes in mean monthly temperature over the past 15 years.

3.5.2 Household sensitivity to climate variability

Fuel-wood sustainability

Fuel-wood volume used per year: The amount of money used on energy per month was expressed in terms of fuel-wood bundles by dividing the amount of money spent on fuel-wood by the unit cost of one bundle of firewood. The volume of a firewood bundle of known price in the area was estimated by the use of a water displacement method (Figure 5). With the volume of a fuel-wood bundle and number of bundles per month, the fuel-wood volume used monthly per household was calculated. The volume of firewood used per year was later calculated from the volume used per month.

Figure 5: Displacement method for firewood bundle volume estimation

Bundle of firewood *(A),* Displacement method in progress *(B & C)*

Estimation of standing fuel-wood volume: To estimate the volume of fuel-wood available to each household, the formula below was used; $Volume = \pi \frac{DBH^2}{4} * Hieght$

The value obtained represented a tenth of an acre and was therefore multiplied by the ten to get the acre value of the volume. This was then multiplied by the actual number of acres the household had and then expressed in hectare terms.

Fuel-wood sustainability: To estimate the sustainability of household fuel-wood stock, the number of years it would take to use the available fuel-wood volume was calculated. This was done by dividing household standing fuel-wood volume by its annual fuel-wood use volume. However, this doesn't put into consideration the increment in tree volume with years as well as the new stock from planting and natural regeneration. Farm trees grow on fertile agricultural soils with more nutrients and are also much more spaced compared to forest trees. Spacing and site index have a positive correlation with growth and increment of trees (Kabogozza, 2011). With these facts in mind, it was assumed that the increment of farm trees exceeds that of forest trees. Thus, in order to estimate increment per tree on farms in the study area, the maximum mean annual increment (MAI) of 45 $m^3/ha/year$ for eucalyptus trees with 75% stand density index in Uganda that was recorded by FAO (2001) was used. Following this MAI, an increment of $0.04m^3$per tree per year was used to calculate the additional volume in the subsequent years. An assumption that no trees regenerate is used since the factors that determine farmer's decision to plant are not known in this study. With these assumptions, in order for a household to be considered sustainable, the annual increment should be equal or more than the fuel-wood use volume.

Although coffee plants are used for fuel-wood in some cases, it was excluded in the calculation of fuelwood. This is because farmers take years without cutting them for fuel-wood. For that reason, only farm trees and woodlots were considered in this calculation.

3.5.3 Resilience index

The resilience index was used to analyze the role of AFPs in increasing resilience of farmers' to climate variability. Resilience index was analyzed with the aid of web diagram developed using units of resilience variables expressed on a scale of 1 to 5. Units for each resilience variables were obtained as described below.

Diversification of income sources; the unit for diversification of income sources of a household was based on the number of income sources it had. The higher the income sources, the higher the diversification potential of a household. The higher the diversification of income source, the more resilient the household is to climate variability.

Tropical livestock units; the TLU of a household were calculated based on conversion factors for tropical livestock described by Jahnke et al (1988). Each livestock type corresponds to a given unit as described in the table below. The higher the TLU of a household, the more resilient it is to climate variability.

Table 3: Tropical livestock units of livestock animals in Kirumba

Livestock	**Cow**	**Goat**	**Sheep**	**Pig**	**Chicken**	**Turkey**	**Duck**
Conversion factor	0.7	0.0	0.1	0.2	0.01	0.01	0.01

(Source: Jahnke et al., 1988)

Landholding; land holding per household per group was expressed on hectare basis and compared statistically. The land a household has, the more resilient

AFPs Income: Agroforestry income per household was a summation of annual income from all agroforestry products from a farm. The higher the income a household has, the more resilient it is.

Crop production per hectare; to estimate the effect of AFPs on crops, crop production per hectare of land owned by the household was used. This was obtained as a quotient of annual crop income and total land holding of a household.

4 CHAPTER FOUR: RESULTS

4.1 Socioeconomic characteristics of respondents

A total of 102 farmer households were visited and interviewed. Of these, 51 were VI farmer households and 51 were non-VI farmer households. The respondents were generally the head of households, otherwise mostly senior members, if the head was not available.

Of the household heads interviewed, 50% were between the 18- 39 years, 25% were above the age of 60 and the remaining 25% ranged between 18-39 years. Generally, a majority of the households were of middle age class. In the case of gender, 73% of the households were male headed whereas 27% were female-headed. The average household size consisted of 7 individuals, with an average of 3 adults and 4 dependents per household. Each household on average had 2.3 ha. On average, a VI household had more land (2.7 ha) than a non-VI household (1.9 ha).

Table 4: Socio-economic characteristics of respondents (N=102)

Characteristic	Variable	Frequency			Percentage
		VI	Non-VI	Total/average	
Age group	18-39	07	18	25	25
	40-59	29	23	52	50
	Above 60	15	10	25	25
Gender	Male	39	35	74	73
	Female	14	16	28	27
HH size	Average size	7	6	7	
	Dependents	4	3	4	
	Adults	3	3	3	
Land	Average land size (ha)	2.7	1.9	2.3	

(Source: Field survey, 2017)

4.2 Climate variability

4.2.1 Rainfall

Between 2001 and 2015, mean annual rainfall recorded was 1135mm. Examination of the monthly averages over this time span showed that the months of March and April received the highest rainfall amounts and the lowest amounts in the months of June and July.

Rainfall trend

In general terms, the trend shows that there has been a significant increase (p=0.000) in the amount of rainfall received from 2001 to 2015 (Figure 6). A regression analysis performed on the trend shows that it is significant (p= 0.00 and R^2= 0.36)

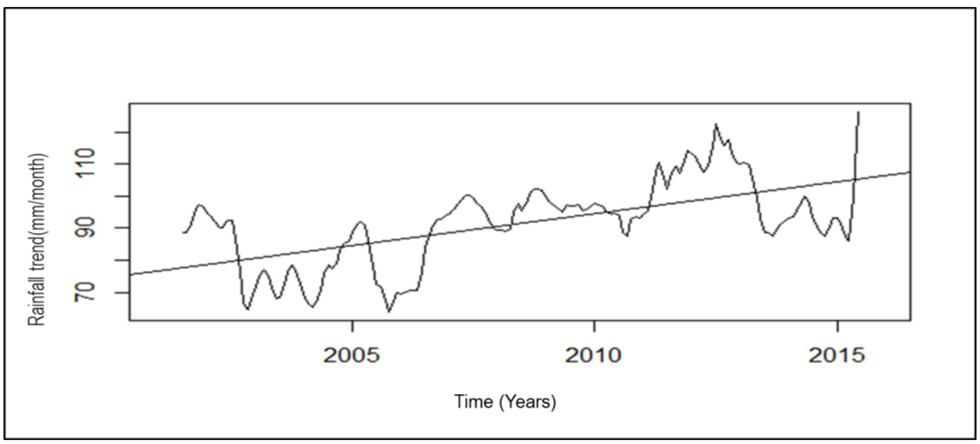

Figure 6: 2001-2015 rainfall time series and trend in Kirumba

(Source: NEMA)

Changes in rainfall patterns

The rainfall received in five-year periods of 2001-2005, 2006-2010 and 2011-2015 was 964, 1130 and 1311mm/year respectively which also indicates an increase mean annual rainfall over time. There is a shift in the mean monthly rainfall pattern between the period of 2001-2005 and 2011-2015 in graph D. The shift also indicates the dry season narrowed in the period between the 2011 and 2015. There is also a strong monthly variability for both periodic mean maximum rainfall with an increasing trend as illustrated in Graph B, C and D (Figure 7).

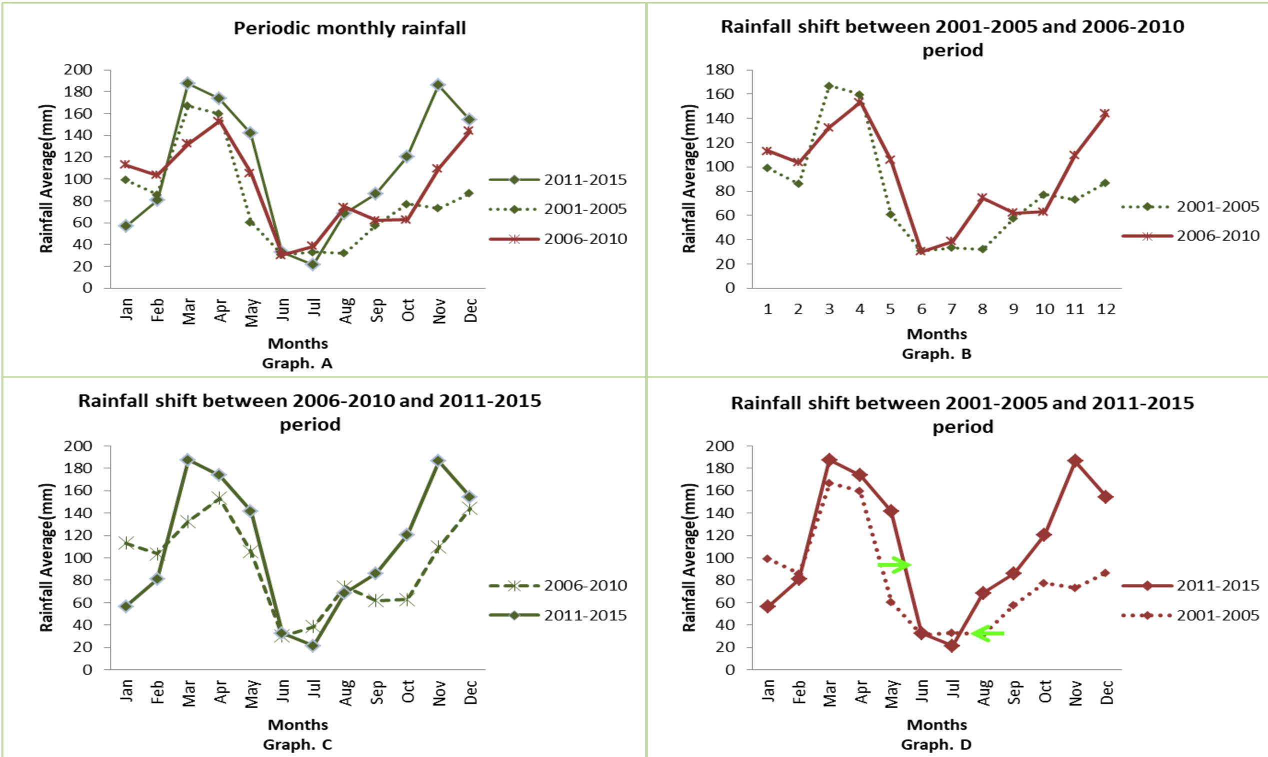

Figure 7: Shift in rainfall season between 2001 and 2015

(Source: NEMA, 2016)

4.2.2 Temperature

Periodic analyses of the changes in the mean monthly temperature show that there is a general decrease in the mean monthly temperature of Uganda in the last 15 years. This change is much visible in the comparison of periodic mean monthly temperature between 2001-2005 and 2011-2015 as illustrated in graph D (Figure 8). The maximum and minimum temperature lowered 25.8^{0}C and 23.0^{0}C to 25.3^{0}C and 22.2^{0}C respectively.

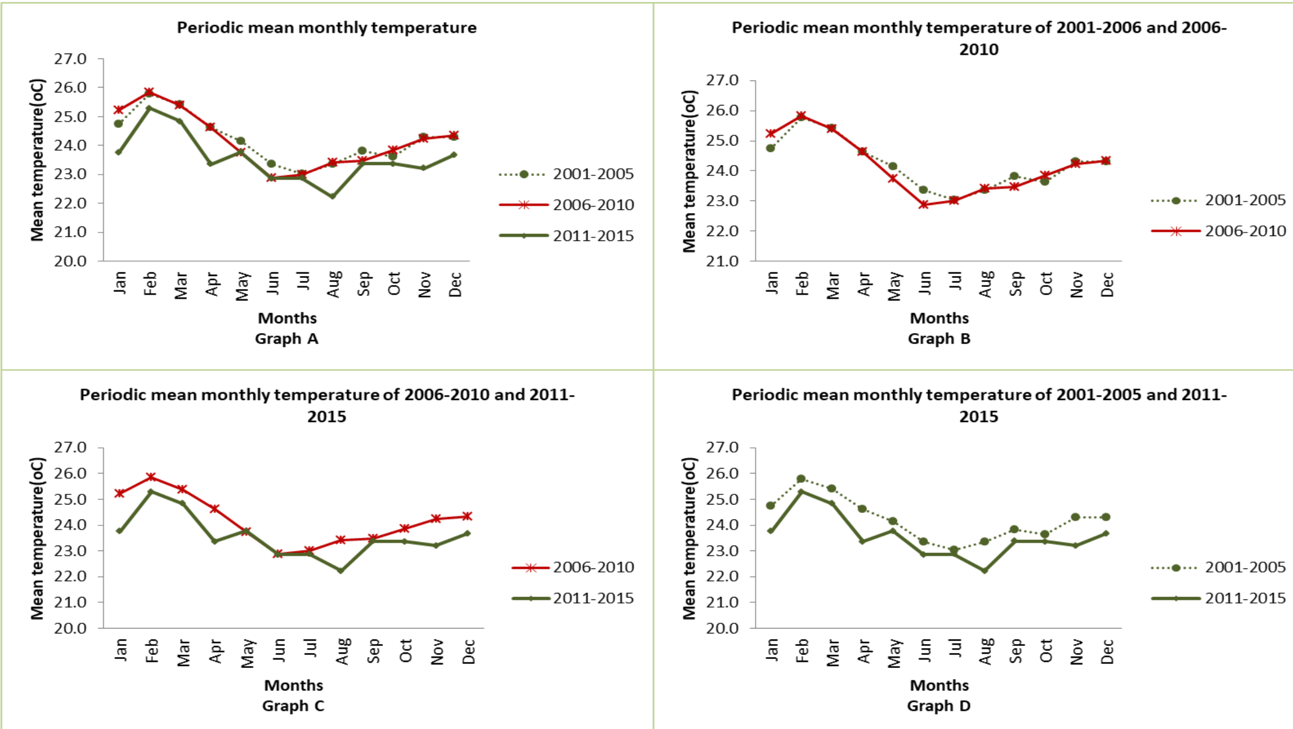

Figure 8: Changes in periodic mean monthly temperature in Uganda

(Source: World Bank global climate database)

4.3 Characteristics of agroforestry systems and its components

4.3.1 Characteristics of AFPs

Four agroforestry systems were identified in the area. These included; home-gardens, plantation crops, pastoral live fences, and woodlots. Home-gardens were registered in all households interviewed in the study area. Plantation crops were found in 40 VI households and 31 non-VI households whereas pastoral live fences were found in 24 VI households and 10 non-VI households. Woodlots on the hand were found among 9 VI households and 15 non-VI households. Home-gardens were the commonest AFS as they were registered in all 102 households while the least prominent AFS was woodlot plantation which was practiced by only 24% of all respondent households. Plantation crops and pastoral live fences AF practices are found mostly in VI households while majority of woodlots in the surveyed households were among non-VI households (Figure 9).

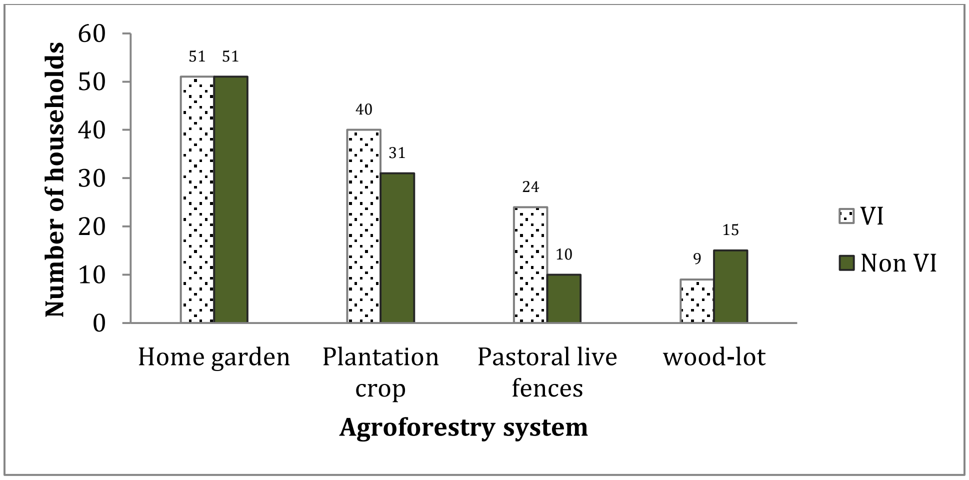

Figure 9: AFS in VI and non-VI households in Kirumba, Rakai

(Source: Field survey, 2017)

Home gardens

Home gardens in the study area consist of an assemblage of plants, which include trees, shrubs, cash crops, food crops, and vegetables (Figure 10). These grow in or adjacent to a homestead or home-compound. The size of the home-garden varied from one household to another. The average size of the home-garden is 0.2ha with a minimum and maximum size of 0.08 ha and 1 ha respectively.

Home-gardens were characterized with a multi-layered structure made of at least 3 layers. The upper layer is dominated by trees that are widely spaced. The most common species in this layer includes *Ficus natalensis, Persea americana* (avocado) and timber species such as *Grevillea robusta* and *Measopsis eminii.* The middle stratum comprises of mostly fruit tree such as *Mangifera indica, Artocarpus hetrophyllus*, and cash crops such as coffee. It also includes the climber-cash crops such as vanilla and passion fruits. The lower stratum includes mostly herbaceous plants and food crops like maize, beans, and vegetables such as Nakati, chillies and *Amranth spp*.

Domestic animals are also integral parts of the home-gardens that are managed by farm households. The major animals in the study area include; cows, goats, chicken and pigs. 98% of the domestic animals are enclosed and there is restricted entry into the farming fields. Usually, farmers use the "cut and carry" or zero grazing system to feed their animals. This is the system where green grasses and other edible tree leaf and branches, as well as crop residues after harvest, are carried and fed to animals.

Plantation crop

For both VI and non-VI households, the main plantation crop species is *Coffea robusta.* The size of the Coffee plantations varied from one household to another with the smallest covering an area of 0.04 ha while the largest one is 2.4 ha. The size of coffee plantation varied significantly between VI and non-Vi farmer households (Welch t-test p-value=0.001189). On average, a VI farmer had 0.6 ha whereas a non–VI farmer had 0.3 ha. The stocking of coffee plantations in this area varied from 300 to 700 trees per hectare which is low compared to the recommended of 1000 to 1200 trees per hectare. Traditional *banana spps* (matooke) are usually intercropped with the coffee plants (Figure 10). Trees such as *Ficus natalensis*, *Mangifera indica* and *Persea americana* as were also scattered within the plantation field.

Figure 10: Agroforestry systems in the study area

A) Home-garden B) Plantation crop

Woodlots

All woodlots in the study area comprised of Eucalyptus species stands. The dominant eucalyptus species grown is *Eucalyptus grandis* and *Eucalyptus camedulensis* or a combination of the two. The size of the stands varied from one household to another. The average size of woodlots encountered was 0.6 ha with the smallest woodlot size of 0.08 ha and the biggest of 3.2 ha. Majority of the woodlots in the study area were below seven years of age and were almost fully stocked with at least 700 trees per hectare. Older stands of 12 years and above in the study area had been heavily selectively logged and have less than 400 trees per hectare.

Pastoral live fences

Pastoral live fences are trees and shrubs planted for the purpose of acting both as a fence and fodder for livestock. In the study area, these are planted around fields especially home-gardens. They are a source of fodder for the livestock and also restrict entry of animals into the garden especially during the planting season. The major woody perennial species for pastoral live fences include *Calliandra, Accacia* and *Ficus natalensis*.

4.3.2 Agroforestry components

Tree characteristics

All farmers in the study area had at-least one woody species on their farm which included coffee perennials, woodlots and farm trees. The average stocking of farm trees per hectare is 36 trees with a minimum of 5 trees and a maximum of 200 trees. VI farmers have significantly higher number of such trees per hectare than non-VI farmers (P-value<0.05).

48 woody species were registered in the study area (Detailed list in Annex 3). These included fruit trees, timber trees and multipurpose trees and shrubs. On average, the least number of tree species recorded on a farm was 2 and the maximum was 18 species. The size of the trees varied from one species to another. The largest farm tree recorded in the study area was *F. natalensis* with a DBH of 43.3cm while the smallest tree was of citrus species with a DBH of 2.5cm. The tallest tree recorded on the other hand was *Grevillea robusta* with a height of 24m while oranges still had the shortest height of 4m. Of all the trees measured, 90% fell into diameter classes 10-20cm.

All households had at least one fruit tree. The commonest fruit tree was *Persea americana* which is found in 95% of all households interviewed. Other frequently recorded fruit trees included *Mangifera indica (84%)* and *Artocarpus heterophyllus (87%)*, *Citrus spp (28%), Psidium guajava (49%), Vangueria apiculata (19%).* Fruit trees were mainly planted near the home compound and home-garden for protection from outsiders. They also regenerated naturally in crop field far away from the homestead.

The most frequent timber tree species registered was *Ficus natalensis* which was registered in over 93% of all households. It was planted all over the farm because of its functions for example bark-cloth, leaves for manure and firewood. It was also found in the household compound for shade. Other frequent timber tree species included *Measopsis eminii (44%)* and *Grevillea robusta (*33%), which were mainly randomly planted in coffee plantations and on the farm boundary.

Certain species were more common in VI households than in the non-VI households. These were the tree species given by the VI agroforestry project such as *Grivellia robusta, Eriobotrya japonica,* and *Measopsis eminii* (Figure 11).

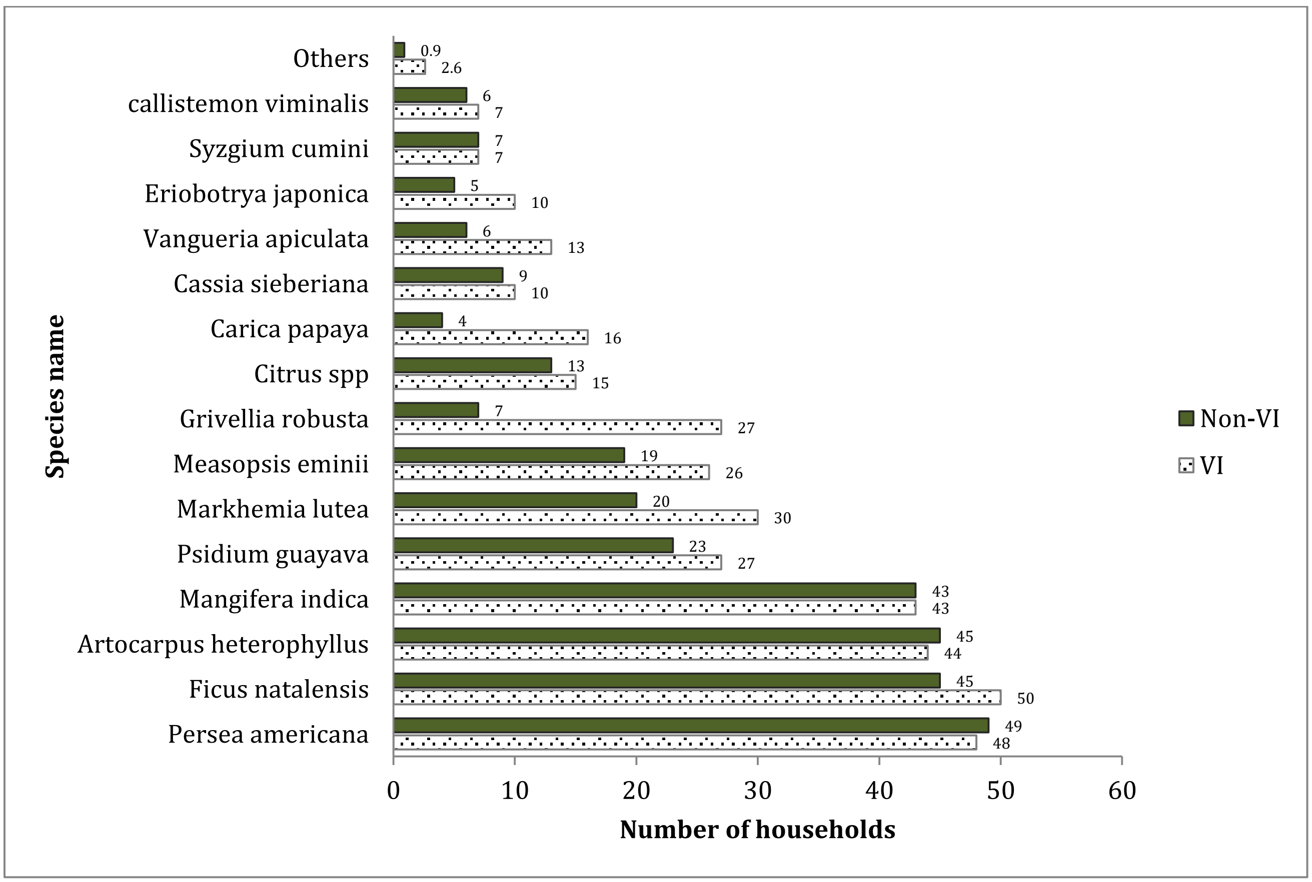

Figure 11: Dominant species in VI and non-VI households

(Source: Field survey, 2017)

Dominant tree species in the study area had a variety of functions ranging from provision for products such as fruits, firewood, fodder and services such as shade, nitrogen fixation, among others. Table 5 summarizes the products and services obtained from the 8 dominant tree species that are preferred for planting by at least 30% of the households in the area.

Table 5: Functions and uses of the dominant tree species planted in Kirumba

Scientific name	Local name	Frequency	Uses
Persea americana	Avocado	95	Fruit, firewood, fodder
Ficus natalensis	Mutuba	93	Medicine, shade, fencing, bark cloth, fodder, timber, manure, nitrogen fixer
Artocarpus heterophyllus	Ffene	87	Fruit, firewood, shade, lorry bodies
Mangifera indica	Muyembe	84	Fruit, shade, fodder, firewood, medicine
Psidium guayava	Mupeera	49	Fruit, firewood
Markhamia lutea	Musambya	49	Poles, timber, firewood
Measopsis eminii	Musizi	44	Timber, firewood, shade
Grivellia robusta	Grivellia	33	Timber, firewood

(Source: Field survey, 2017)

Livestock characteristics

Of all household interviewed, 95.1% had livestock while only 4.9% didn't have. Seven different types of livestock identified in the study area and these included goats, cows, sheep, chicken, pigs, turkey, and duck. The most dominant livestock type in the study area is pigs and chicken found in 78% and 60% of all households respectively. The least common livestock types in the area are sheep (1%) and turkey (1%) (Figure 12). One household has 1.8 TLU on average and in comparison; VI households have more livestock (2.1 units) than non-VI households (1.6units).

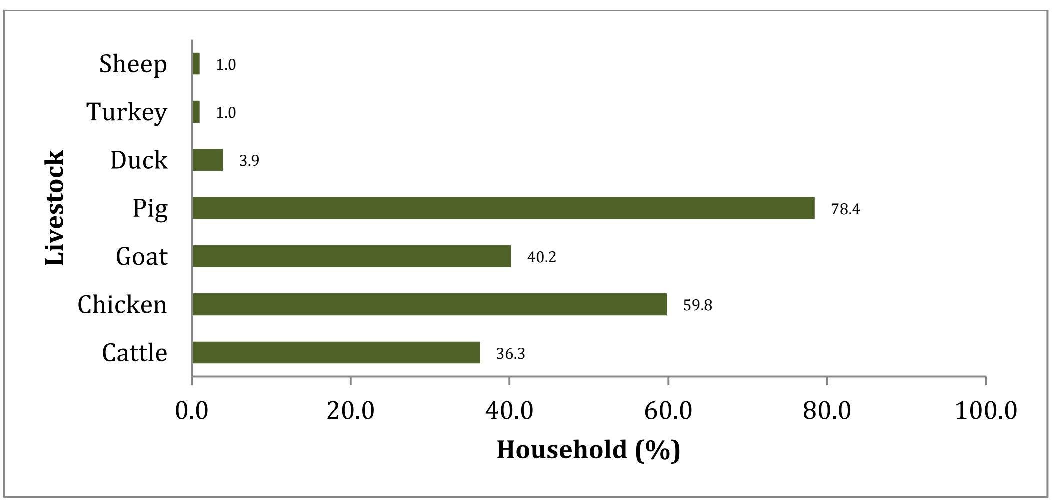

Figure 12: Frequency of livestock in Kirumba

(Source: Field survey, 2017)

Crop characteristics

Both cash crops and food crops are grown in the area. All respondent households cultivated at-least 5 types of crops mainly for subsistence use. Maize, local banana, beans, sweet banana, groundnuts and cassava comprised a list of major food crops in the area. Farmers usually intercropped 2-3 food crops but in some cases, certain food crops such as, sweet potatoes and maize are cultivated as mono-crops particularly during the growing season. Other food crops included vegetables such as chillies, *Amaranth spp., nakati*.

The major cash crops included coffee, vanilla, tomatoes, pineapples, passion fruits and watermelons. Vanilla was usually grown within the home garden but other cash crops were usually grown as mono-crops.

4.4 Farmers' sensitivity with AFPs

4.4.1 Land

The average land holding per household in the area was 2.3 ha. There is no significant difference (p=0.054) between the landholding of VI and non-VI households (Table 6).

4.4.2 Trees products and services

All households in the study area had at least one tree on their farms. VI households (42) have significantly higher number of trees than non-Vi households (P=0.000) than non-VI households (20) (Table 6).

Figure 13: Some of the agroforestry products from farms in the study area

A) Papaya fruits B) F. natalensis timber C) F. natalensis bark cloth

Various products and services were derived from trees (Figure 13). Fruits were the major products received from trees and were reported by 88% of all respondent households while the main service received from trees is shade which was reported by 18% of all respondents. Other products from AFPs included bark cloth, firewood, and fodder and were reported by 75%, 86% and 28% of all respondents respectively. Timber, medicine, and manure were also reported by 13%, 6% and 5% of the interviewed households (Figure 14).

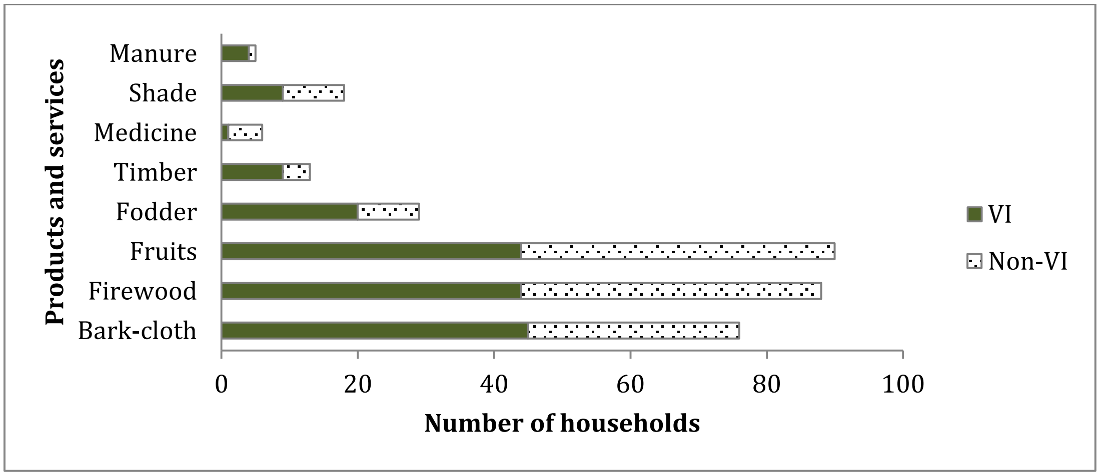

Figure 14: AFPs products and services for VI and non-VI households

(Source: Field survey, 2017)

4.4.3 Erosion intensity

Farmers in Kirumba recognize the need to control soil erosion. Contours and mulching are the main erosion control methods used in the study area (Figure 15). 84% of all households had contours on their farms while 57% practiced mulching.

Figure 15: Erosion control methods practiced in Kirumba

Mulching (A), Contours (B)

Generally, 86% of all household agree that AFPs are very good in reducing soil erosion. Only 5% of all respondent households reported that AFPs are poor in preventing soil erosion. 49 out of the 51 VI household interviewed agree that AFPs are good in preventing soil erosion.

From the field observations made on the farm, 81% of all households in the study area experience very-low to moderate erosion with the majority (40%) falling under the "low" erosion class. Only 19% of the households interviewed high to very high erosion. VI households registered more numbers in the lower erosion class (from very low to moderate) compared to the Non-VI households. Non-VI households had more numbers in the higher erosion classes (from high to very high) than VI households (Figure 16).

There is no association between the number of trees per hectare and the erosion class to which the farm belongs (chi-square test, P=0.7849) (Table 6). This implies that the stocking does not influence erosion thus raising questions on the role of trees in erosion control in the study area.

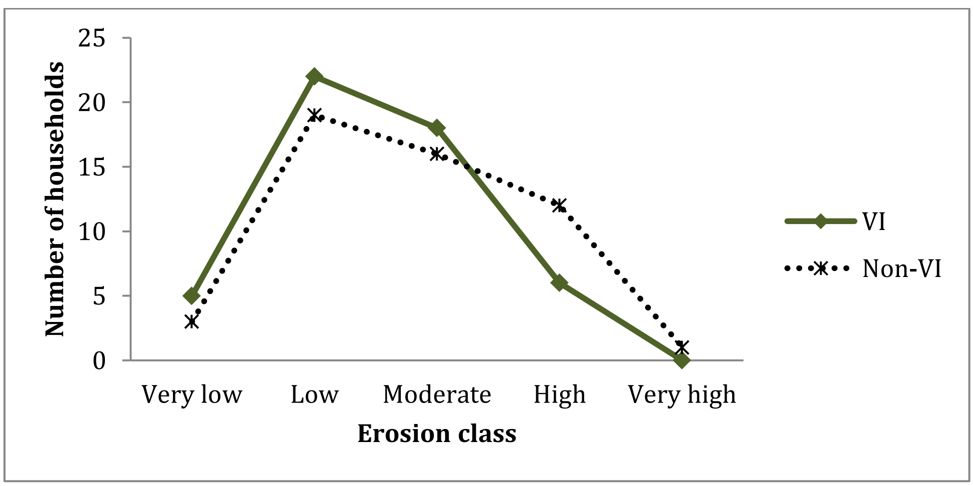

Figure 16: Comparison of erosion classes of VI and non-VI households

(Source: Field survey, 2017)

4.4.4 Fuel-wood energy use

Out of the 102 respondents interviewed, 76% get fuel-wood exclusively from the farm. The remaining 24% obtain fuel-wood from the market or the forest or bush or a combination of two of three. 86% of the households rated AFPs as good sources of fuel-wood when asked to rate AFPS in providing fuel-wood whereas only 5% rated it as poor fuel-wood.

The average fuel-wood energy amount used per households per month is equivalent to $18.5. The minimum amount used per household is equivalent to $2.8 while the maximum is $41.7. Variation in fuel-wood use is mainly determined by the family size (Pearson's correlation: P=0.00). However, there is no significant difference between the amount of energy used for cooking in VI households and non-VI households. 81% of the households in the study area do not pay for the cooking energy. 28% of the non-VI farmers paid for the cooking energy used in their home while only 10% of the VI farmers paid for cooking energy.

On average, each household uses 21.6 m^3/year. The highest standing fuel-wood volume recorded on a household was $237m^3$/ha while the lowest was $6m^3$/ha. VI households generally showed significantly higher (p=0.00251) fuel-wood sustainability than the non-VI households (Table 6). On average, a VI household can use their standing fuel-wood stock for 8 years while a non-VI household for 3 years. The average increment on VI households is $7.5m^3/year$ while on non-Vi households is $1.3m^3$/year. These increment values are less than the annual fuel-wood use which indicates that both household groups are generally unsustainable (Details in Annex 5).

The following table summarizes the results of the statistical comparison of sensitivity variables of VI and non-VI households and their level of significance.

Table 6: Summary of statistical tests on farmers' sensitivity in Kirumba

Sensitivity variable	VI household (Median score)	Non-VI household (Median score)	Test	P-Value/ significance
Trees/ hectare	42	20	Man-U test	0.0000***
Land (ha)	2.00	1.60	Man-U test	0.05439*
Fuel-wood stock (years)	3.35	1.38	Man-U test	0.00251***
Erosion intensity (Category)			Chi-square	3.837*

(N=102) *** Highly significant (P-value=0.01), ** Significant (P-Value=0.05), * Not significant (P-Value>0.05).

4.5 AFPs in increasing resilience to climate variability

4.5.1 Diversification of income sources

The farmers in the study area have both on-farm and non-farm income sources. 54% of the households are involved in only on-farm activities while 46% are involved in both on-farm and non-farm activities. Majority of VI farmers (32 out of 51) are involved in on-farm income activities than non-farm sources (19 out of 51). For non-VI, 29 out of 51 farmers interviewed are rather involved in non-farm activities and 22 out of 51 are involved in on-farm (Table 7). From this, it's clear that non-farm activities are of more importance to non-VI households than to VI.

Table 7: Income sources farmers in Kirumba

Group	Income source		Total
	On-farm	On-farm and Non-farm	
VI	32	19	51
Non VI	22	29	51
Total	54	48	102
Percentage	53.9	46.1	100

(Source: Field survey, 2017)

Of all household interviewed, 77% reported to receive most income from agriculture. Only 2% of the households have civil work as their major source of income while others are mainly engaged in business work or both agriculture and business. Although many non-VI households have non-farm work, only a small percentage of 21% (6 out of 29) manage to balance between non-farm and on-farm work. On the other hand, 7 out of 19 (37%) of the VI households with both on-farm and non-farm work manage to balance outcomes from both income sources (Figure 17).

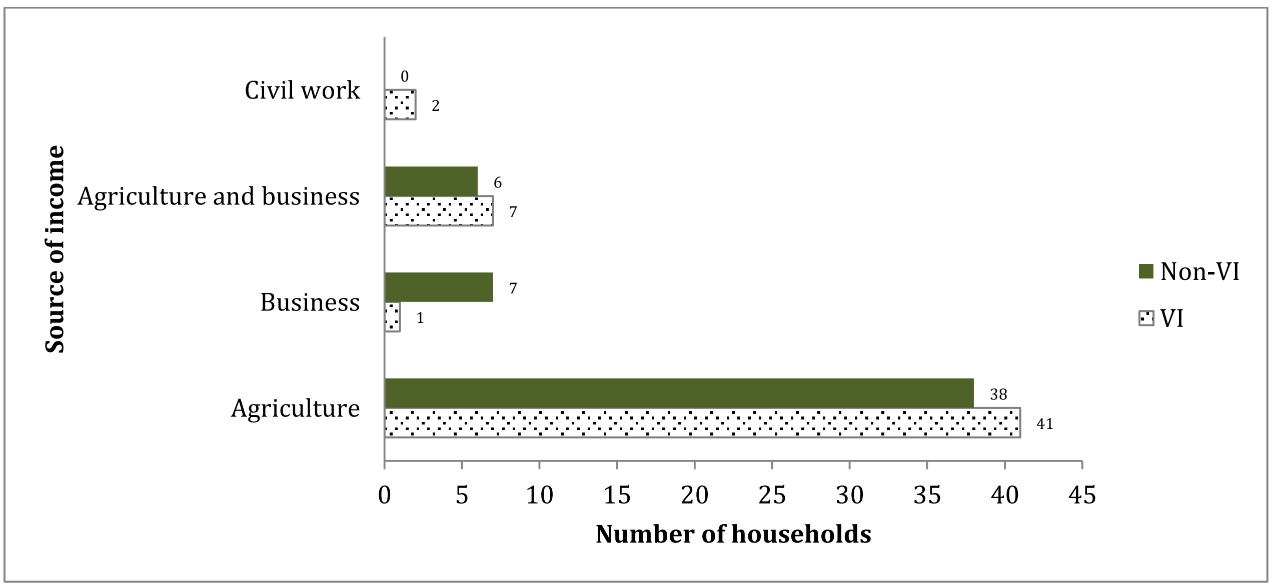

Figure 17: Source of most income for VI and non-VI households

(Source: Field survey, 2017)

4.5.2 Income

Total income

Majority of the households (53% of all households) reported receiving a total monthly income ranging from $28-$83. Calculation of household's average total monthly income revealed that the monthly income of VI households is $86.59 and that of non-VI households is $69.72. This equates to an average annual income of $1039.06 and $836.59 for VI and non-VI households respectively (Details of calculation in Annex 6).

Agroforestry income

Agroforestry income is generated from the sale of timber, firewood, poles, fruits, livestock, and crops. The annual income from agroforestry is $1026.3 for VI households and $642.89 for non-VI households. Most income was generated from selling crop while the least income was from selling bark-cloth for both farmer groups (Table 8). The agroforestry annual income received by VI households is significantly higher p=0.0016 than that received by non-VI households (Table 9).

Table 8: Household agroforestry income

(USD 1 is equivalent to UGX. 3600)

Agroforestry product	VI per annum income(USD)	Non-VI per annum income(USD)
Livestock	234.61	181.10
Crops	632.09	410.59
Fruits	11.11	7.64
Timber/poles	53.24	34.72
Bark-cloth	21.17	8.85
Firewood	74.07	0.00
Total	1026.30	642.89

(Source: Field survey, 2017)

Agroforestry income constitutes 98.9% of the total household income for VI households and 76.9% of the total annual income for the non-VI households. This indicates that VI households are more dependent on AFPs than the non-VI households.

4.5.3 Agroforestry assets

Land, trees, livestock, and crops were the major assets found in both VI and non-VI households in Kirumba. VI households in the area generally had higher land holdings and significantly more trees than non-VI households as reported in the previous section 4.4. In the case of livestock, VI households had 2.1 TLU on average which was higher than that of non-VI households who had 1.6 TLU (section 4.3.2). A Man-U Whitney test to compare the difference in the median of the TLU of the two farmer groups revealed it was highly significant at p=0.0004. Also, crop yield per hectare was highly significant (p=0.0018) among VI households ($145.8) than in non-VI households ($43.4) (Table 9).

Table 9: Statistical tests on farmers' resilience in Kirumba

Resilience variable	VI household (Median score)	Non-VI household (Median score)	Test	P-Value/ Significance
Assets				
Trees/ hectare	42	20	Man-U test	0.0000***
Land (ha)	2.00	1.60	Man-U test	0.0544*
Livestock (TLU)	1.59	0.60	Man-U test	0.0004***
Crop yield/ha (USD)	145.8	43.4	Man-U test	0.0018***
Income				
AFPs income(USD)	504.2	201.4	Man-U test	0.0016***
Diversification of income (Count)	19	29		

(N=102) *** Highly significant (P-value=0.01), ** Significant (P-Value=0.05), * Not significant (P-Value>0.05).

4.5.4 Resilience index

A radar diagram (figure 18) was used to display the difference in the resilience index of VI and non-VI households (Annex 7). From the diagram, it's clear that the VI-households web is bigger than the non-VI web at all variables except for diversification of income sources.

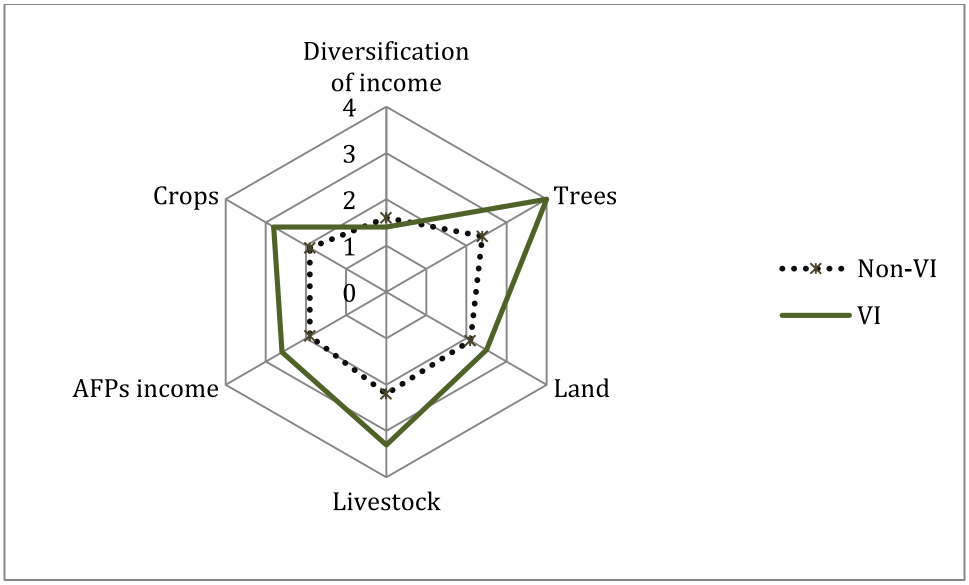

Figure 18: Radar graph showing resilience index of VI and non-VI households

(Source: Field survey, 2017)

4.6 Perception of farmers to AFPs and climate variability

4.6.1 Indicators, causes and effects of climate variability to farmers in Kirumba

All households interviewed reported experiencing drought or a period of prolonged dry spell as an indicator of climate variability. Of these households, 8% also reported having experienced a period of prolonged rainfall period where rainfall comes earlier than expected

Causes of climate variability

The major activities that were reported to cause climate variability by the interviewed households were swamp drainage for agriculture and deforestation. Other causes of climate variability reported included destroying the environment, use of solar, fertilizer use and population increase. Four respondent households do not know the cause whereas six of them think its nature taking its course. The graph in Figure 19 summarizes the different causes of climate variability reported by VI and non-VI household.

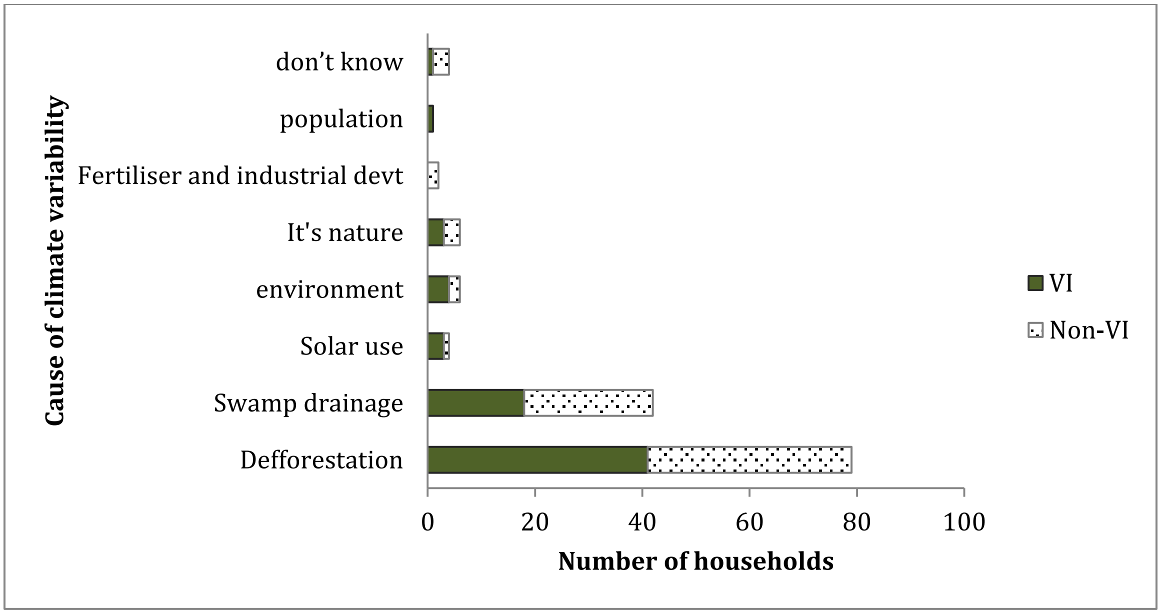

Figure 19: Causes if climate Variability

(Source: Field survey, 2017)

Effect of climate variability

The main effect of climate variability experienced by farmers is decrease in crop yield as a result of crops drying or rotting. A few respondents (7%) also reported an increase in crop yield as a result of prolonged rainfall (Table 10).

Table 10: Effect of droughts on farm households in Kirumba

Climate variability	**Effect on the farm**	**Frequency (N=102)**			**Percentage (N=102)**
		VI	**Non-VI**	**Total**	
Drought	Crops dried	37	29	66	64.7
	Low yield	28	25	53	52.0
	Famine	20	19	39	38.2
	Water shortage	7	4	11	10.8
	Diseases increase	4	2	6	5.9
	Animals died	0	3	3	2.9
Prolonged rainfall	Plant disease and rotting	3	3	6	5.9
	Low yield	2	4	7	6.9
	Increase yield	4	3	7	6.9

(Source: Field survey, 2017)

4.6.2 AFPs in managing effects of climate variability

The households in the study area manage the effects of climate variability in different ways. The highest percentage of the households manages climate variability effects with savings (82%), livestock (38%), store food (29%) and timber (15%). A small percentage manages with loans, irrigation, and fruits which comprised of 2%, 2% and 4% respectively (Details Annex 8).

When asked whether agroforestry helps in climate hazard management, 81% of all respondents agreed to this and only 2% disagreed while the remaining 17% were not sure whether it helped or not. Agroforestry products and services such as fruits, firewood, timber, bark-cloth, and shade were reported as ways in which AFPs help in managing climate hazard. 66 out of 102 households reported that provision of shade during drought is major way in which AFPs help in climate hazard management (Figure 20).

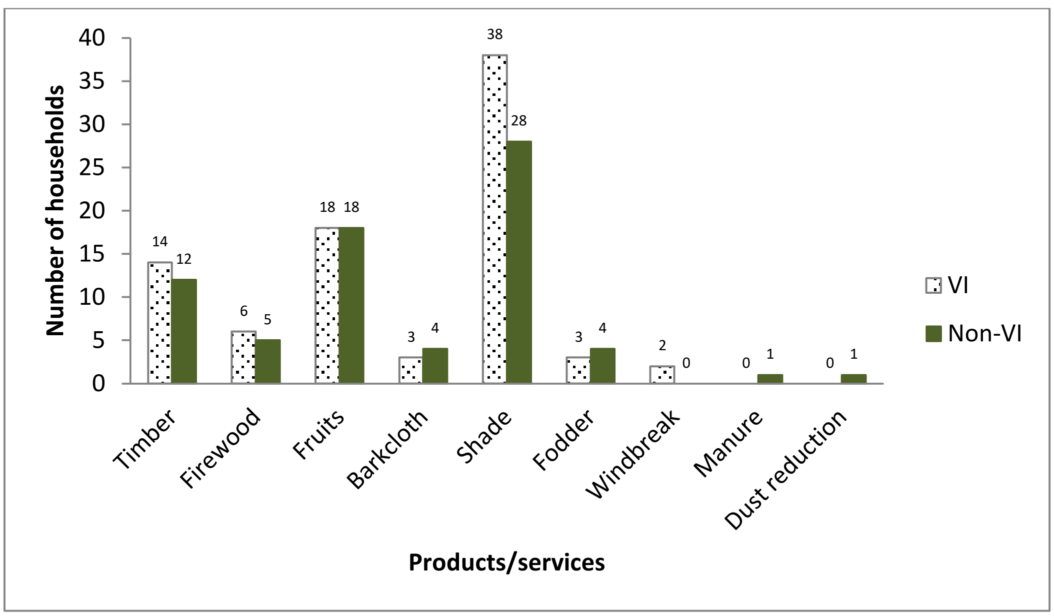

Figure 20: AFPs products and services that contribute to management of climate variability

(Source: Field survey, 2017)

5 CHAPTER FIVE: DISCUSSION

5.1 Climate variability

The results of the study reveal that there has been climate variability in Kirumba with increasing rainfall and decreasing mean annual temperature. These observations are in contrary to mainstream climate effects reported by most studies in literature which mainly indicate increasing drought which relates to reduced rainfall and increasing temperature (Mwaura et al., 2014; Zinyengere et al., 2016). Physical evidence of increasing rainfall and decreasing temperature is also lacking in Kirumba. Whereas rainfall and temperature changes as one observed in Kirumba should be ideally beneficial to the agricultural production of rural communities, farmers have a high perception of drought as an indicator of climate variability. This is probably as a result of its overall impacts on crop, livestock and tree production and considering that even small changes may disturb the overall farm and tree productivity (Hepworth et al., 2008). Moreover, the main effect of climate variability that the farmers in Kirumba reported experiencing is the drying of crops which is a result of drought conditions.

Human activities are also responsible for the increase in drought vulnerability in rural areas (Shiferaw et al., 2014). Increasing population growth in drought-prone areas increases unsustainable land and resource use which increases drought sensitivity (ibid). In Uganda, a population growth rate of 3.3% has been seen with increasing land fragmentation which makes a small increase in temperature and rainfall deficient very hard for farmers to deal with. Additionally, the OPM in Uganda reports that the cattle corridor is one of the most affected areas by drought as it decreases potential grazing land (GOU, 2012). Part of Rakai district lies within the cattle corridor which is characterized by high rainfall variability and the periodic late onset of rainfall and drought (McGahey and Visser, 2015; Rakai district development plan, 2010-2013).

Although physical evidence of increasing rainfall is lacking in Kirumba, many reports have indicated increasing rainfall in other parts of Uganda. For example, in 2007, there were recurrent floods in many parts of Uganda which included mainly the Northern and Eastern districts and scattered areas in Central Uganda (IFRC, 2007). Heavy rains in 2013 caused the banks of the Nyamwamba River and resulted in flooding in Western Uganda's Kasese district (IFRC, 2013). Landslides triggered due to heavy rainfall were experienced in Kasese, Buduuda and many parts of Eastern Uganda in 2005, 2010 and 2011 (ibid). Hepworth et al. (2008) also reported that Uganda would experience increases in extreme precipitation in their study on the implications of climate change in

Uganda**.** The results also revealed that rainy season shifted and rainfall is received earlier than before in some months. This is a typical observation in Uganda nowadays; rainfall comes so early that farmers cannot use the local knowledge to determine the onset of growing season and consequently, their harvest if affected (Mwaura et al., 2014).

Only a handful of households in Kirumba reported prolonged rainy season as a one of the climate variability they experienced. Although extreme rainfall events such as flood and landslide cause adverse and sudden impact in the places they occur, the overall increase in rainfall occurrence has been beneficial for crops and pastoral conditions and is often ignored (OCHA, 2013).The major disadvantage of the prolonged rainy season that farmers in Kirumba experience is rotting of crops. This was reported by just a few individuals indicating that the losses via this problem are quite negligible.

5.2 Agroforestry practices in Kirumba

Farmers in Kirumba practice several agroforestry systems which implies that they are involved in the multiple land use management involving a mixture of crops, trees/shrubs, and animals. Sebukyu et al. (2012) reported similar findings in the study on adoption of agroforestry by farmers in Masaka district. All households in Kirumba have home gardens comprising of a wide range of crop and tree and are basically for households subsistence needs. Growing a wide range of crops and shrubs in home-gardens for subsistence use is a risk-averse method that farmers use to cope with climate effects. Most studies on agroforestry systems in the Uganda also report similar uses of home-gardens in the various districts of Uganda (Okullo et al., 2003; Sebukyu et al., 2012).

Coffee plantation crops were found to be dominant in Kirumba. Coffee is a major cash crop grown by 500,000 farmer households in Uganda (Verter et al., 2015). 90% of the coffee is grown on small-scale landholding of 0.5 to 5acres at “low input” and “low output” levels, often intercropped with beans and bananas for food security (Kamugisha, 2006) It is no wonder that the study revealed that it was the most dominant cash crop in the Kirumba. Moreover, in Uganda, coffee is mainly cultivated in the central and southern districts (57%), Eastern Uganda (23%) and Western Kasese (10%) and to a lesser extent, in areas like Mpigi, Wakiso, and Rakai (10%) (Verter et al., 2015). The stocking of coffee was low compared to the recommended of 800 to 1000 trees per hectare. This is because the traditional coffee-banana system is practiced in the area and the spacing between coffee trees increases. Many farmers also claimed that the recent drought period experienced left some coffee trees dry and therefore these were removed selectively.

Another agroforestry system in Kirumba was woodlots. Due to the increasing demand for wood for fuel-wood and poles for construction, woodlots have been widely established on many farms in various parts of Uganda (Kabogozza, 2011). Woodlots have become popular among development agencies in Africa as a means of improving fuel-wood supply to rural communities and generating income for households (Jacovelli & Caevalho, 1999 cited in Buyiinza et al., 2008). One of the approaches for tree planting encouraged by VI agroforestry was rotational woodlot. The study, however, revealed that most woodlots in the study area were found among non-VI households. Different studies in developing countries have also stressed a scarcity of fuel-wood as one of the key factors to motivate farmers in adopting rotational woodlot technology (Buyiinza et al., 2008; Kabogozza, 2011). Similarly, the growing knowledge of future fuel-wood shortage among non-VI households is a possible motivation for woodlots establishment.

Farmers tend to avoid planting trees that may have negative effects on the production of other conventional agricultural crops. VI farmers were generally biased about planting Eucalyptus- the most common woodlot species in the area, on their farms. They mentioned that eucalypts dry all crops around them. This is the commonly known allelopathic effect of eucalyptus described in the literature and it is widely considered to be one of the causes of biodiversity reduction in *Eucalyptus* plantations (Chu et al., 2014). Pine which is the other dominant plantation species in Uganda was avoided on the farm because it's repellant effect on insect pollinators.

Nonetheless, the average woodlot size of VI household was almost double the size of that in non-VI households. The possible explanation for this is the relation to the landholding of the two farmer groups. VI household with more land can allocate more land to woodlots than non-VI households. Additionally, non-VI households mainly used woodlots for fuel-wood production while VI-households used woodlots for production of poles and timber. Whereas the latter requires intensive management with strict silvicultural practices, the former is a not as strict and therefore easy to manage. This could be another difference in woodlot plantation frequencies and size for the two farmer groups.

The preferred tree species in Kirumba notably *Persea americana*, *Artocarpus heterophyllus, Mangifera indica* and *Ficus natalensis* have variety of functions that are of importance to rural households. Many studies also stress that the most preferred agroforestry species in the tropics are the ones that yield various functions on the farm (Kyarikunda et al., 2017; Pandey et al., 2016; Sebukyu et al., 2012). Kyarikunda et al. (2017) reported that the priority tree species for agroforestry are multipurpose that yield various products such as edible fruits, timber, construction, and firewood. Sebukyu et al. (2012) also found *Persea americana* and *Mangifera indica* as some of the most planted agroforestry tree species in Masaka. Households practicing agroforestry prefer planting local tree species suitable for fodder and fuel-wood production for household consumption (Pandey et al., 2015).

5.3 Role of AFPs in reducing sensitivity to climate variability

Practicing agroforestry plays a role in reducing the sensitivity of farmers by reducing soil erosion, increasing fuel wood requirements and increasing the capital stock of trees and land as discussed below;

5.3.1 Land

VI households had more land than non-VI household which indicates that they are less sensitive to climate variability. Agroforestry has been shown to improve farmers' incomes in a number of different ways such as through fruit and timber sale (Sanchez et al., 1997). This income may have been used by the VI farmers to acquire more land hence the higher landholding they have at the moment (ibid). However, the difference in landholding may also be attributed to the fact that household with more land were naturally selected during the implementation of the VI agroforestry project leading to pre-selection bias. A study done by Pandey et al. (2015) also revealed that households practicing agroforestry almost have double the land as those that do not. Famers with more land tend to have a lot of fallow lands that they can easily allocate to tree planting and therefore will show more interest than those with low land holding (ibid). However, since the VI agroforestry project targeted households with 0.5 to 5 acres, there is a possibility that there was no pre-selection bias but this cannot be completely ruled out.

5.3.2 Trees

Trees yielded different products and services such as fruits, firewood, bark-cloth, fodder, shade and manure that are essential for household well-being in Kirumba. Similar results have been reported by several studies on the use of agroforestry trees (Nair., 1993; Pandey et al., 2016; Linger, 2014). VI households who had more trees on their land essentially had more natural capital than non-VI households and hence less sensitive to climate variability. This is because they managed to plant more trees with VI agroforestry project which non-VI household didn't. This may also be because the former had more land than the latter as Pandey et al. (2016) argued that households with more land have the ability to sustain more trees than those with low landholdings.

Farmers recognize trees are important in buffering against drought and floods. Modification of temperatures by providing shade and shelter was the most frequent response to ways how trees help in the period of drought. This observation is consistent with other studies on the multifunctional role of trees by sustaining production during wet and dry seasons (Smith, 2010; Sanchez et al., 1997). Trees are less sensitive to extreme weather conditions than non-perennial plants (Sanchez et al., 1997).

On the other hand, trees can also contribute to the increase in the sensitivity of farmer households. Farmers reported that calliandra species had become invasive and hard to control. Calliandra was introduced for fodder in VI households by the VI agroforestry project. However, at the time of the research majority of the households had already cut it because of its invasiveness. The VI agroforestry officer attributed the problem of invasiveness to mismanagement by the farmers. He pointed out that constant pollarding for fodder and firewood was necessary to avoid this problem. Other studies have also reported that having trees on the farm can impact on its productivity. For instance, a dense canopy of trees that inhibits light access can affect crop growth (Mbow et al., 2014; Nair, 1993)

5.3.3 Erosion intensity

Farmers in Kirumba recognize soil erosion as a problem and they invest a lot of time to put in place control measures such as contours and mulching. They also perceive that AFPs are important in preventing soil erosion. This finding is similar to those presented by Okoba and Graaff (2005), who report that farmers consider soil erosion a problem although it may not be the priority.

The erosion intensity is generally low in the study area for both groups of household because of the erosion control methods practiced by both groups. This is owed to the training in soil conservation which was received from various projects in the area such as VI agroforestry and Masaka Diocesan Development Organisation (MADDO) project. VI-households showed slightly better erosion classes than non-VI households although this difference wasn't significant. The Soil conservation practices disseminated by the projects involved the use of simple techniques that could easily be adopted by farmers. It therefore of no wonder that farms of both VI and non-VI households had generally low erosion intensities. However, its also worth noting that VI households had a double opportunity of training in these practices and hence the higher number of households falling in the low soil erosion classes.

The success of agroforestry in reducing soil erosion depends in large part on the type and intensity of the agroforestry practice (Tharlakson et al., 2012). Although the intensity of AFPs was higher in the VI households, the type was essentially the same both household groups. In agroforestry systems, the beneficial effects of protecting the soil surface depend on the spatial and temporal coverage of the tree component (Sanchez et al., 1997).

Tree cover helps to mitigate erosion through two main functions, the first of which is removing water from the soil profile through the interception and transpiration processes. The other important function relates to the ability of the root systems of many trees to extend into the surrounding soil far beyond their branches and not only hold the soil in place but also improve the drainage of the soil. This prevents soil compaction and helps water soak into the ground instead of flowing over its surface. However, other studies have indicated that the role of trees in managing soil erosion is determined by the type of tree species. In the Mediterranean region, areas, where eucalyptus was planted, suffer severe erosion than those under natural of semi-natural forest due to the lack of tree undergrowth in eucalyptus plantations (Zuazo et al., 2008). The main AFPs (home gardens) in Kirumba mimic the multi-layer characteristics of a natural forest which may be the other reason why the erosion intensity are generally low in the area.

5.3.4 Fuelwood energy use

Fuel-wood is an integral part of farmers' day to day life in Kirumba as it was frequently mentioned as the second most use of trees by the respondents. Other studies on the role of agroforestry also report similar findings (Tharlakson et al., 2012; Pandey et al., 2015). UBOS (2016), also reports that 83% of households in the Rakai use fuel-wood energy for cooking which further supports this finding. Moreover, fuelwood is not only used for household energy but also generates additional income. In fact, 5% of the households sold firewood as one of the ways of managing variability in climate.

Majority of the households in Kirumba collect fire-wood from their farm. This shows that farmers rely more on personal fuelwood supplies than other fuel-wood sources. Whereas majority VI households get firewood from their farms, those who spend money to acquire firewood are non-VI households due to the low fuelwood stock on their farms. This shows that there is fuel-wood scarcity on farms in Kirumba as in many parts of rural Africa as quoted by other studies in literature (Kandel et al., 2016; Pandey et al., 2015; Tharlakson et al., 2012). VI households with bigger family size use higher amount of fuelwood energy on average than the non-VI households.

This finding is related to that of Kandel et al. (2016) in Nepal who explain that the energy needs of households increases as the size of the family increase.

Whereas VI households have enough trees to sustain their fuelwood needs for 8 years, non-VI households only have 3 years on average. This means Non-VI household will tend to buy fuel-wood more in the near future. This is more-so an opportunity for the VI households to increase their off-farm income through selling of fuelwood which will, in turn, reduce their general sensitivity to climate shocks. However, results also revealed that fuelwood supply by farm trees of both VI and non-VI households are generally unsustainable when consider the annual increment of trees in relation to the annual fuel-wood use. These findings highlight that there is a need to improve tree cover on local farms to provide wood in an increasingly fuel-scarce environment. This is consistent with Tharlakson et al. (2012) who also highlights the same necessity in western Kenya.

5.4 Role of AFPs in increasing resilience to climate variability

VI households have a generally higher resilience index than non-VI households. The former had significantly higher units of almost all resilience index variables used in this study than the latter. Non-VI households only showed more resilience in terms of diversification of income sources. The difference in the resilience index is attributed to practicing agroforestry as well as other factors as discussed in the sub-sections below;

5.4.1 Diversification of income sources

Non-VI households are more diversified based on the number of income sources they have. This indicates that they are more resilient to climate variability. Over dependence on one income source makes a household vulnerable to hazards (Femi, 2016). VI households are generally more dependent on agriculture than non-VI households which make them less resilient to climate shocks. Diversification of income sources is however not only defined by the increase in the number of sources but also the balance of the different sources of income (Minot et al., 2006). Households with two income sources, each contributing half of the total, would be more diversified than households with two sources, one contributing more than half of the total (ibid). Although non-VI households engage more in non-farm activities than VI households, there is still a lack of balance in the percentage contribution. Majority of households who strike a balance between on-farm and non-farm activities are VI-farmers.

Femi (2016) also argues that diversification of income can be when a farmer moves from the production of low-value crops to higher-value crops, livestock, and nonfarm activities. Diversification of income may include multiple farm locations where farm plots are sited in different geographical locations within the neighborhood so that if bad weather conditions affect the farm in one location, it might not spread to the other locations (ibid). VI households have more livestock and tend to embrace cash crops such as vanilla, coffee more than the non-VI farmers which may mean that they are more diversified. This may be because they have more income and can manage to sustain these activities. As Barrett et al (2005) argued that richer households tend to be more diversified and consider diversification as a means of increasing overall income. But, considering crop and livestock diversification as a measure of diversification of income is unlikely to reduce income risk because the yields of different crops are closely correlated (Femi, 2016). Therefore, increasing resilience by diversification of income sources for both groups of farmers is generally poor and the difference is negligible.

5.4.2 Income

VI farmers received significantly high income from AFPs than the non-VI farmers which indicates that AFPs greatly improve farm income. Agroforestry has been shown to improve farmers' incomes in a number of different ways (Garrity 2006; Tharlakson, 2012). For example, lower Nyando farmers involved in AF project had an average, between USD 19-137 (Tharlakson et al., 2012). This is lower than the case in Tanzania where AF practitioners in Mwanga District had an extra income of USD 617.5 annually on average than non-AF participants (Quinon et al., 2010). In this study, VI households had received USD 384.38 more from agroforestry than non-VI households. These differences in incomes between farmers from different areas can be contributed to factors such as AFPs adopted, number or type of trees species and crops established and sold, markets price of agroforestry products, land size, age of the trees and bargain power of farmers (Abebe et al., 2010).

VI farmers reported receiving income from selling different products such as fruits, fuel-wood, poles, and timber. Although non-VI households reported the same, it's quite obvious they are unable to sell more products and so have not received substantial benefits from AFPs. Morton (2007) explains that individuals with more income have higher ability to cope with changes in climate as they can easily take on other livelihood options. Similarly, VI households with more income, have a high ability to cope in case of climate shock than non-VI households.

5.4.3 Assets

Livestock

Practicing agroforestry increases the TLU of households since VI households had more TLU than non-VI households. Livestock is one of the assets that farmers in Kirumba using in managing climate variability. This implies that VI-households with more TLU are more resilient than non-VI households. The difference in TLU may be due to the availability of enough fodder especially from shrubs such as calliandra which the VI agroforestry project encouraged farmers to plant. VI farmer also received a wide range of ideas about different plants/ trees that could be used as fodder in their training with VI agroforestry. For instance, the majority of non-VI farmers had no idea that leaves of *Persea americana* and *Ficus natalensis* are good fodder for goats and cows and yet these were the most dominant species in the study area. Nair (1993) pointed out that agroforestry has been practiced for centuries in the tropics but farmers do not fully optimize the benefits it provides. Trees on farm provide shade to livestock which reduces the energy needed for regulating body temperatures and so results in higher feed conversion and weight gain. Agroforests also contribute significantly to savings on feed costs, higher survival and milk production (Nair, 1993). The presence of fodder tree has also a crucial role in increasing the number of livestock which are important assets during the time of crisis. Reports from dry land of Africa showed that presence of fodder trees in gardens not only increase the number of livestock but also reduces livestock forage cost (Linger, 2014)

Land

Land is another farm asset that increased with practicing agroforestry. VI households had higher land holdings than non-VI households. This may be attributed to a number of reasons such as an increase in income, pre-selection bias as discussed in section 5.3 above. In assets terms, this implies that VI households with more land on average have higher chances for planting crops and trees or transferring it for monetary gain than non-VI households.

Trees

Trees were sold as timber, poles or firewood during periods when the climate conditions were not suitable for survival of most seasonal crops. Various authors in literature reported similar findings (Mbow et al., 2014; Linger, 2014; Tharlakson et al., 2012). Linger (2014) reported that trees are a source of income for rural households. Fruit tree species especially were was an indicator of additional revenue to farmers (ibid). Further analysis also showed that VI households sold more tree products than non-VI households which is expected as the former are more involved in agroforestry than the latter. Tharlakson et al. (2012) also reported that lower Nyando farmers who had mature trees had more income than middle Nyando farmers who had just planted trees.

Trees not only helped to generate income for farmer households but also in reducing hunger. Fruit trees especially are very important to households because when consumed, people do not get as hungry as they would. Farmers also mentioned very often that coffee trees and crops near trees survived during extreme dry seasons. Mengistu (2008) also confirms that fruit trees have a significant role during environmental crisis of household by helping to avoid frequency of hunger and decreasing the number of meals per day.

Trees can also be used for insurance. Although not directly indicated in such terms, many farmers in Kirumba with *Measopsis eminii* considered it in higher regard compared to other trees on the farm. In drought-prone environments, such as Rajasthan, as a risk aversion and coping strategy, farmers maintain trees as an insurance to avoid long-term vulnerability against drought, insect pest outbreaks and other threats, instead of a yield-maximizing strategy aiming at short-term monetary benefits (Pandey et al., 2011).

Crop yield

VI households had significantly higher crop production per hectare than non-VI household. This means that they obtained more income from crop sale than their counterparts. Although, this may be attributed to a range of different factors such as individual farm capacity and crop species used, having trees on the farm has also been reported to increase crop yield. Dead tree leaves and branches are used to fertilize the soil. *F. natalensis* for example is used in farms because its leaves decompose very fast compared to other tree leaves. Farmers clearly stated that bananas and coffee plants near *F. natatlensis* trees always produced better crops than those in isolation. Other tree species such as Acacia are Nitrogen fixers and their presence on the farm is essential for crop growth. Trees also modify microclimatic conditions including temperature, water vapor content of air and wind speed, which can have beneficial effects on crop growth (Smith, 2010). Other studies in literature also show that an increase in the number of livestock leads to an increase in food stock due to the fact that livestock waste is used in farming to improve crop yield (Linger, 2016).

A central hypothesis is that productivity is higher in agroforestry compared to monoculture systems due to complementarities in resource-capture i.e. trees acquire resources that the crops alone would not. Based on the ecological theory of niche differentiation; different species obtain resources from different parts of the environment, such as, *Grevillea robusta* are fast growing and less competitive, while tree roots of *Persea americana* and *Syzgium species* are reported to extend deeper than crop roots and are therefore able to access soil nutrients and water unavailable to crops, as well as absorbing nutrients leached from the crop rhizosphere (Pandey, 2007; Smith, 2010; Nair, 1993).

On the other hand, negative interactions have been also been observed between trees and crops. In fact, it is still a challenge in many agroforestry systems to establish the optimal combination of trees and crops (Mbow et al., 2014). For instance, competition for water between crops and trees may lead to reduced productivity compared to a monoculture system (Smith, 2010). Too much shade may also deprive crops of the light they need for maximum production (ibid). Certain trees species didn't complement crops as was expected by the project. *Calliandra spp,* for example, became invasive and was later seen as a nuisance on farms where it had been grown. Similarly in the case of pine, although it's a good timber species, it was completely avoided because it was believed to produce pheromones that repelled insect pollinators. Production of biochemical by plants can prevent germination, growth, and reproduction of other plants (Smith, 2010). All these factors may exclude agroforestry as the major reason for the difference in crop yield per hectare between the two farmer groups.

It may therefore also be argued that farmers who chose to participate in the agroforestry projects were already more capable than those that didn't. Undertaking ventures like agroforestry requires a lot of labour inputs and in fact, this is one of the constraints of practicing agroforestry (Nair, 1993). Therefore, VI agroforestry project participant farmers are generally more capable and committed than their counterparts and hence the higher crop yield per hectare. This is also portrayed by the fact that VI households are more involved in on-farm activities than non-VI households with more non-farm activities.

5.5 Perception to AFPs in managing climate variability

Farmers in Kirumba are aware of the changes in climate that are happening around them. They recognize both drought and prolonged rainy seasons as indicators to changes/variation in climate. However, they majored a lot on drought that has greater and prolonged impact on their well-being/ livelihood as discussed above. Furthermore, they are aware of the causes of the changes or variability in climate. Majority mentioned deforestation and swamp drainage activities as major causes of climate variability. Coincidentally, these are among the major activities that different development and environment agencies are fighting to avoid climate change and its effects (Verchot et al., 2007). They additionally mentioned that due to the cutting of trees, pests moved from trees to crops and hence the recent maize armyworm pest.

Farmers generally agree that AFPs products and services as good strategies in managing effects of climate variability. Farmers ranked savings as the main strategy they use to manage during climate variability. Savings are usually in terms of livestock, dry food and money. It is no wonder livestock ranked second to savings. Many studies have also referred to livestock as one of the forms of saving used by farmers in rural areas (Copestake, 2008; Janhke et al., 1988; Femi et al., 2016). Trees are also becoming more recognized as a form of insurance and are increasingly being used by farmers to avoid the risk of total loss in the event of a drought or flood (Pandey, 2007; Chavan et al., 2016). It is therefore unsurprising that timber was also ranked highly as one of the agroforestry products that both farmers groups in Kirumba use to manage climate variability.

6 CHAPTER SIX: CONCLUSION AND OUTLOOK

AFPs certainly contribute to reducing farmers' vulnerability to climate variability in Rakai basing on the results of the formulated specific objectives of the study. Climate variability has and is happening in Kirumba and its effects are apparent although not as extreme as one manifested in the neighboring districts. Four agroforestry systems which were identified in Rakai play a great role in sensitivity reduction and in increasing resilience of farmers to effects of climate variability. This is through increasing fuel-wood stock on farm, reducing erosion intensity, increasing income and assets such as land, trees, livestock, and crop production. VI agroforestry project participant households showed less sensitivity and are higher resilience to climate variability compared to the non-VI agroforestry project participant households. This is because VI households generally had more trees and land as well as more fuelwood stock than non-VI households. They also had a higher resilience index based on the available assets and annual income from agroforestry. This indicates that promotion of agroforestry by the VI agroforestry project has been of utmost importance to the farmers in Kirumba.

However, it is hard to make a concrete statement on the extent to which AFPs can contribute to vulnerability reduction in Kirumba. This is mainly because although VI households show reduced vulnerability compared to non-VI households, both groups still have low levels of assets such as landholding and general annual income. Similar livelihood practices that both farmer groups generally exhibit such as farming practices and the household setting, may make it hard to differ in the level of vulnerability. Therefore, they are all still restricted in optimizing tree density on their farms although most households are well aware of the use of trees on the farm. In order for this to happen, motivational factors such as political and market dynamics that determine farmers' decision to plant trees have to be considered by implementing projects. These are also exogenous factors that can influence vulnerability and are not in control of the household practices. These factors may have a higher impact on farmers than the ones researched and therefore, there is a need for further investigation with these factors incorporated.

Critical analysis of some variables in particular fuel-wood supply sustainability and diversification of income sources also showed both households are generally still vulnerable. Although this was done based on many assumptions due to limited time and resources, it provides a clear picture of the prevailing vulnerability situation in Kirumba. A similar study which addresses some or all the assumptions drawn here is therefore recommended in order to obtain more realistic results and conclusions about this topic.

Outlook

Tree planting in home-gardens, pastoral live fences, small-scale woodlot and scattered trees in coffee plantations are important AFPs in the study area and should, therefore, be maintained. However, there is still generally a big necessity to increase trees on the farm for agroforestry practice to stand out as strategies for reducing the impact of climate variability especially for ensuring fuel-wood sustainability. More projects such as VI should come up and not only stop at giving trees but motivate farmers to replant. Intensify training in practices like seed collection, nursery management so that even when the project phases out, farmers still have access to planting material.

Eucalypts which dominated woodlots in Kirumba are with no doubt very significant economically as well as socially. However, they have been associated with some disadvantages that may increase the vulnerability of farmers to climate shocks in the area. Encouraging the use indigenous tree species in woodlots, therefore, is key to avoiding such problems. Moreover, some indigenous tree species are becoming rare and a number of them are already registered in the red data lists of conservation agencies.

Other energy alternatives such as biogas should be considered. A lot of residuals go to waste yet they can be put to good use for energy production. Although most biogas technology may seem too sophisticated for the rural farmers in Kirumba, there are also simple ways of manufacturing biogas that have been promoted in some parts of Uganda. Such adoptable practices should also be considered in this area and other areas so as to address the seen and fore-seen effects of climate variability.

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ANNEX

Annex 1: Question catalogue for key informant interviews

1) What is VI agroforestry background especially in Rakai district
2) Who were the target group and what criteris was used for selection of participant households?
3) What were VI agroforestry operation activities in Rakai
4) What tree species and shrubs were distributed to farmers?
5) How were the tree species acquired?
6) How many households did VI agroforestry work with?
7) Who managed the nurseries/ Did people buy the seedlings or not?
8) What are the effects of climate variability that have generally been experienced, when were they experienced?
9) Comparison of the situation now and then when the climate was better. What has changed?
10)

Annex 2: Household questionnaire

1. Personal information

a) Farmer number					
b) Farmer group	☐ VI		☐ Non-VI		
c) Parish and Village					
d) Name of the respondent		Age		Gender	
e) Head of the household		Age		Gender	
f) Education level	Respondent		Head of HH		

2. Household information

a) Family size	Children (< 14)		Adults (> 14)	
b) Type of house	☐Grass thatched	☐ Wooden	☐ Bricks	
c) Household source of income	☐On-farm	☐ Off-farm	☐ Non-farm	☐ Other
d) Where do you get most income?				
e) How many acres of land do you have?				
f) How many trees do you have on your farm?				

3. Livestock information

a) Is the livestock enclosed?	☐ Yes			☐ No		
b) What is the percentage of land occupied by livestock						
c) Livestock	Goats	Sheep	Cow	Rabbits	chicken	Others

d) Number						
e) How many livestock do you sell per year?						
f) How much do you sell it?						

4. Crop information

Crops	Maize	Beans	Peas	Banana	Cassava	Potatoes	G.nuts	Other
a) Cover area (acres)								
b) How much crops did you produce annually? (estimate using last season) (Kg or sacks)								
c) How much do you sell?								
d) How much is a kg?								
e) Use of the crop residues								

5. Tree utilization

a) What is the use of the trees on farm?	☐ Protection		☐Products. Which products?		
b) Have you harvested your trees before?	☐No ☐ Yes.	If yes, for what purpose?			
c) How many trees do you harvest?		☐ Month ☐ Year ☐…….. years			
d) What do you use the tree residues for?	☐Charcoal	☐Manure	☐Biogas	☐None	☐Others

6. Energy access and supply

a) What do you use for cooking at home?	☐ Firewood	☐ Charcoal	☐ Biogas	☐Other
b) How much do you pay per month?				
c) How much do you use per month				
d) Where do you get it from				
e) How far is the nearest forest?				
f) Do you use trees on farm for fuel-wood?	☐ No ☐ Yes	If yes, how much does it contribute to the total fuel-wood consumption?		

7. Climate variability

a) Has your farm experienced climate hazards?	☐ No ☐Yes	If yes, which ones?
b) How was the farm affected?		

c) What do you think is the cause of climate variability?		
d) How much loss did you incur?		
e) How did you manage the climate hazard?		
f) Did having trees help in climate hazard management?	□ No □yes	If yes, how?

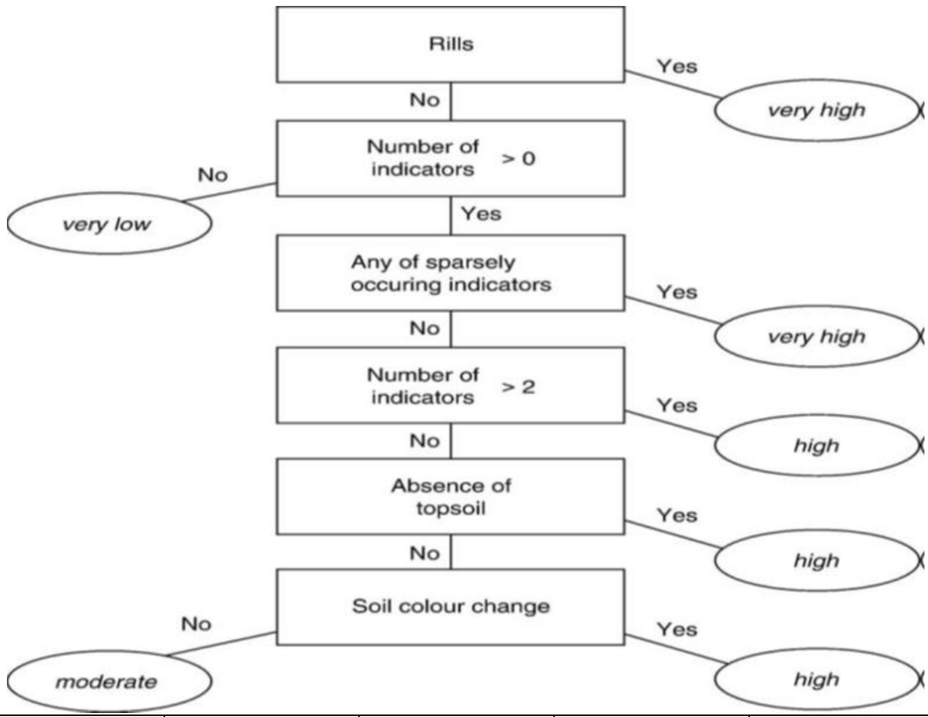
8. Perception

a) On a scale of 1-5, 1 meaning strongly disagree and 5 meaning strongly agree, how do you rate the use AFPs during the period when you experienced hazard				
□Strongly disagree	□Disagree	□Moderate	□Agree	□Strongly agree
b) How do you rate the use of AF□Ps in providing fuel for energy during this period?				
Very poor	Poor	Fair	Good	Very good
c) How do you rate the use of AFPs in reducing soil erosion?				
Very poor	Poor	Fair	Good	Very good

Field observation and assessment

9. Soil erosion intensity

a) Position of the farm on the slope	□ Up-slope	□Mid-slope	□ Up-slope	
b) Erosion control method	□ Contours	□Mulching	□ Terraces	□ Others
c) Indictors of erosion	□ Absence of top soil □ Soils color change □ White soft stones	□Patches of bare land □ Rock exposure □ Washing of crops □ Others	□Poor seed germination □ Poor crop development □ Downslope soil deposition ………………………………	
d) Type of erosion	□Sheet	□Rill	□Gully	

e) Soil erosion classification tree	

f) Soil erosion classification	☐ Very low	☐ Low	☐ Moderate	☐ High	☐ Very high

10. Agroforestry Practices

a) Tree characteristics	Tree number	Species	Diameter (cm)	Height (m)
b)				
c) Arrangement	Description:			
	Sketch of the arrangement			

Annex 3: List of species, common names and use

Species name	Common name	Code	Frequency	Uses
Albizia coriaria	Mugavu	Ac	8	Firewood, timber, poles
Aleurites molucana	Kabakanjagala	Am	4	Barkcloth, firewood, oil
Annona muricata	Sourcop tree/kitafeeri	Ama	1	Fruits, firewood,
Artocarpus heterophyllus	Jackfruit/fene	Ah	89	Firewood, fruits, lorry boards
Azadirachta indica	Neem tree	Ai	7	Firewood, medicine, timber
Calliandra calothyrsus	Callindra	Cc	10	Fodder, firewood
Callistemon viminalis	Bottle brush/nyambalazitonya	Cv	13	Firewood, ornamental, medicine, shade
Canarium schweinfarthii	Muwafu	Cs	4	Fruits, firewood, timber
Carica papaya	Pawpaw	Cp	20	Fruits
Cassia sieberiana	Drumsick tree/cassia	Cs	19	Fodder, firewood
Casuarina equisetifolia	Australian pine/kalivario	Ce	7	Firewood, timber
Cedrella odorata	cedero	Co	4	Firewood, ornamental, timber
Chrysophyllum albidum	Nkalati	Ca	1	Timber, firewood
Citrus reticulata	Mangaada	Cr		Fruits, medicine
Citrus sinensis	Pomelo/Mucungwa	Cts	28	Fruits, medicine
Dracaena fragrans	Luwaanyi	Df	15	Boundary mapping
Dracaena steudneri	Kajolyanjovu	Ds	3	Medicine
Entada abyssinica	Mwoloola	Eta	3	Firewood, medicine
Eriobotrya japonica	Loquat/musaali	Ej	15	Fruits, firewood,
Erythrina abyssinica	lucky bean tree/ jirikiti	Ea	1	Utensils, bee forage, nitrogen fixing, fencing, mulch
Eucalyptus camadulensis	kalituunsi	Ec	26	timber, firewood, poles
Eucalyptus grandis	kalituunsi	Eg	26	timber, firewood, poles
Ficus exasperata	Muwawu	Fe	1	timber, firewood
Ficus natalensis	Mutuba	Fn	95	barkcloth, firewood, timber, fodder,
Grevillea robusta	Silky oak/ kabiliiti	Gr	34	timber, firewood
Measopsis eminii	Umbrella tree/musizi	Me	45	timber, firewood
Mangifera indica	Mango/muyembe	Mi	86	fruits, firewood, medicine, fodder, shade
Manihot gaziovii	Kiwogowogo	Mg	1	firewood
Markhamia lutea	Nile tulip/musambya	Ml	50	poles, timber, medicine
Melia azedarach	Chinaberry/mutankuye ge	Ma	3	medicine, firewood, timber, poles, windbreak
Milicia excelsa	Muvule	Mie	2	timber, firewood, shade, mulch, ornamental
Moringa oleifera	Moringa	Mo	3	food, firewood

Moros alba	Nkenene	Ma	3	fruits, fencing, shade, firewood, fodder
Moros mesozygia	mukooge	Mm	1	fruits, firewood
Persea americana	Avocado	Pa	97	fruits, fodder, firewood, timber
Polyscias fulva	settala	Pf	7	Timber, carvings, mulch, firewood
Prunus africana	Mugwbuzito	Pa	2	Timber, medicine, firewood, shade, windbreak
Pseudospondias microcarpa	African grape/muziru	Pm	2	Timber, firewood, shade, windbreak
Psidium guajava	Guava/mupeera	Pga	50	fruits, firewood
Punica granatum	Pomegranate/ komamawaanga	Pgm	2	fruits
Sapium ellipticum	musasa	Se	4	firewood, medicine
Spathodea campanulata	Fountain tree/Kifabakazi	Sca	5	medicine, firewood
Syzgium cumini	Jambul/jambula	Sc	14	Fruits, firewood, timber
Teclea nobilis	Enzo	Tn	2	timber, building poles
Bridelia micrantha	Katazamiti	Bm	1	Building poles, fodder
Unidentifiedr	Kabalire	Unr	3	timber, medicine
Vangueria apiculata	Tugunda	Va	19	fruits, firewood, poles

(Source: Field survey, 2017)

Annex 4: List of equations and calculations

a) Comparing groups- *Mann-Whitney U test*

$$U_1 = R_1 - \frac{n_1(n_1+1)}{2}$$

$$U_2 = R_2 - \frac{n_2(n_2+1)}{2}$$

Where,

U = the Mann-Whitney statistic,

n_1 and n_2 = the number of cases in samples 1 and 2 respectively, and

R_1 and R_2 = the sum of the ranks for the sample 1 and 2 respectively

b) Exploring relationships

i. Pearson's product moment correlation

$$\rho_{X,Y} = \frac{E[(X-\mu_X)(Y-\mu_Y)]}{\sigma_X \sigma_Y}$$

Where;

$\rho_{X,Y}$ =Pearson's population correlation coefficient

E = Expectation

μ_X = Mean of X

μ_Y = Mean of Y

σ_X = Standard deviation of X

σ_Y = Standard deviation of Y

ii. Linear regression

$Y_1 = \beta_0 + \beta_1 X_1 + \varepsilon$

Where;

Y_1= Response

X_1= Predictor

β_0= Y-intercept

β_1= Regression coefficient

ε = Residual value/ error

iii. Chi-square test

$X^2 = \sum \frac{(O_i - E_i)^2}{E_i}$

Where;

X^2= Chi squared

O_i= Observed value

E_i= Expected value

iv. Coefficient of determination

$R^2 = \frac{SS_{reg}}{SS_{tot}}$

Where;

R^2 = coefficient of determination

SS_{reg} = Explained sums of square

SS_{tot} = Total sums of square

c) Crop yield per hectare

$Crop\ yield\ per\ hectare = \frac{Annual\ income\ from\ crops}{Household\ land\ holdin\ (ha)}$

Annex 5: Fuelwood stock and sustainability

Group	Annual fuelwood use (cm^3)	Fuelwood stock (Years)	Annual increment (cm^3)	Sustainability
VI	21.9	8.5	7.5	No
Non-VI	21.3	2.8	1.3	No
Total	21.6	5.6	4.4	No

Annex 6: Calculation of total household income

(USD 1 is equivalent to UGX. 3600)

Income class	Monthly income (USD)	VI household income		Non-VI household income		Average household income	
		Frequency	Income	Frequency	Income	Frequency	Income
>$28	$28	5	140	9	252	14	392
$28-$83	$55.5	20	1110	27	1498.5	47	2608.5
$83-$139	$111	16	1776	10	1110	26	2886
<$139	$139	10	1390	5	695	15	2085
	Total monthly income		4416		3555.5		7971.5
	Average monthly income/HH		86.59		69.72		78.15
	Average annual income/HH		**1039.06**		**836.59**		**937.82**

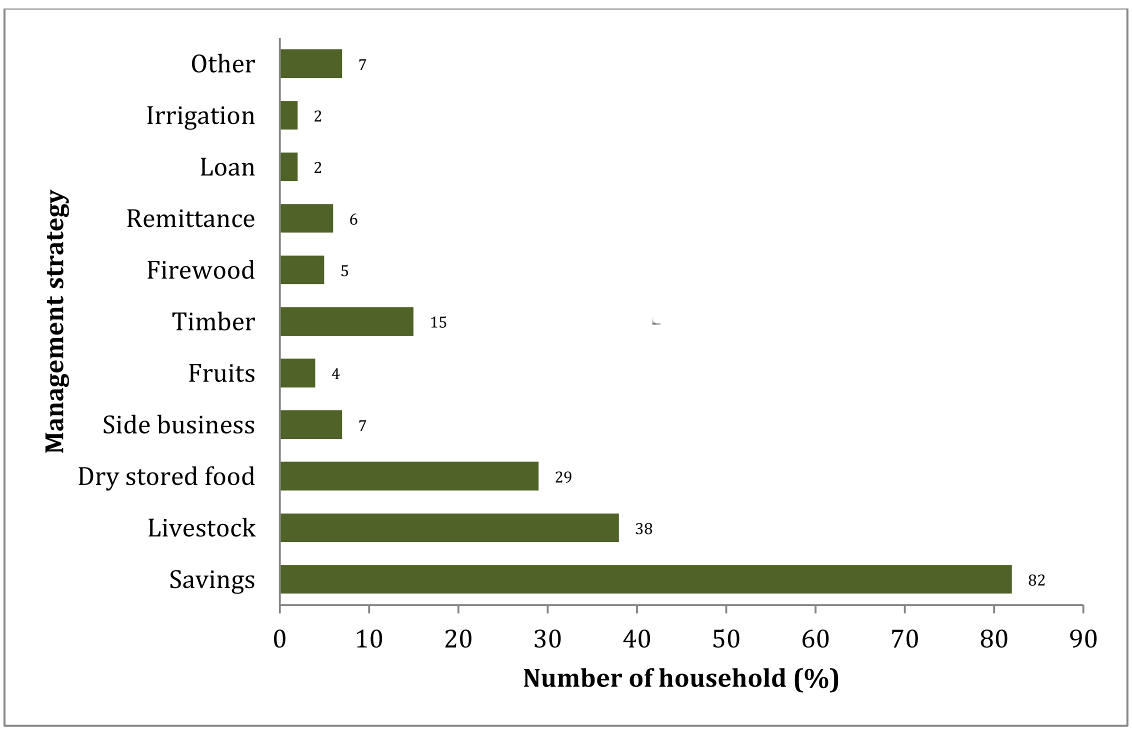
(Source: Field survey, 2017)

Annex 7: Calculation of resilience index

Class	Score	VI-households		Non-Vi households	
		Frequency	Total score	Frequency	Total score
		Land(ha)			
0.01-1	1	11	11	14	14
1.01-2	2	22	44	29	58
2.01-3	3	5	15	2	6
3.01-4	4	7	28	2	8
4.01-20	5	6	30	4	20
Total		51	128	51	106
Land index			2.5		2.1
		Trees/ha			
1-10	1	3	3	7	7
11-20	2	6	12	21	42
21-30	3	5	15	20	60
31-40	4	11	44	3	12
41-200	5	26	130	0	0
Total		**51**	**204**	**51**	**121**
Tree index			**4**		**2.4**
		Livestock(TLU)			
0.0-0.5	1	8	8	26	26
0.51-1.0	2	12	24	10	20
1.01-1.5	3	6	18	3	9
1.51-2.0	4	9	36	5	20
2.01-20	5	16	80	7	35
Total		**51**	**166**	**51**	**110**
Livestock index			**3.3**		**2.2**
		Crop yield/ha ($/ha/yr.)			
0-100	1	19	19	34	34
100.01-200	2	7	14	5	10
200.01-300	3	3	9	3	9
300.01-400	4	8	32	2	8
>400.01	5	14	70	7	35
Total		**51**	**144**	**51**	**96**

Crop yield index			**2.8**		**1.9**
		Income($/yr.)			
0-300	1	20	20	31	31
301-600	2	6	12	11	22
601-900	3	8	24	0	0
901-1200	4	6	24	2	8
1201-800	5	11	55	7	35
Total		**51**	**135**	**51**	**96**
Income index			**2.6**		**1.9**
		Diversification of income sources			
	1	32	32	22	22
	2	19	38	29	58
Total		**51**	**70**	**51**	**80**
DOI index			**1.4**		**1.6**

Annex 8:General strategies used by farmers to manage effects of climate variability in Kirumba



Annex 9: List of persons interviewed

Name	Group	Parish	Village	Age	Interview date
		Key informants			
Fred Mujurizi	VI agroforestry Officer	Rakai		52	**6/5/2017**
Lukyamuzi Pascal	Extension worker	Lwamba	Bweruga	56	**4/5/2017**
Owomuburi Vincent Masanso	Chairperson	Lwamba	Kijumbula	56	**4/5/2017**
Jessica Lusiba	Elderly farmer	Buyiisa	Kakondo	51	**5/4/2017**
Nathan Sharp Buye	Elderly farmer	Lwamba	Lwamba	74	**5/4/2107**
		Participant Farmers			
Kiwanuka Protazio	VI	Lwamba	Bweruga	56	5/3/2017
Mathias Mulumba Jjuko	VI	Lwamba	kyenvubu	50	4/5/2017
Mutunzi Robert	VI	Buyiisa	Buyiisa	40	4/28/2017
Kamulegeya Aloysius	VI	Buyiisa	Boteera	54	5/10/2017
Madrine kalibala	VI	Lwamba	Bweruga	71	4/19/2017
Magembe Lawrence	VI	Buyiisa	kawule	58	5/10/2017
Namwenda Justine Wasswa	VI	Lwamba	Lwamba	42	4/20/2017
Max Katuumba	VI	Lwamba	Bweruga	57	4/11/2017
Nalwoga Goretti	VI	Kabuwoko	Kabuwoko	52	4/6/2017
Mugumya Mike	VI	Buyiisa	Buyiisa	35	4/10/2017
Evelyn senyonga	VI	Kabuwoko	Busowe	50	4/12/2017
Angella Namwanje	VI	Buyiisa	Buyiisa	54	4/28/2017
Kulabako Florence	VI	Buyiisa	Buyiisa	35	4/11/2017
Sendawula Robert	VI	Buyiisa	Buyiisa	40	4/10/2017
Lukyamuzi John	VI	Buyiisa	Lwemikoma	80	4/26/2017
Nagadya Betty	VI	Buyiisa	Buyiisa	60	4/11/2017
Nandagire Harriet	VI	Lwamba	Lwamba	36	4/20/2017
Selwaano Lukanga	VI	Buyiisa	Lutuunga	53	4/28/2017
Jjumba Francis	VI	Lwamba	Ntovu	68	4/27/2017
Catalina Semwogerere	VI	Buyiisa	Buyiisa	66	4/11/2017
Nakabugo Gonzaga	VI	Buyiisa	Buyiisa	60	4/11/2017
Kakooza Emanuel	VI	Lwamba	Bweruga	62	4/5/2017
Teddy Kasozi	VI	Buyiisa	Buyiisa	62	5/16/2017
Katamba Ddiba	VI	Buyiisa	Lwemikoma	46	4/26/2017
Imaculate Nabakooza	VI	Buyiisa	Buyiisa	62	5/18/2017
Yiga Achileo	VI	Buyiisa	Buyiisa	40	4/6/2017
Kakooza Charles	VI	Buyiisa	Lwemikoma	37	4/26/2017

Namaganda Regina	VI	Buyiisa	Buyiisa	65	5/18/2017
Ssempiira peter	VI	Buyiisa	kawule	54	5/18/2017
Kiwanuka Achilles	VI	Lwamba	Kijumbula	56	4/5/2017
Micheal Kunguvvu	VI	Kabuwoko	Segero	57	4/21/2017
Kawooya Henry	VI	Buyiisa	Buyiisa	64	4/10/2017
Namakula Everesta	VI	Buyiisa	Buyiisa	51	4/26/2017
Kivumbi John Bosco	VI	Buyiisa	Kakondo	54	5/16/2017
Segiriinya Edward	VI	Lwamba	Kijumbula	44	5/3/2017
Nakaweesi Leonia	VI	Buyiisa	Buyiisa	54	4/6/2017
Kato Damiano	VI	Kabuwoko	Kabuwoko	26	4/25/2017
Gonzaga Senyonjo	VI	Buyiisa	Lwemikoma	45	5/17/2017
Semwaaya Eleneo	VI	Lwamba	Bweruga	56	5/5/2017
Sembuzze Vincent	VI	Buyiisa	Buyiisa	43	4/6/2017
Nansamba Harriet	VI	Kabuwoko	Kabuwoko	29	4/6/2017
Getrude Lubega	VI	Kabuwoko	Kabuwoko	40	5/15/2017
Nandyoonsi Betty	VI	Buyiisa	Boteera	55	5/17/2017
Ssimbi Peter	VI	Lwamba	Lwamba	74	4/27/2017
Lwebuga Josephat	VI	Buyiisa	Buyiisa	40	5/9/2017
Ntuunda Edward	VI	Lwamba	Lwamba	65	4/27/2017
Muwanga Herman	VI	Buyiisa	Buyiisa	45	5/9/2017
Sebandeke Steven	VI	Kabuwoko	Kabuwoko	36	5/15/2017
Angella Namakula	VI	Lwamba	Lwamba	40	4/20/2017
Nabbosa Jean rose	VI	Buyiisa	Buyiisa	71	5/15/2017
Katakeenga Charles	VI	Buyiisa	Buyiisa	65	5/15/2017
Mayiga Francis	non VI	Kabuwoko	kabuwoko	62	4/21/2017
Semwanga Joseph	Non VI	Buyiisa	kawule	42	5/9/2017
Kaweesi Emanuel	non VI	Kabuwoko	kindulwe	53	4/12/2017
Nambalirwa Harriet	non VI	Lwamba	Bweruga	43	4/19/2017
Nabachwa Molly	non VI	Kabuwoko	kindulwe	22	4/12/2017
Mugereka Peter	non VI	Lwamba	Lwamba	72	4/20/2017
Paul Kavuma	non VI	Lwamba	Lwamba	60	4/20/2017
Nakabira Rose	non VI	Buyiisa	Buyiisa	33	5/16/2017
Nalwoga Margret	non VI	Buyiisa	Gogonya	38	5/16/2017
Sarah Nantongo	non VI	Kabuwoko	kindulwe	36	4/12/2017
Joseph Kakooza	non VI	Kabuwoko	kindulwe	42	4/12/2017
Namuddu Goretti	non VI	Kabuwoko	kindulwe	49	4/12/2017
Kimbowa Everest	Non VI	Lwamba	Bweruga	44	5/5/2017
Kibuye Gerald	Non VI	Buyiisa	Buyiisa	40	5/17/2017
Mary Nabulime	non VI	Buyiisa	Boteera	52	5/9/2017

Namubiru Solome	Non VI	Buyiisa	kawule	47	5/9/2017
Jane Francis Namukwaaya	non VI	Kabuwoko	Kabuwoko	36	4/25/2017
Joyce Nababi	non VI	Buyiisa	Lwemikoma	40	4/26/2017
Kasooba Joseph	non VI	Lwamba	Ntovu	25	4/27/2017
Cissy Nabiryo	non VI	Lwamba	Kamutuuza	46	4/27/2017
Nakakeeto Catherine	non VI	Kabuwoko	Kabuwoko	37	4/25/2017
Semakula David	non VI	Kabuwoko	kabuwoko	44	4/21/2017
Rev. Tulina omubeezi Emmanuel	non VI	Kabuwoko	Kabuwoko	62	4/25/2017
Alex Mugerwa	Non VI	Lwamba	Kijumbula	32	5/5/2017
Nakintu Lucy	non VI	Kabuwoko	Kabuwoko	54	4/25/2017
Moses Katumba	non VI	Buyiisa	Buyiisa	34	4/25/2017
Sango Luke	Non VI	Buyiisa	Buyiisa	27	5/9/2017
Katakuli John	non VI	Lwamba	Bweruga	62	4/19/2017
Paul Kankaka	non VI	Kabuwoko	kabuwoko	31	4/21/2017
Nakanjako Maria	non VI	Kabuwoko	kabuwoko	47	5/4/2017
Mbuga Vincent	non VI	Buyiisa	Lwemikoma	60	4/26/2017
Imelda Jumba	non VI	Lwamba	Bweruga	47	4/19/2017
Joseph Kaggwa	non VI	Buyiisa	Gogonya	36	5/16/2017
Julius Katongole	non VI	Buyiisa	Kakondo	35	5/18/2017
Nassali Florence	Non VI	Buyiisa	Buyiisa	30	5/8/2017
Nanyoonjo Margret	non VI	Lwamba	Lwamba	37	4/19/2017
Nassali Margret	non VI	Lwamba	Bweruga	43	4/19/2017
Ssali Richard	non VI	Lwamba	Lwamba	37	5/19/2017
Immaculate Nanyanzi	non VI	Kabuwoko	kabuwoko	50	5/4/2017
Waligo Charles	Non VI	Buyiisa	Boteera	47	5/17/2017
Nakibwaami Rose	non VI	Buyiisa	Kakondo	61	5/18/2017
Maria Veneranda Nabachwa	non VI	Buyiisa	Kakondo	59	5/18/2017
Betty Namutebi	non VI	Lwamba	Lwamba	42	4/27/2017
Edward Sekidde	non VI	Lwamba	Lwamba	63	4/27/2017
Julius Bwanika	non VI	Buyiisa	Boteera	32	5/11/2017
Annet Nakagwa	non VI	Lwamba	Lwamba	68	5/19/2017
Nabweteme Goretti	Non VI	Buyiisa	Buyiisa	46	5/11/2017
Yiga Gyaviira	non VI	Lwamba	Lwamba	43	5/19/2017
Katende Daniel sekikubo	Non VI	Buyiisa	Buyiisa	40	5/11/2017
Kanyike Mike	Non VI	Buyiisa	Buyiisa	37	5/8/2017
John Drake Kibuye	non VI	Kabuwoko	Segero	65	5/4/2017