DISEASE PREVALENCE AND SHADE TREE DIVERSITY IN SMALLHOLDER COCOA FARMS

CASE STUDY: BUNDIBUGYO DISTRICT, WESTERN UGANDA

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Date of Submission: 30/03/2021

Submitted to: FACULTY OF AGRICULTURE

Dedication

I dedicate this report to my dear family, friends, and relatives but also the farming community.

May God Bless You

Acknowledgement

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LIST OF ACRONYMS

AFS4FOOD	Agroforestry Systems for Food
CDP	Cocoa Development Project
CMB	Coffee Marketing Board
CPB	Cocoa pod borer
CRIG	Cocoa Research Institute of Ghana
CVI	Content Validity Index
FAO	Food and Agricultural Organization
S/C	Sub County
SPSS	Statistical Package for Social Scientists
UBOS	Uganda Bureau of Statistics
UK	United Kingdoms
UNDP	United Nations Development Program
US	United States
VSD	Vascular-streak dieback

ABSTRACT

The study aimed at assessing the impact of different cocoa Agro forestry systems on disease prevalence and yield on small holder farmers in Bundibugyo district. The specific objectives of the study were to compare the prevalence of cocoa diseases under different Agro forestry systems and to compare yield traits of cocoa beans in different cocoa Agro forestry systems

The target population was 120 respondents and a sample size of 92 respondents guided by Yamanne, (1967), the sample was selected using SRS and purposive sampling as the sampling techniques. The questionnaire was pre-tested using a selected group of respondents from the target population to ensure reliability and validity of the questions and responses.

All data were coded and analysis was carried using descriptive statistics where statistical package SPSS was used to obtain chi squared test values of perceptions from respondents. Data was presented in tables to help simplify analysis and analysis was mainly done using descriptive analysis to obtain chi squared values and the level of significance was at 95%

Association between Black pod disease and shade diversity was non-significant. It was established that incidence of black pod rot disease was non-significantly associated with presence of all shade tree species; association between witch's broom disease incidence with presence of *Maesopsis eminii*was highly significant ($\chi2$= 55.41, ($p<0.05$); Association between witch's broom and presence of *Persea Americana* ($\chi2$=9.79), ($p<0.05$), *Eucalyptus globulus* ($\chi2$=16.71), ($p<0.05$),*Markhamia obtusifolia* ($\chi2$=3.95), ($p<0.001$), schefflera *actinophylla* ($\chi2$=4.32), ($p<0.001$), *Mangifera indica* ($\chi2$=6.46), ($p<0.001$) was significant though these trees were planted in small numbers. Association between frosty rot disease incidence with presence of *Maesopsis eminii* was highly significant($\chi2$= 25.90), ($p<0.05$). there was a significant association between frosty with presence of *Eucalyptus globulus* ($\chi2$=6.76), ($p<0.05$);*Mangifera indica* ($\chi2$=4.85), ($p<0.001$); though these trees were planted in small numbers. There was a highly significant association between swollen shoot virus with presence of *Maesopsis eminii* ($\chi2$= 31.55), ($p<0.05$), and *Cinnamomum tamala* ($\chi2$= 19.22), ($p<0.05$).Association between die back disease incidence with presence of *Maesopsis eminii* was highly significant ($\chi2$= 52.73), ($p<0.05$).

The study concluded that diseases have a significant association with shade tree diversity.

This study recommended that small holder farms should adopt pruning, clearing of gardens and wedding as management strategies for controlling against pests and diseases. Further recommends that in a bid to improve the yield traits of cocoa beans, appropriate and good shade tree species should be adopted.

CHAPTER ONE

INTRODUCTION

1.0 Background

The cocoa tree (Theobroma cacao) is highly prized for its beans from which cocoa powder and butter are produced. In the past years, world production tripled to a record of 3.7 million tons of dry cocoa beans in 2008 and generated an estimated US$7.4 billion of income for millions of smallholder farmers (ICCO, 2008). Cocoa beans are produced globally. In the western world, cocoa is grown in several countries; Brazil(256,186), Ecuador(128,446), Mexico(82,000), Peru(71,175), Dominican Republic68,021, Colombia(46,739), Papua New Guinea(41,200), Venezuela (31,236) in metric tons. In Africa cocoais produced in the tropical zones around the Equator, where climate conditions are well suited for growing cocoa trees. About 70 percent of the world's cocoa beans come from four West African countries: Ivory Coast, Ghana, Nigeria and Cameroon. The Ivory Coast and Ghana are by far the two largest producers of cocoa, accounting for more than 50 percent of the world´s cocoa. In 2016, the Ivory Coast alone produced approximately 1.6 million metric tons of cocoa beans. Uganda produces (26,000) metric tons per year on a total of more than 14,000 hectares had already been planted on smallholdings and is grown in areas of Mukono, Bundibugyo, Buikwe, Kibaale, Kasese, Jinja, Kamuli, Iganga, Hoima, Mpigi and Luwero. In Bundibugyo district by 1978, 2 fermenters were established, at Bubomboli, and at the district headquarters. However today according to statistics from the commercial office, more than 85% of the population is directly dependent on cocoa, and produces about 18,000 metric tons according to District Production Officer Bundibugyo.

Agroforestry is not a new method or a revolutionary way of farming. In fact, this is one of the oldest methods of agricultural production, but it was abandoned for a while because of the intensification of modern agriculture (Nair, 2007). Furthermore, shading trees can be maintained in cocoa based agroforestry systems to reduce pest attacks (Beer *et al*., 1998) for stabilizing the microclimate (Sporn *et al*., 2009) for soil protection against rain drops (Dietz *et al*., 2005). In the scientific literature, there is consensus that cocoa-based agroforestry systems with dense and divers shade tree stands do harbor high levels of species richness (Jagoret, 2011). Above all, the aim is not only to sustain the forest in cocoa growing areas but also the increase income of the small-scale cocoa farmers. Production technologies such as canopy and weed management, and disease control were developed to counter the farmers' production problems. These technologies increased cocoa production considerably.

In other studies, tree planting is one of the key objectives to improve food security and well-being of African rural households through agroforestry, this directly via the various types of edible plant, medicinal plants, wood and other non-timber products, and directly through the sustainable provision of environmental service like sequestration and storage of carbon by woody component (cocoa, fruit trees, forest trees) in cocoa-based agroforestry but also disease & pest control. Different disease incidences vary according to farming systems. Here, the attention of cocoa diseases evaluation in a cocoa tree shade system is drawn to come out with a better and sustainable system for cocoa production while protecting the environment and conserving biodiversity.

There is quite a number of diseases which are common in cocoa production in Uganda and specifically Bundibugyo. *Phytophthora Pod Rot*also known as *Black pod*, is caused by the fungus *Phytophthora spp.* causes global yield loss of 20 -30% and tree deaths of 10% annually and causing significant losses in favorable environments.*Frosty Pod Rot*is caused by the basidiomycete *moniliophthora roreri*, first reports of the disease date back to the end of the 19th century, where its aggressive effects cause devastation in cocoa plantations. *Witch's broom -Moniliophthora perniciosa* is a fungus responsible for *Witch's broom* disease. The fungus attacks only growing tissues that is, shoots, flowers and pods causing cocoa trees to produce branches with no fruit and ineffective leaves. The pods show distortion and present green patches that give the appearance of uneven ripening. *Dieback* disease, it caused heavy losses of mature trees and seedlings planted near older cocoa. it has been a major problem in the large commercial plantations in Uganda but also in other countries like West Malaysia and Sabah

Shade trees have been observed as part and partial in cocoa production to boost production, disease control, biodiversity and environmental conservation among others. Specific trees have been thought of; palm trees these have often been grown with cocoa plantations in countries like Ghana and Uganda. Maesopsis eminii, coconut (*Cocos nucifera*), neem (*Azadirachta indica*), mangoes (*Mangifera indica)*, tamarind (*Tamarindus indica*), Jack fruit (*Artocarpus heterophyllus*) and avocado (*Persea Americana)* trees grown as multipurpose trees for shade as well fruits for home consumption. However, the exotic avocado has been known host for cocoa diseases in Southeast Asia.

There has been little research on this cocoa shade tree species regarding disease association and prevalence. Therefore, the main objective of this study was to identify shade tree species possessing potential for reducing disease constraints in cocoa farms. Specifically, we aimed at determining the influence of: (i) shade tree species diversity on incidence of diseases in cocoa; and (ii) shade tree species on the incidence of diseases in cocoa.

This chapter presents the background of the study, problem statement, main objective of the study, the specific objectives of the study, research questions, conceptual framework, significance of the study, scope of the study, justification of the study, and definition of key terms

1.1 Background of the study

The cocoa tree (Theobroma cacao L) is highly prized for its beans from which cocoa powder and butter are produced. In the past years, world production tripled to a record of 3.7 million tons of dry cocoa beans in 2008 and generated an estimated US$7.4 billion of income for millions of smallholder farmers (ICCO, 2008)

In Africa, the introduction of cocoa was from the Islands of Sao Tome, introduced in Ghana in 1879; cocoa was introduced in Uganda in 1901 from Kew Gardens in Britain and planted in Entebbe Botanical Gardens. By 1917, commercial exports of cocoa had started and the crop was grown on plantation scale by Europeans and Asians. However, estates, production of cocoa was rendered uneconomical due to poor management of estates, pests and disease infestation as well as lack of foresight and planning. The crop was abandoned around 1924 when world prices fell to very low levels. It was re-introduced in 1958 by small scale farmers specifically to diversify foreign exchange earnings and incomes in Robusta coffee growing areas.(ICCO, 2008)

The first variety to be introduced in the country was Trinitario. Using seeds of the best yielding tree of the Trinitario plots at Entebbe, experimental plots were established at Kituza, currently the Coffee Research Center Kijjudde in Mukono district and at Nyaruru in Bwamba County (Bundibugyo district) in 1939. Performance of this variety was quite good and the experiments indicated the area was suitable for cocoa growing. Around 1950 the government adopted a policy to promote extensive cultivation of cocoa development in Uganda and was stationed at Kituza.

In 1956, the department of Agriculture imported a variety called Upper Amazon hybrid from Ghana. This is a hybrid from the Forastero group which performed better than the Trinitario. Seeds of the Amerando type were also imported from Zaire in 1959 and planted in 1960 at Entebbe and Kituza nurseries. At the same time, a variety trial and seed garden of both Upper Amazon and Amerando were opened at Bubomboli-Bulyambwa in Bundibugyo district. By 1960 at 1960-61, seedlings had already been supplied to farmers for commercial planting. By 1964, the first seedlings had started yielding and the good yields indicated to farmers that cocoa farming was viable. Thus, extensive planning commenced during the period 1964-65.

The seedlings came from the seed gardens at Bubomboli and nurseries at Entebbe, Kituza and Nyaruru. By 1965 a total of 461 hectares had already been planted in Mukono, Bundibugyo and Hoima districts. Kituza sub-station was a nucleus from which agronomic practices for cocoa growing in Uganda were developed. Production technologies such as canopy and weed management, and pest control were developed to counter the farmers' production problems. These technologies increased cocoa production considerably.(ICCO, 2008)

A cocoa Development Project (CDP) was established in 1972 charged with the responsibility of promoting the cocoa industry in terms of increased production and improved quality for the successful penetration of cocoa on the world market. Its immediate objectives and functions then were to diversify agricultural production for exports in the Robusta coffee growing areas; regulate and control production as well as marketing of cocoa; maintain high quality standards in cocoa production; improve standards of the then existing plantations; open up cocoa nurseries to raise seedlings for gap filing and expansion of acreage; introduce improved planting materials and provide enough production inputs; train and upgrade cocoa extension workers; continue and if necessary set up an applied research network on cocoa.

By 1978, a total of 14,000 hectares had already been planted on smallholdings in the districts of Mukono, Jinja, Kamuli, Iganga, Hoima, Bundibugyo, Mpigi and Luwero. All aspects of cocoa production, marketing and exports were carried out by CDP on central fermentaries and driers established in all growing areas. In Bundibugyo district, 3 fermentaries were established. One at Bubomboli, another at Bundibugyo district and the third at Rwingo In Mukono district, fermentaries were established at Kasawo, Kituza, Najjembe, Kyabazala and Nkokonjeru. A private fermentary was also established at Kijjudde under the Salama estates. However, the political and economic instabilities of the late 1970 and early 1980s drastically affected the steady progress of the cocoa industry such that all processing facilities broke subsequent reduction in the acreage of cocoa. In 1983 cocoa processing and marketing functions were transferred to the Coffee Marketing Board (CMB)

IN 1986, FAO and UNDP at the request of the government of Uganda conducted studies to review the status of the cocoa industry in Uganda and to assess the prospects and prerequisites of its expansion and market penetrations. The studies showed that due to neglect and abandonment of cocoa plantation, only 10,000 hectares of mature cocoa were still productive as opposed to 14,000 hectares in1978. The report indicated that Uganda had a high potential for cocoa production which should be exploited with much scope for increasing the volume and value of production for export. (Kimera, 1984; Muwanga, 1994; Makamba, 1992; Mugume, 1994)

Agroforestry is not a new method or a revolutionary way of farming. In fact, this is one of the oldest methods of agricultural production, but it was abandoned for a while because of the intensification of modern agriculture (Nair, 2007). Furthermore, shading trees can be maintained in cocoa based agroforestry systems to reduce pest attacks (Beer *et al*., 1998) for stabilizing the microclimate (Sporn*et al*., 2009) for soil protection against rain drops (Dietz *et al*., 2005). In the scientific literature, there is consensus that cocoa-based agroforestry systems with dense and divers shade tree stands do harbor high levels of species richness (Jagoret, 2011). Above all, the aim is not only to sustain the forest in cocoa growing areas but also the increase income of the small-scale cocoa farmers.

In the context of Agroforestry Systems for Food (AFS4FOOD) project under which this study was carried out, one of the key objectives is to improve food security and well-being of African rural households through agroforestry, this directly via the various types of edible plant, medicinal plants, wood and other non-timber products, and directly through the sustainable provision of environmental service like sequestration and storage of carbon by woody component (cocoa, fruit trees, forest trees) in cocoa-based agroforestry. Here, the attention of cocoa yield evaluation in a cocoa-based agroforestry system is drawn to come out with a better and sustainable system for cocoa production while protecting the environment and conserving biodiversity. The choice for the study of the effect of shade trees on cocoa production yield in a cocoa-based agroforestry system was because despite ecological interest of cocoa, there has been little research on this cocoa-based agroforestry model with regards to its productivity.

1.2 Problem statement

Despite farmers planting shade tree species and other trees growing voluntarily on cocoa farms, diseases, pests have remained a challenge to cocoa farms. Cocoa bean production, soil fertility, environment has also been affected resulting into poor cocoa performance. There is no specific study which has tackled the challenge on the association between disease prevalence and shade tree diversity in small holder cocoa farms.

Deforestation, which can be either for agricultural or city expansion need is considered one of the main environmental problems in the tropics. Cocoa shade tree systems can be a means to address this case of deforestation and mono cropping for farming communities, cocoa growing and other related crops. The problem posed by these cocoa-based shade tree systems is that their association with diseases is not yet known.(Nair, 2007).

The more these natural resources are left with no choice but degradation by the local communities, serious hazards are likely to arise which can cost this country highly in terms of global warming, biodiversity loss, soil depletion leading to loss of soil fertility causing hunger that can introduce conventional farming.

This therefore calls for a study on the association between disease prevalence and shade tree diversity which is of great importance. Reduction of carbon dioxide emission, principal greenhouse gas remains a major challenge for every nation nowadays. At the national and international levels, climate policy, and agricultural development policies have powerful impacts on poverty, livelihoods, greenhouse gas emissions, and overall food, human, and environmental security. Improved understanding of these impacts, and the implementation of appropriate policies based on this understanding would generate improved outcomes that would have major impacts on human welfare and environmental sustainability.

1.3 Objectives of the study

This section presents the objectives of the study which are subdivided into the general objective and the specific objective.

1.3.1 Main Objectives

To assess the impact of shade tree species on disease prevalence in cocoa among small holder farms.

1.3.1 Specific objectives

1. To determine the influence of shade tree diversity on incidence of diseases in cocoa

2. To determine the influence of shade tree species on disease incidence in cocoa.

1.4 Research questions

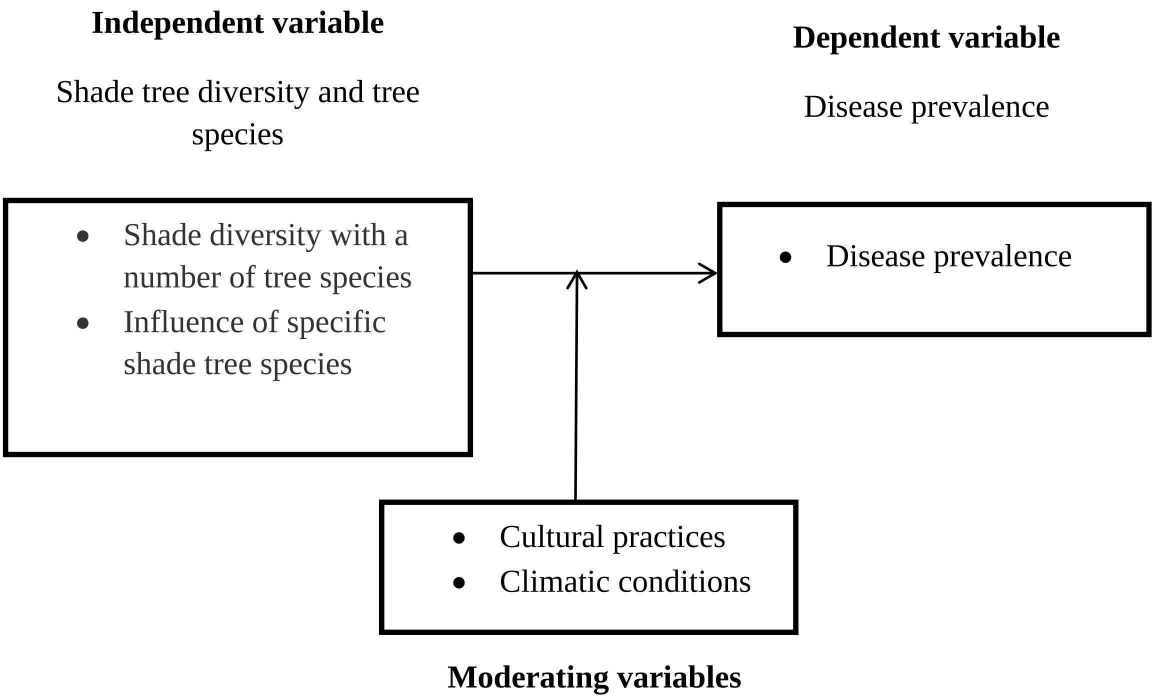
1. What is the relationship between disease prevalence and shade treediversity

2. What influence does the shade tree species have on disease prevalence?

1.5 Conceptual Framework

Conceptual framework showing the relationship between disease prevalence and shade tree species diversity.

Figure 1.1: Conceptual framework showing, dependent variables, independent variables and moderating variables.



Source: *Designed by the researcher (2020)*

Figure 1 above shows a conceptual framework of cocoa shade treediversity and disease prevalence. The independent variable was cocoa shade tree species diversity which were operationalized intoshade tree diversity with one tree species to tree specieswhereas the dependent variables were disease prevalenceand the moderating variables of the study were cultural practices, climatic conditions.

1.6 Significance of the study

This study will serve as a partial requirement for the award of a Master Degree in Agro Ecology

This study will also contribute to the available body of knowledge and provide reference literature and recommendations for further areas of studies to future researchers.

The study will contribute to policy maker's knowledge in the area of agriculture through guiding them in decision making process and policy formation process with regards to cocoashade tree diversity, disease prevalence and yield

Cocoa farmers may gain through access to increased knowledge in the areas of alternative cocoa shade tree systems used by farmers in managing disease prevalence and yield.

1.7 Scope of the study

This section presents the limitations of this study; the scope is divided into three major sections which include the geographical scope, content scope and time scope of the study.

1.7.1 Geographical scope

The study was conducted in Bundibugyo district. Bundibugyo District is bordered by Ntoroko District to the northeast, Kibaale District to the east, Kabarole District to the south, and the DRC to the west and north. The coordinates are 00°43′N 30°04′E

1.7.2 Content scope

This study focused on the influence of shade tree diversity on disease prevalence among small holder farms. It dealt with cocoa farmers, local government especially production department, cocoa private companies and other agricultural personnel both at district and other levels.

The study was limited to comparing the disease prevalence and shade tree diversity among small holder cocoa farms.

1.7.3 Time scope

The researcher focused on the period between 2010 and 2020 since this is the period within which cocoa farmers in Bundibugyo district have experienced high prevalence disease rate and low yield of cocoa.

1.8Justification of the study

The rational of this study was to determine the influence of shade tree diversity on disease prevalence among small holder farms. It is hoped that the study may generate information which may enable cocoa farmers to put in place effective and adequate cocoaAgroforestry systemsso that they can be able to reduce the disease prevalence rate and increase the yield of cocoa.

1.9 Definition of key terms

Shade trees are trees that with its applications, crops are purposely raised under trees canopies and within the resulting shady environment. For most uses, the understory crops are shade tolerant or the over storey trees have fairly open canopies a conspicuous example is the grown cocoa. This practice reduces weeding costs, mired attack in cocoa and increases the quality and taste of the cocoa.(NGALA, 2015)

Agroforestry is defined as the combination of forest trees with crops, or with domestic animals, or both,(Kellimore, 2010). Agroforestry is a land use management system in which trees or shrubs are grown around or among crops or pastureland. It combines agricultural and forestry technologies to create more diverse, productive, healthy, and sustainable land-use systems (NGALA, 2015).

Agroforestry systems include both traditional and modern land-use systems where trees are managed together with crops and animal production systems in agricultural settings. The presence of trees on external and internal boundaries, cropland, homestead plots or any other available niche of farmland, defines the Agroforestry systems structurally(Mkandawire *et al*., 2003)

Deforestation is defined as the conversion of forest to another land use or the long-term decline of forest cover below the minimum threshold of 10% (FAO, 2006). Its causes are many and vary from one country to another with some examples like pressure, poverty and Agriculture. (NGALA, 2015)

Forest Degradation is a process of change within the forest that negatively affects its characteristics (Mkandawire *et al*., 2003). It also refers to the reduction of capacity of a forest to produce goods and services. Capacity includes maintaining the structure and ecosystem functions. A degraded forest provides only a lim7ited amount of goods and services and maintains only limited biological diversity. It lost its structure, function, species composition and productivity normally associated with natural forests (Kellimore, 2010)

Biological diversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (Colombia et al.)

CHAPTER TWO

LITERETURE REVIEW

2.0. Introduction

This chapter highlights what other scholars have written. It presents the theoretical review, cocoa origin and distribution, classification of cocoa, description of cocoa, the ecology, seed production, planting, insect pests, utilization of cocoa, cocoa shade trees and lastly summary of the literature.

2.1 Theoretical Review

This study was underpinned by the portfolio theory. Portfolio theory is used to analyse the risk of hypothetical Agroforestry systems (Blandon, 1985). It has been shown that the relationship of the returns of the components of an Agroforestry system, expressed in terms of the covariance or correlation of returns, is of vital importance in correctly defining risk (Blandon, 1985). Agroforestry systems can be classified as efficient or inefficient. Inefficient systems are such that an alternative system exists which has a greater return for the same level of risk. Thus, inefficient systems do not represent rational choices for Agroforestry systems. The conclusion is reached that it is impossible to design a ‘best’ system, but rather a set of efficient systems of differing risk and return can be defined. This set of efficient systems is referred to as the efficient frontier (Blandon, 1985). Reeves and Lilieholm (1993) implemented it for a case study in Costa Rica using the MOTAD method of linear risk programming.

Trieda and Nitra (2016) used the portfolio theory to determine the systematic risk in agriculture. Their findings showed that from the point of production orientation, the crop farms recorded higher return and also higher risk in comparison to the animal farms. The development of risk and return reflects the structural changes in Slovak agriculture, which has been continually changing in the way of increasing the share of crop-oriented farms

(Trieda and Nitra, 2016). In this study the different cocoa Agroforestry systems were compared basing on the level of disease prevalence and yield to determine the more efficient cocoa Agroforestry system. High disease prevalence and low yield were perceived as risks in this study.

2.2 Cocoa Origin and distribution

Cocoa is a perennial crop that responds well in rainy tropical areas, with a maximum annual average of 30 - 32ºC.

It thrives under shades and in areas with annual rainfall between 1,500mm to 2,000mm.

According to International Cocoa Organisation, it grows in countries lying between 10 degrees north and 10 degrees south of the equator.

It does well in soil containing coarse particles with a reasonable quantity of soil nutrients to a depth of 1.5m to allow the development of a good root system.(Mkandawire et al., 2003)

The genus Theobroma originated from the Amazon and Orinoco basin, and subsequently spread to Central America, particularly Mexico, where it was known and used by the local population. The Olmec and Mayas, and later the Toltecs and Aztecs considered it the "food of the gods" (Wessel and Quist-Wessel, 2015). In the 16th century, Spanish explorers were the first to bring cocoa beans to Europe. Nowadays, cocoa has become one of the most important cash crops and is a key ingredient for many sweets and cosmetics. Since the discovery by Europeans, the tree quickly spread and become important throughout the humid tropics (ICCO, 2008).

Theobroma has been divided into twenty-two species of which T. cocoa is the most widely known. It was the Maya who provided tangible evidence of cocoa as a domesticated crop (Petithuguenin, 2000). Archeological evidence in Costa Rica indicates that cacao was drunk by Maya traders as early as 400 BC. The Aztec culture, dominant in Mesoamerica from the fourteenth century to the conquest, placed much emphasis on the sanctity of cocoa. The first outsider to drink chocolate was Christopher Columbus, who reached Nicaragua in 1502 searching for a sea route to the species of the East. But it was Hernan Cortes, leader of an expedition in 1519 to the Aztec empire, who returned to Spain in 1528 bearing the Aztec recipe for *xocoatl* (chocolate drink) with him. The drink was initially received unenthusiastically and it was not until sugar was added that it became a popular drink in the Spanish courts (ICCO, 2013). There are thousands of clones of cacao in the field gene banks in different areas of the world. Some of the largest collections are at the Cocoa Research Institute in Tafo, Ghana (6,000 accessions), the International Cocoa Gene bank in Trinidad (1,872 accessions), and CEPLAC in Brazil (1,749 accessions). The Tropical Agriculture Research Station, in Mayaguez, Puerto Rico, has 372 accessions (Brunner *et al.*, 2007)

2.3 Classification

Theobroma cacao belongs to the plant kingdom, *mangnoliophyta* division in the *mangnoliopsida* class, under *malvale* order in the family *malvaceaes* (Purseglove*et al*., 2012) cacao types are classified into three main groups: Criollo, Forastero and Trinitario. Criollo cacao developed in Northern South America, and has thin wall, red or yellow fruits. The seeds are large, round, white or pale purple, not astringent, and produce the highest quality chocolate. (Purse glove*et al*., 2012)

Unfortunately, Criollo types are low yielding and susceptible to many diseases, and are rare in cultivation. Forester cacaos are from the amazon basin, and have a thick wall, smooth, usually yellow fruit. The seeds are flattened and purple in color. Forastero cacaos are very productive, and dominate the world cacao production. Trinitario cacao arose in Trinidad as hybrids of Criollo and Ferastero type. They are highly variable, and considered high quality for chocolate production(Wessel and Quist-Wessel, 2015). There are approximately 22 Theobroma species, and about 15 are utilized for their edible pulp or seeds. Theobroma cacao is the most important species within the genus *theobromae*. *Theobromagrandiflorum* (cupuassu), *Theobromagileri* (mountain cocoa), *T, bicolor* (macambo) and *T. subincanun* (wild cocoa) are other species utilized for their sweet, edible pulp and edible seeds.(Wessel and Quist-Wessel, 2015)

2.4 Description

The cocoa plant is medium-sized tree, reaching 20-30 feet (4-8m) tall. Branches are produced in groups of three to five. The leaves are simple, 4-8 inches (10-20 cm) long, light to dark green and soft and flexible. New growth is bright red or pink. Small whitish flowers are produced on the branches and trunk, singly or in groups of 3-5. Fruits are 5-10 inches (13-26 cm) in length and 2-3 inches (5-7.6) in diameter. The fruit has a hard shell which may be smooth or ridged, elongated or rounded, red, yellow, or orange, and contains between 20-50 seeds, surrounded by a cream colored, sweet- sour, aromatic pulp (Mkandawire *et al.*, 2003)

The original habitat of the cocoa plant is the tropical forest with a canopy of tall trees, rainfall and humidity is high, so the plants grow tall. In the garden, plant height at 3 years can reach 1.8-3 meters and at the age of 12 years reached 4.5-7 meters (Andres, C., Bhullar, G.S., 2016) Cocoa plant is dimorphs (two forms have branches), that is, orthotropy branches (branches that grow upward) and plagiotropic (branches that grow sideways) (Nomo B, 2005). Cocoa is a plant with feeder root surface (mostly developing lateral roots near the surface). Thickness of rooting zone in the good soil is 30-50 cm. at low soil water soils, roots grow long and riding the lateral roots into the soil, whereas at high soil water and clay soils, the roots do not grow up riding so deep and lateral roots grow near the soil surface (Arno *et al*., 2011)

2.5Ecology

Mean minimal temperatures of less than 21 c is not suitable for cocoa cultivation (Braudeau, 1969; Pedelohore, 2012). Average rainfall of 1250-3000m per annum and preferably between 1500-2000 m with dry season of not more than three months with less than 100 mm rain per month is ideal but the quantity is less important than the distribution. Rainfall can be supplemented with irrigation during dry months. Temperature varying between 30-32 c mean maximum and 18-21c mean minimum but around 25c is considered to be favorable. Humidity is uniformly high in cocoa growing areas, often 100% at night falling to 70 or 80% by day some times during the dry season. The larger and greater leaf area than plants growing at medium (70-80%) and high (90-95%) humidity under the letter conditions leaves and tend to be curled and withered at the top. The other effect of humidity concerns the spread of fungal diseases and the difficulties of drying and storage. Cocoa is a tap-rooted plant and grown on a wide range of soil types and the standards for soil suitable for cocoa vary considerably. The best soil for cocoa is that which is rich in humus, deep well-drained soils free from iron concentrations and high in nutrient content (Opeke, 2005; Onakoya, 2011).

The cocoa tree is a shrub undergrowth native of the Amazon rainfall rainforest and can grow well in a very dense shade. It is now shown that the shading is a limiting factor of production and should be maintain to pass more than 50% of light (Mossu*et al*., 1990).

2.6 Seed production

Cocoa seeds readily germinate when sown and do not pass through a dormancy period. For raising seedlings, seeds of mature pods are taken from high yielding mother plants. The mother plants selected should have medium or large green pods with an average dry bean of not less than one gram. A more suitable procedure for planting good quality seedlings is to collect hybrid seeds from biclonal or polyclonal seed garden involving superior self-incompatible parent (Onakoya, 2011). They lose viability on extraction from the pod within five to seven days, unless specially treated. Cocoa seeds are therefore best stored in pods whereby they remain viable for up to four weeks after harvesting. If it is therefore necessary to extract the seeds from the pods for storage, the extracted seeds should be mixed with moist fine sand, moist sawdust or moist ground charcoal. The mixture should therefore be stored in a cool dry place and under such conditions; extracted seeds can be stored for two to three weeks (Onakoya, 2011).

2.7 Planting

Each seed is sown in a bag whose land has been copiously watered the previous day. The seed is place flat on the surface and middle of the bag, then pushed down to a centimeter in depth and covered with soil. Another watering is done immediately after planting; watering can contain a pre-emergent herbicide containing for example Diuron (15g of commercial product at 80% in 100 liters of water for 2500 bags). The nursery is the place where the seed are germinated and where seedlings are raised for five to seven months, sometimes more, for their field planting. The nursery should be established on a flat surface or slightly sloping area, well drained and not flooded, close to a permanent water source, close to a passable road and as close as possible to the planting site. In areas where wind can be strong, installing the nursery too close to the forest edge should be avoided (Mossu*et al*., 1990)

The location should be cleared of all vegetation, the soil thoroughly cleaned and, if necessary, drainage ditches dug in the direction of steepest slope. A frame stake, in wood or bamboo, 3m high, should be built to support some 2.5m above the ground shading passing about 50% off the total luminosity. Such shading can be easily obtained using fronds. They dry slowly and allow a gradual transition from any external light, which acclimatize and harden the young seedlings before field planting. In many countries the shade of the nursery is provided by various permanent crops such as rubber, palm oil or *Gliricidia sp*. Lateral protection is often required to complete the if the place is very clear and to avoid any depredation animals. There should be an area of 80m nursery for seedling required for planting a hectare (Mossu*et al*., 1990). Diseased plants and plants with twisted tap-root should be thrown away and planting should be done in a day when the soil is moist and when the sky is cloudy (FAO, 2006).

2.8 Insect pests

2.8.1Mirids

The mirid (*sahlbergellasingularis*) is one of the primary pests affecting cocoa (*Theobroma cacao* L.) production in Africa associated with 25 t0 40% production losses. *Sahlbergellasingularis* is widely distributed in West Africa. Present throughout the forest zone, from Sierra Leone to the Democratic Republic of Congo, and its life history is well known on cocoa. However, knowledge of S. singularis population structure in cocoa plantations is incomplete. About one century ago, miridsadapted to cocoa, a newly introduced cash-crop in West Africa. Its natural host-plant is mainly forest trees of the *Malvaceae* (Chaouis*et al*., 2012)

Mirids also known as capsids are insects that use their needle-like mouthparts to pierce the tissues of cocoa trees and sunk the sap. During this process they may inject toxic saliva into the plants. Infestation on cocoa pods results in minor direct losses. However, the holes created on the pods during feeding often make the pods vulnerable to black pods, which often cause more losses than the mirids itself. Moreover, attacks on shoots and young branches reduce the canopy of the tree becomes susceptible to other pests and diseases. Young trees cab die within a year if the attack is serious and even mature trees can be affected very severely. Losses can be as high as 30% or more if infestation is severe (David, 2005; Ebewore*et al*., 2013)

2.8.2 Cocoa pod borer (CPB)

Cocoa pod borer (*Conopomorphacramerella*) is a pest of cocoa in south-East Asia. It first appeared in Sabah, Malaysia, in 1980, but at that time there was no quantitative information on the damage it could cause (Roger, 2003).

Cocoa pod borer causes losses to cocoa by boring through the well and into the pod, feeding on the pulp of beans and placenta of the pod. Damage to the funicles of pods results in malformed and undersized beans, in sever infestation it produces small flat beans that are often stuck together. It also causes the pod to yellow or ripen unevenly and prematurely. The beans from seriously infested pods are completely unusable, and over half the potential crop can be lost in heavy infestations. In light infestations, there may be no economic loss but controls is still needed to prevent the development of more serious infestation (Crop Protection Compedium, 2014)

2.8.3Witches' Broom

Taphrina betulina is a fungus responsible for Witches' Broom disease. During the last century the fungus spread throughout all of South America, Panama and the Caribbean, causing great losses in production. The most visible effect can be seen in Brazil where the introduction of the disease in the region of Bahia caused a decrease in production of almost 70% during a period of 10 years (Robert, 1989). The fungus attacks only growing tissues that is, shoots, flowers and pods causing cocoa trees to produce branches with no fruit and ineffective leaves. The pods show distortion and present green patches that give the appearance of uneven ripening.

The life cycle of the fungus is synchronized with the phenology of the host. One of the most influential factors for the adequate reproduction of the fungus is water. Basidiospores are released at night are related to the level of humidity of about 80% and favorable temperature comprise between 20 and 30 c. The spores are capable of being disseminated locally by water and convection currents and over long distances by wind. Host resistance is recommended as the best option for economic and sustainable control.

2.8.4 Frosty Pod Rot

Is caused by the basidiomycete*moniliophthora roreri* it is found in all north-western countries in South America. First reports of the disease date back to the end of the 19th century, where its aggressive effects caused devastation in Colombian and Ecuadorian cocoa plantations. The fungus has now spread all over the Latin America region, causing significant losses in production, even resulting in the abandonment of cocoa farms (Wessel and Quist-Wessel, 2015). The fungus infects only actively growing pod tissues, especially young pods. The time from infection to the appearance of symptoms is about 1-3 months. The most outstanding symptom is the white fungal mat on the surface. The large number of spores produced (44 million spores per cm) and the genetic variability endows the fungus of spores' considerable adaptability (Taylor, 1998; Adejumo, 2004).

The dry, powdery from spores allows the fungus to be dislodged by water, wind or physical disturbance of the pod. Disease incidence varies with cultivar, pod age and rainfall. Generally, the greatest production is when rainfall is high. All cocoa species seem to be susceptible to this disease. The use of copper and organic protectors has proved to reduce incidence of the disease. Systematic fungicides such as Flutolanil have been found effective, although the use of agrochemicals is not economically sustainable in view of the cocoa (Olaniran*et al.*, 1977; Adejumo, 2004)

2.8.5 Phytophthora Pod Rot

It's also known as Black Pod, is caused by the fungus *Phytophthora spp.* Three fungal species of the same genus are responsible – *P. palmivora, P. megakarya* and *P. capsici*. Megakarya causes global yield loss of 20 -30% and tree deaths of 10% annually. *P. megakarya* is the most important pathogen in central and West Africa, known as the most aggressive of the Pod Rot pathogens. *P. capsici* is widespread in Central and South America, causing significant losses in favorable environments (NGALA, 2015)

One major difference between *P. palmivora* and *P. megakarya*, is the damaging species on cacao, the production, maturation, and liberation of sporangia are grouped in short period of time *for P. palmivora*, and in an extended period for *P. megakarya*(Wessel and Quist-Wessel, 2015). On a single cocoa pod, zoospores can be released from sporangia for over 30 days when infected by *P. megakarya*(NGALA, 2015) Based on this basic difference between two species, we strongly believe that an effective screening strategy for bio control candidates of *P. megakarya* needs to lay emphasis on endophytic strains that could control the production and maturation of sporangia on cocoa pods since sporangia and, in turn, zoospore are the major propagules for the dissemination of this fungal disease.

Pods can be attacked at any stage of development, and the initial symptoms are small, hard, dark spots on part of the pod. Internal tissues, including the beans, are colonized and shrivel from a mummified pod.

2.8.6 Vascular-streak dieback (VSD)

This was distinguished from the various dieback syndromes of cocoa induced by environmental factors and insects in Papua New Gunea (PNG) IN THE 1960S (Wessel and Quist-Wessel, 2015). It caused heavy losses of mature trees and seedlings planted near older cocoa. The disease was later shown to be caused by a new genus and species of basidiomycete, *Oncobasidiumtheobromae*. VSD has since been found in most cocoa growing areas in South and Southeast Asia and PNG, from New Britain in the east to Hainan Island. Chaina in the North and Kerala State, India, in the West, it has been a major problem in the large commercial plantations in West Malaysia and Sabah. It is widespread in Indonesia, including in the fine flavor cocoa plantations in East and West Java, and in the large areas of newer cocoa plantings is Sulawesi. It has also been reported from southern Thailand, Burma, Vietnam, and the southern Philippines. The only known host other than cocoa is avocado which is also an exotic plant in Southeast Asia and the Pacific. It is believed that the fungus evolved on an as yet unidentified indigenous host in Southeast Asia/Melanesia and transferred to introduce cocoa. Thus VSD is another example of new encounter disease inn cocoa(Wessel and Quist-Wessel, 2015)

2.9 Cocoa shade trees

Cocoa (*Theobroma cacao L.*) landscapes in West and Central Africa consist of a mosaic of smallholder cocoa farms that range in their structural diversity and species richness between highly diverse cocoa Agro forests like those encountered in southern Cameroon (Nomo, 2005; Sonwa*et al.*,2007) and cocoa monocultures, which exist in parts of Ghana and Côte d'Ivoire(Owino, 1992) and (Huxley *et al*., 1989). Tree diversity in cocoa farms offers farmers a range of agronomic, economic, cultural, and ecological benefits (Rice and Greenberg 2000; Duguma*et al*., 2001; Di Falco and Perrings ,2003; Somarriba and Beer, 2011). However, the composition and structure of shade tree stands in mixed systems have been reported to also cause excessive shade, which can lead to high humidity and create favourable conditions for black pod diseases in cocoa systems (Dakwa*et al*. 1976; Opoku *et al*. 2002) and also affect the mechanisms that drive fruit losses on cocoa trees (Bos*et al*., 2007). Monocultures of cocoa tend to have higher productivity under high-input conditions (fertilizer and pesticides) than cocoa in mixed systems (Gockowski*et al*., 2013) but also have shorter economic life span compared with low input, mixed systems, which sustain production over a relatively long period of time (Obiri*et al*., 2007). Hence, discussions on tree diversity, density and canopy cover in cocoa systems have been polarized between environmentalists looking for the long-term sustainability and those who seek to increase cocoa bean production in the short term (AbebeMekoyaKassa, 2008)

Environmentalists argue that cocoa farms with a diversity of forest tree species can connect fragmented forests and form corridors for animal passage, helping to conserve and improve the integrity of the ecosystem (Schroth and Harvey 2007; Asare*et al*. 2014). In upholding its environmental obligations, Rainforest Alliance through the Sustainable Agriculture Network has developed environmental criteria and indicators for cocoa production which advocate for 70 emergent non-cocoa tree species per hectare of cocoa of which 12 must be native species (SAN, 2005). This is estimated to provide a canopy cover of approximately 40 % for cocoa trees underneath the upper canopy, although it is not clear at what stage in the life of the cocoa and tree plantation this would be. This density is equivalent to shade tree spacing of 12 m × 12 m. In Ghana these criteria and indicators have been modified to meet requirements of the Ghana Cocoa Board (COCOBOD) through the Cocoa Research Institute of Ghana (CRIG), whose aim is primarily focused on optimal cocoa production. The recommendation is to plant up to 18 emergent trees (≥12 m height) per hectare (24 m × 24 m) also providing permanent canopy cover corresponding to approximately 30–40 % shade (Owino, 1992)

The variations in the recommended number of trees with respect to the appropriate range of shade cover per ha can be attributed to the species and structural diversity of trees in the system i.e., tree species, density, tree characteristics like canopy architecture, diameter at breast height, trunk height as well as age. Such variations may exist as a result of farmers' management practices, which include the area cultivated and the tree species configurations in the cocoa systems. This is because in Ghana and the rest of West Africa shade tree recruitment is part of an anthropogenic process in which the eventual density and structure of trees is as a result of farmers' preferences (Asare, 2010). However, this process makes it difficult for farmers to determine in advance and over the life span of the cocoa trees the amount of canopy cover available at any particular stage and age.

There is limited information on factors that influence tree species configuration and how this affects canopy cover in cocoa systems. These gaps in knowledge in part have led to the uncoordinated management of naturally regenerated desirable forest trees, rather than advance planning of their composition and arrangements in cocoa systems (Andres, C.; Bhullar, G.S, 2016). Over the last couple of decades, rapid expansion of extensive cocoa growing systems characterized by no-shade cocoa production has been cited as one of the major drivers of deforestation and forest degradation in West Africa (Asare, 2006a). Paradoxically, shade grown cocoa holds the potential to reverse this trend. The first aim of this work was to understand the factors influencing variability in tree density and diversity and how this contributes to canopy cover by shade trees in cocoa farms. Secondly, we tried to identify a simple indicator for canopy cover for different tree species in cocoa systems in order to help farmers determine appropriate canopy levels.

2.10 Utilization of cocoa

The main constituents of the cocoa bean are cocoa fiber, cocoa butter and the shell. These are separated during industrial processing. The fat-free fiber contains about 3% of theobromine which can be converted into caffeine. In the manufacturing of chocolate, the roasted nibs are ground into a mass to which extra cocoa butter is added along with other ingredients mainly sugar. In the making of milk chocolate, milk solids are added to the mass. Cocoa butter which constitutes some 56% of food cocoa beans is a high-grade vegetable fat with a number of valuable virtues. It melts at body temperature; it has good keeping qualities; it does not readily develop free fatty acids and it is readily digestible and agreeable to the palate. (Joseph K Mukiibi,)

Its aromatic properties and the other qualities are not readily reproduced and there is limit to the use of cocoa butter substitutes. The cocoa bean therefore, constitutes the raw material of important industries which manufacture.(Wessel and Quist-Wessel, 2015)

Semi-finished products intended for other industries, like cocoa mass used for making chocolate, biscuits and confectionery; melted cocoa intended for various food industries or sweet products; and cocoa butter used in making sweets, chocolate, perfume and other cosmetics and pharmaceutical preparations.

Finished products intended for direct consumption such as chocolate powder, bars and chocolate confectionery. ICCO (1996b) documents that apart from soft drinks which have a large market than confectionery; confectionery is far bigger than any other food or beverage category in terms of market value/retail selling prices.

By-products of this industry such as husks, fats extracted from husks and germ are used to feed cattle, manufacture fertilizer, pharmaceutical products and soap.

Utilization of cocoa beans continues to be undertaken predominantly in the non-cocoa producing countries where industrial processing has developed. The major cocoa importing countries with advanced industrial processing are the United States, Netherlands, France, Germany and the United Kingdoms. Some cocoa growing countries are also increasingly utilizing the cocoa beans. These include Brazil, Cote d' Ivoire, Mexico, Malaysia, Indonesia and Ghana.

2.11Summary of the Literature Review

From the literature reviewed above, there is a knowledge gap about the specific shade tree species which should be grown in cocoa plantations. Most trees grown by farmers are grown voluntarily without any knowledge of pest and disease control. Therefore, this study sought to address this knowledge gap through providing information regarding disease prevalence and shade tree diversity among small holder cocoa farms in Bundibugyo.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This chapter presents the methodology of the study. It highlights the study design, study area, the study population, sampling procedure, sample size and sampling technique, data collection methods, quality control methods, data management and processing, data analysis, ethical considerations and limitation of the study.

Materials and methods

3.1 Study design

The study used a cross sectional research design to collect data one point at a time (Sekeran, 2003). The study triangulated quantitative and qualitative methods, the quantitative approach was used to quantify findings using measures of central tendency, correlation and regression techniques while as qualitative approach was used to gain explanations for any phenomenon.

The study looked at how specific objectives were answered; this was done through applying different methods of data collection (photographing, observations and questionnaires). Each method was employed where applicable depending on which variable in question.

3.2 Study area

The study took place in Bundibugyo district, and 4 sub-counties were selected where respondents considered for qualitative & quantitative data were selected using judgmental sampling. Ngamba S/C located in the southern part of the district, Busaru S/C central part of the district, Buganikere T/C located in the central region of the district, Mirambi S/C located in eastern side of the district, which is 1 from Bughendera County located in the southern part of Bundibugyo and 3 from Bwamba County located in the northern side.

3.3 Target population, sampling frame and sample size

Uganda is estimated to have 20,000 hectares of land for cocoa growing , although there is no clear data on the number of farmers growing cocoa (https://www.aboutuganda.com/uganda/agriculture/cocoa-growing-in-uganda).Bundibugyo community has a predominantly agricultural population estimated at about 60,000, with a density of 150 inhabitants per square kilometre. For Bundibugyo, data on the exact population number has not been available; it has been estimated at 30,000 households in the district and about 42,000 farmers are involved in cocoa farming according to Production Officer Bundibugyo. However, the study area had 7,190 cocoa farmers and current farmers register indicated 120 farmers with five acres and above in the study area. Eighty-two (82) respondents (Table 1) were reached out of 120 cocoa farmers who cultivate on more than five acres of land (Word Bank, 2016) reflecting a response rate of 68.3%. The respondents were selected from four sub counties namely Mirambi, Ngamba, Buganikere and Busaru

Table.1 Number of cocoa farmers in the selected sub counties

Sub county name	No. of cocoa farmers	No. selected respondents	Actual respondents
Mirambi	2200	36	21
Ngamba	1450	24	19
Busaru	1890	31	21
Buganikere	1650	27	21
Total	**7,190**	**118**	**82**

3.4. Data collection

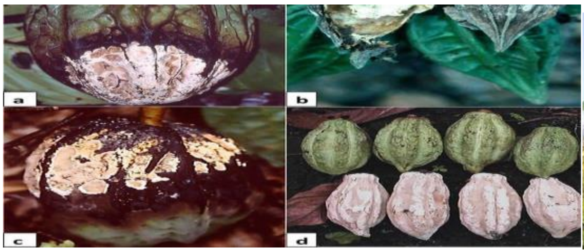
3.4.1 *Influence of shade tree diversity on disease incidence*

Data was collected at household level, considering individual farmers and basically this was primary data derived direct from the cocoa farmers to whom questioners were administered. Various methods were employed during data collection not limited to, questionnaires, observations and photograph.

Questionnaires, these were developed and administered at farmer level. This tool was able to capture the diseases types and the rate of attack against shade diversity. After identifying the sample size, every farmer was subjected to answer the questionnaire. Questionnaire was used because of its ability to collect vast data and gave various options to selected respondents to make their selection (Amin, 2005). Questionnaires were aided by photos of specific diseases to enable respondents give valid information as indicated in the appendix. The sample questions were but not limited to; Do cocoa diseases attack your farm, which type of cocoa diseases attack your farm, how many types of trees do you have on your cocoa farm?

Observations; specifically, the study also required observing specific cases and through this, visual data were recorded which helped in enriching this thesis. This focused on areas of; signs and symptoms of cocoa diseases, extent of damages caused by cocoa diseases.

Photography; pictures were taken in form of data to be collected. The researcher took and compiled photos where need be in a way of collecting data. These provided evidence to some cases which were found in the field and farmers were able to identify diseases by the aid of these photos.




Frosty pod rotCocoa dieback


Cocoa swollen shoot virusWitches’ broom

Cocoa pod rot

3.4.2 Effect of shade tree species on disease incidence

Data was collected at household level, considering individual farmers and basically this was primary data derived direct from the cocoa farmers.

Questionnaires were developed and administered at farmer level - respondents for this research. This tool captured the diseases types and the specific tree species. The sample questions were; which type of trees species do you grow on your farm, which type of cocoa diseases attack your farm, how often do cocoa diseases attack your farm?

Observations were used to observing specific disease symptoms, visual data were recorded which helped in enriching this thesis. Tree species on farm were observed, signs and symptoms of cocoa diseases.

3.6 Quality control methods

Quality control was ensured, for the case of questionnaires, there was pre testing before allowing the questionnaire to the field. The study was under the guidance of the supervisor who effectively performed the duties of the research supervisor.

3.6.1 Validity

The number of respondents for pre-testing should be smaller, usually 1% to 10% of the sample size (Mugenda and Mugenda, 1999).

The researcher therefore used respondents within the range of 1% to 10% of the sample size while pre-testing the instrument.

The validity of the instruments was tested using the Content Validity Index (CVI) using expert judgment, taking only variables scoring above 0.7 accepted for research (Amin, 2005). The Content Validity Index was measured using the formula

$$CVI = \frac{\text{Number of items declared valid}}{\text{Total number of items}}$$

$= \underline{14.79} = 0.87 = 17$

Additionally, face validity was also used to determine the extent to which a test is subjectively viewed as covering the concepts it's supposed to measure. Face validity was used on people who may not necessarily be experts in the area of the study. In this case the CVI was 0.87, it was actually considered to be excellent.

3.6.2 Reliability

The study instruments were pilot tested on a sample of 10 respondents. The internal reliability or consistence of the instrument wasmeasured using the Cronbach's alpha coefficient taking only variables with an alpha coefficient value more than 0.7, accepted for research (Amin, 2005).

Table 2: The reliability test results of the study

Narrative Summary	Cronbach Alpha coefficient	Number of items
Disease Prevalence	0.894	11
Shade tree diversity.	0.771	6
Average	0.8325	9

Source: *Primary data, (2020)*

The response results were confirmed to be reliable as reflected in the table above. Sekaran (2003) asserts that Cronbach Alpha Coefficient that ranges between 0.6 – 0.8 is more acceptable. From the table below the Cronbach Alpha Coefficient was 0.0.8325 implying that the findings of the pilot study reflected that the study instruments were reliable.

3.7. Data management and processing

Data collected was managed and processed using computer statistical package, SPSS where results were communicated through descriptive method. The data collected was managed and analyzed by the researcher so that it serves its purpose. The completed questionnaires and data sheets were administered and the researcher ensured that they were completed and consistently filled well. The filled questions were coded and entered in the statistical package (SPSS) and excel for analysis.

3.8 Data analysis

3.8.1. *Influence of shade tree diversity on disease incidence*

The questionnaire was pre-tested using a selected group of respondents from the target population to ensure reliability and validity of the questions and responses. All data were coded and analysis was carried using descriptive statistics where statistical package SPSS was used to obtain the chai squared test values of perceptions obtained from respondents. Data was presented in Bar graphs to help simplify analysis and analysis was mainly done using descriptive analysis where issues of association and significance of responses were compared.

3.8.2 Effect of shade tree species on disease incidence

The questionnaire was pre-tested using a selected group of respondents from the target population to ensure reliability and validity of the questions and responses. All data were coded and analysis was carried using descriptive statistics where statistical package SPSS was used to obtain chai squared test values of perceptions from respondents.Data was presented in tables to help simplify analysis and analysis was mainly done using descriptive analysis to obtain chai squared values and the level of significance was at 95%

3.9 Ethical considerations

This study took into account the ethical aspects of the respondents. It took care of the respondents' beliefs and norms, religions and other social aspects. The authorization letter was issued out clearing the commencement of this research.

3.10 Limitations of the study

This study did not go beyond its limitations, geographically, it concentrated within the specific administrative units specified, Ngamba, Buganikere, Busaru, and Mirambi and unnecessary questions not relevant to the study, were minimized as much as possible.

CHAPTER FOUR

PRESENTATION, ANALYSIS AND INTERPRETRATION OF RESULTS

4.0 Introduction

This chapter analyses and interprets the study findings arising from the field information collected from respondents that aims at assessing disease prevalence and shade tree diversity among small holder farms. small holder farmers in Bundibugyo district. The first section presents the response rate, followed by presentation and analysis of the study findings in relation to the specific objectives of the researchers' study.

4.1 Response rate

A total of 109 questionnaires were distributed but 82 filled-up questionnaires were returned as reflected in the response rate table 4.1 below.

Table 3: Response rate of respondents

Particulars	Sample	Returned questionnaires	Percentages
Questionnaires	92	82	89.13%
The Overall Response Rate			**89.13%**

Source: *Primary Data, (2020)*

The table 3 above shows a resultant response rate of 89.13% suggesting that the results contain substantial information and the survey results were representative of the survey on assessing disease prevalence and shade tree diversity among small holder cocoa farms in Bundibugyo district. The proportionately high response rates of 89.13% suggested more accurate survey results (Amin, 2005).

4.2 Results

4.3 *Influence of shade tree diversity on disease incidence*

Black pod rot disease

The association between shade diversity and disease incidence was non-significant (Fig 1). Regardless of the different shade diversity systems recorded from several respondents, the disease incidence was reported by all respondents. Therefore, this means that with or without the presence of shade diversity, black pod rot disease incidence would still be present on these farms.

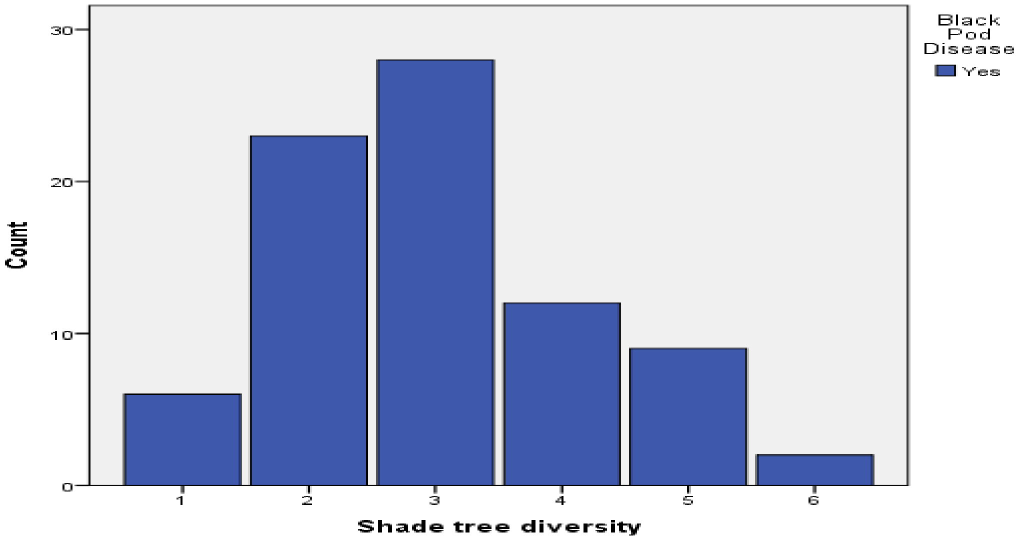


Figure 2: Black Pod rot disease in association with shade tree diversity

Witch's Broom disease

Shade diversity 1 had 8 farmers, 3 reported disease incidences on their farms and 5 did not have the disease. Shade diversity 2 had 27 farmers, 14 farmers reported disease incidence while 13 farmers did not report the disease on their farms. Shade diversity 3 had 35 farmers, 15 reported the disease presence and 20 did not have disease. Shade diversity 4 had 14 farmers, 6 reported disease presence and 8 did not report the disease on their farms. Shade diversity 5 had 9 farmers and all reported disease incidence. Shade system 6 had 2 farmers and both reported disease incidence. (Fig 2)

There is a significant association between the shade diversity 1,2,3&4 and witch's broom disease. At diversity 3 &4 respectively, the disease incidence cases were lower than the normal cases. association between the disease incidence and shade diversity 5&6 was insignificant (Fig 2) Only diseased cases were reported by respondents.

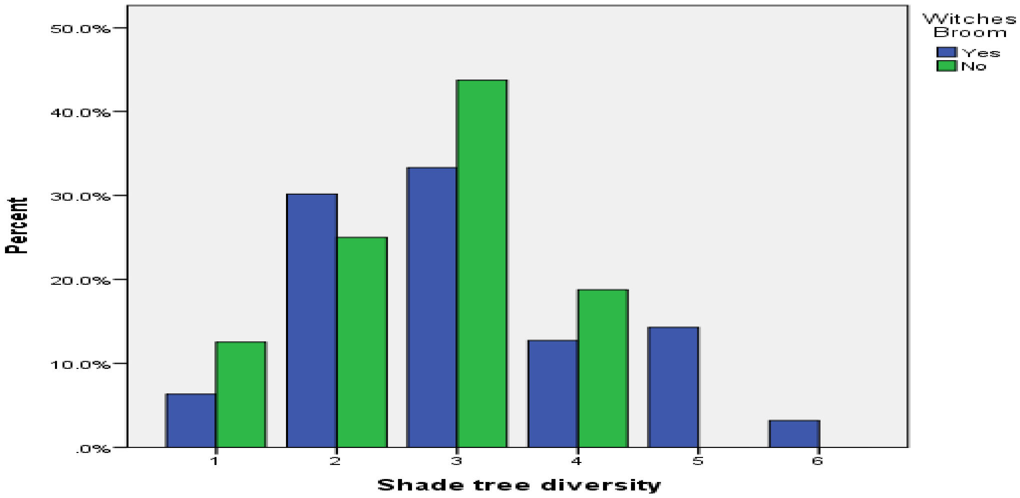


Figure 3: Witch's Broom disease in association with shade tree diversity

Frost pod rot disease

The analysis of the frost pod rot disease incidence in (Fig 3), followed several trends; Shade diversity 1-3 there were influences noticed though not significant. Shade diversity 4-6 had completely no influence on disease incidence.

The disease incidence case across all shade diversity suppressed by far the normal case (shade diversity 1,2,3) and at shade diversity 4,5,6, disease incidence was at the peak

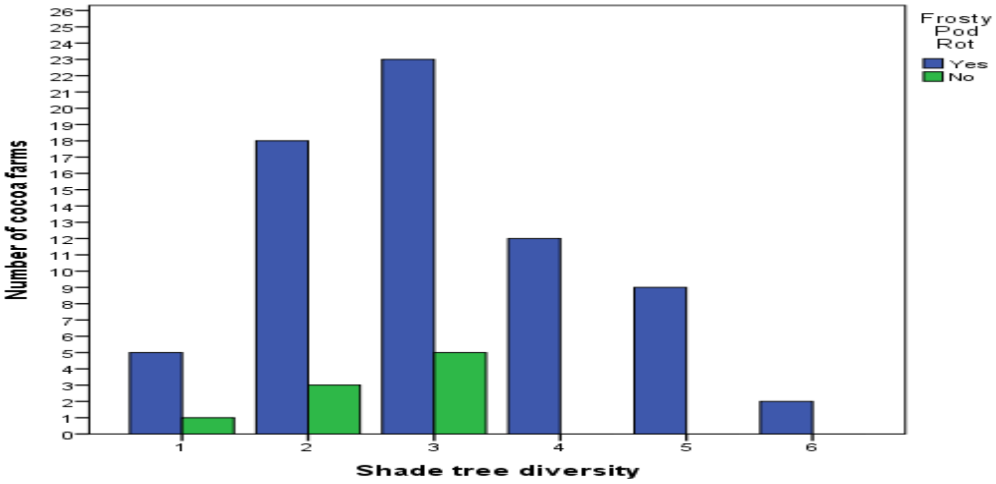


Figure 4:Frost pod rot disease incidence with shade tree diversity

Cocoa Swollen shoot virus

The analysis of cocoa swollen shoot virus (Fig 4); there are quite significant levels at each shade diversity. The disease prevalence at shade diversity 1,2,3,4&5 is negatively influenced. This means these shade systems limited in some way the occurrence of the disease. Unlike shade diversity 6 which had no influence on the disease occurrence.Disease prevalence was reported across all shade tree diversities. However, shade diversity 1,2,3,4&5 had an influence on the on the disease prevalence as opposed to shade diversity 6

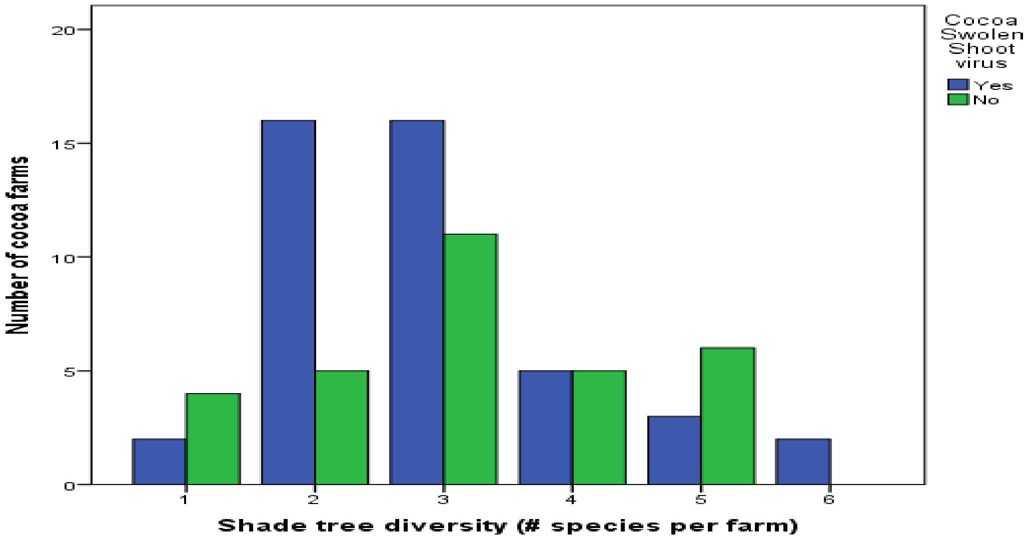
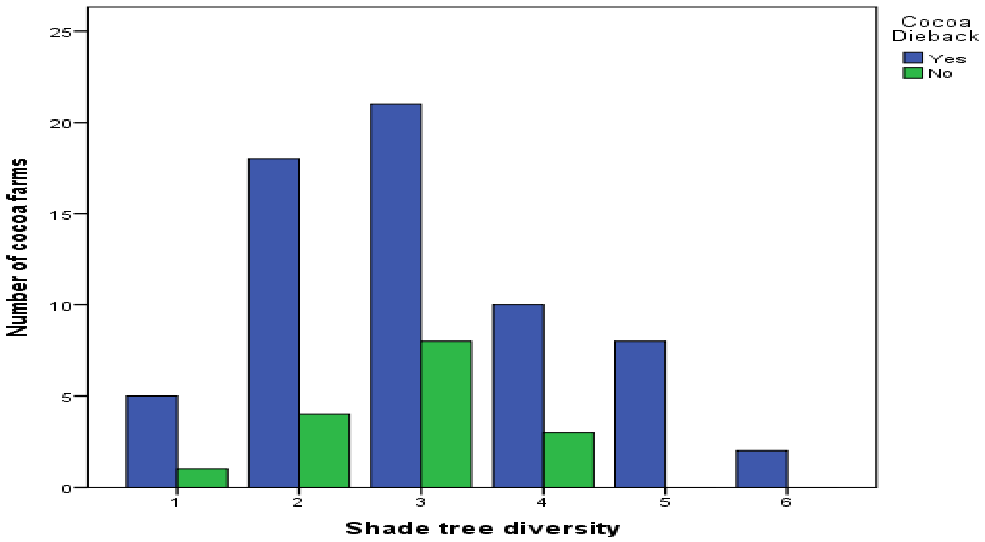


Figure 5:Cocoa Swollen shoot virus prevalence in shade tree diversity

Cocoa Dieback Disease

Although there are bits of un diseased cases at shade diversity, 1.2.3&4, the association between cocoa die back disease and shade diversity are insignificant. The diseased cases were far surpassing un diseased cases. (Fig 5). And at shade diversity 5&6, there was no influence in limiting disease incidence



6: Cocoa Dieback in association with shade tree diversity

4.5 Effect of shade tree species on disease incidence

Black pod rot disease with shade tree species

Black pod rot disease incidence waspresent in all tree shade species as represented by 100% (all farms) (Table 2).Farmers asserted that the diseases incidence occurred on all farms.However, farmers with *Maesopsis eminii*registered the highest number of 58 disease incidence cases, followed by *Persea Americana* 29, *Artocarpus heterophyllus*27, *Cinnamomum tamala* 23, Eucalyptus globulus 23, *Mangifera indica*14, *Spathodea campanulata*9

Table 4: Analysis of black pod rot disease with shade tree species in Bundibugyo District

Shade tree species		Disease presence		Total	Shade tree species		Disease presence		Total
		Yes	**No**				**Yes**	**No**	
Maesopsis eminii	Yes	58	0	58	*Eucalyptus globulus*	Yes	23	0	23
	No	22	0	22		No	57	0	57
	Total	80	0	80		Total	80	0	80
Markhamia obtusifolia	Yes	13	67	80	*Pinus sabiniana*	Yes	3	0	3
	No	67	13	80		No	77	0	77
	Total	80	80	160		Total	80	0	80
Schefflera actinophylla	Yes	14	0	14	*Arecaceae*	Yes	11	0	11
	No	16	0	16		No	69	0	69
	Total	30	0	30		Total	80	0	80
Cinnamomum tamala	Yes	23	0	23	*Ficus capensis*	Yes	2	0	2
	No	57	0	57		No	78	0	78
	Total	80	0	80		Total	80	0	80
Artocarpus heterophyllus	Yes	27	0	27	*Psidium guajava*	Yes	2	0	2
	No	53	0	53		No	78	0	78
	Total	80	0	80		Total	80	0	80
Triplochiton seleroxylon	Yes	5	0	5	*Citrus X sinensis*	Yes	2	0	2
	No	75	0	75		No	77	0	77
	Total	80	0	80		Total	79	0	79
Persea Americana	Yes	29	0	29	*Aleurites moluccanus*	Yes	9	0	9
	No	50	0	50		No	71	0	71
	Total	79	0	79		Total	80	0	80
Albizia glaberrima	Yes	1	0	1	*Spathodea campanulate*	Yes	1	0	1
	No	79	0	79		No	79	0	79
	Total	80	0	80		Total	80	0	80
Glicidia sepium	Yes	4	0	4	*Morinda lucida*	Yes	2	0	2
	No	76	0	76		No	78	0	78
	Total	80	0	80		Total	80	0	80
Mangifera indica	Yes	14	0	14					
	No	66	0	66					
	Total	80	0	80					

Association of witch's Brom disease in shade tree species

The association between witch's broom and presence of *Maesopsis eminii*was highly significant ($\chi 2$=55.41),(p<0.05), (Table 3). Association between witch's broom and presence of *Persea Americana* ($\chi 2$=9.79),(p<0.05), *Eucalyptus globulus* ($\chi 2$=16.71), (p<0.05),*Markhamia obtusifolia*($\chi 2$=3.95), (p<0.001), *scheffleraactinophylla* ($\chi 2$=4.32),(p<0.001), *Mangifera indica* ($\chi 2$=6.46), (p<0.001) was significant for disease incidence though these trees were planted in small numbers as indicated in the table below. There was a non-significant association between witch's broom incidence with presence of *Artocarpus heterophyllus*, *Triplochiton seleroxylom, Albizia glaberrima*, *Triplochiton seleroxylom, Pinus sabiniana, Arecaceae*, *Psidium guajava,* Citrus X sinensis, *Aleurites moluccanus, Spathodea campanulate, Morinda lucida.*

Table 5: Association of Witch's Broom in shade tree species

Shade tree species		Disease presence		Total	Chi-squared	Shade tree species		Disease presence		Total	Chi-squared
		Yes	No					Yes	No		
Maesopsis eminii	Yes	58	0	58		*Eucalyptus globulus*	Yes	11	11	22	
	No	5	16	21	55.41***		No	52	5	57	16.71***
	Total	63	16	79			Total	63	16	79	
Markhamia obtusifolia	Yes	13	0	13		*Pinus sabiniana*	Yes	3	0	3	
	No	50	16	66	3.95**		No	60	16	76	0.79
	Total	63	16	79			Total	63	16	79	
Schefflera actinophylla	Yes	14	0	14		*Arecaceae*	Yes	6	4	10	
	No	49	16	65	4.32*		No	57	12	69	2.76
	Total	63	16	79			Total	63	16	79	
Artocarpus heterophyllus	Yes	18	8	26		*Ficus capensis*	Yes	2	0	2	
	No	45	8	53	2.65		No	61	16	77	0.52
	Total	63	16	79			Total	63	16	79	
Triplochiton seleroxylon	Yes	4	1	5		*Psidium guajava*	Yes	2	0	2	
	No	59	15	74	0		No	61	16	77	0.52
	Total	63	16	79			Total	63	16	79	
Persea Americana	Yes	17	11	28		*Citrus X sinensis*	Yes	1	1	2	
	No	45	5	50	9.79***		No	62	14	76	5.19
	Total	62	16	78			Total	63	15	78	
Albizia glaberrima	Yes	1	0	1		*Aleurites moluccanus*	Yes	9	0	9	
	No	62	16	78	0.26		No	54	16	70	2.58
	Total	63	16	79			Total	63	16	79	
Glicidia sepium	Yes	5	0	5		*Spathodea campanulata*	Yes	1	0	1	
	No	58	16	74	1.36		No	62	16	78	0.26
	Total	63	16	79			Total	63	16	79	
Mangifera indica	Yes	5	6	11		*Morinda lucida*	Yes	2	0	2	
	No	56	10	66	6.46*		No	61	16	77	0.52
	Total	61	16	77			Total	63	16	79	

*, ** and *** stand for significance at 5, 1 and 0.1% error margin, respectively

Prevalence of frosty pod rot disease with shade tree species

Prevalence of *frost pod rot* disease was highly associated with presence of*Maesopsis eminii* ($\chi2$=25.90),(p<0.05);*Eucalyptus globulus*($\chi2$=6.76), (p<0.05); planted 6/44 farms, *Mangifera indica*($\chi2$=4.85), (p<0.001); were not responsible for disease incidence since they were planted in small numbers.Presence of *Schefflera actinophylla*, *Artocarpus heterophyllus*, *Triplochiton seleroxylon*, *Persea Americana*, *Arecaceae* tree species, *Ficus capensis*, *Psidium guajava*, *Glicidia sepium*, *Citrus X sinensis*, *Aleurites moluccanus*, *Spathodea campanulate*, *Morinda lucida*, *Pinus sabiniana* had non-significant association for disease incidence.

Table 6: Prevalence of Frost Pod Rot Disease with shade tree species

Shade tree species		Disease presence		Total	Chi-squared	Shade tree species		Disease presence		Total	Chi-squared
		Yes	No					Yes	No		
Maesopsis eminii	Yes	56	0	56		*Eucalyptus globulus*	Yes	17	6	23	
	No	13	9	22	25.90***		No	52	3	55	6.76***
	Total	69	9	78			Total	69	9	78	
Markhamia obtusifolia	Yes	8	4	12		*Pinus sabiniana*	Yes	3	0	3	
	No	36	27	63	2.04		No	66	9	75	0.41
	Total	44	31	75			Total	69	9	78	
Schefflera actinophylla	Yes	14	0	14		*Arecaceae*	Yes	10	1	11	
	No	55	9	64	2.23		No	59	8	67	0.08
	Total	69	9	78			Total	69	9	78	
Artocarpus heterophyllus	Yes	24	3	27		*Ficus capensis*	Yes	2	0	2	
	No	45	6	51	0.01		No	67	9	76	0.27
	Total	69	9	78			Total	69	9	78	
Triplochiton seleroxylon	Yes	5	0	5		*Psidium guajava*	Yes	2	0	2	
	No	65	9	74	0.71		No	67	9	76	0.27
	Total	70	9	79			Total	69	9	78	
Persea Americana	Yes	23	6	29		*Citrus X sinensis*	Yes	1	1	2	
	No	45	3	48	3.83		No	67	8	75	3.09
	Total	68	9	77			Total	68	9	77	
Albizia glaberrima	Yes	1	0	1		*Aleurites moluccanus*	Yes	9	0	9	
	No	68	9	77	0.13		No	60	9	69	1.32
	Total	69	9	78			Total	69	9	78	
Glicidia sepium	Yes	4	0	4		*Spathodea campanulata*	Yes	1	0	1	
	No	65	9	74	0.55		No	68	9	77	0.13
	Total	69	9	78			Total	69	9	78	
Mangifera indica	Yes	10	4	14		*Morinda lucida*	Yes	2	0	2	
	No	59	5	64	4.85*		No	67	9	76	0.27
	Total	69	9	78			Total	69	9	78	

***, ** and *** stand for significance at 5, 1 and 0.1% error margin, respectively**

Association of cocoa swollen shoot virus disease with shade tree species

Association between swollen shoot virus and presence of *Maesopsis eminii* ($\chi2$=31.55), (p<0.05); *Cinnamomum tamala* ($\chi2$=19.22), (p<0.05); was highly significant.(Table 5). Association between swollen shoot virus and *Eucalyptus globulus*($\chi2$=14.10), (p<0.05); *Persea Americana* ($\chi2$=11.17), (p<0.05);*Aleurites moluccanus* ($\chi2$=7.21), (p<0.05); was significant though these tree species were planted in small numbers (Table 5). *Markhamia obtusifolia,*Schefflera *actinophylla*, *Artocarpus heterophyllus*, *Triplochiton seleroxylem, Albizia glaberrima, Glicidia sepium, Mangifera indica, Pinus sabiniana, Arecaceae, Ficus* *capensis, Psidium guajava, Citrus X sinensis, Spathodea campanulate, Morinda lucida* were non-significance for disease incidence.

Table 7: Prevalence of Swollen Shoot Virus Disease in tree species

Shade tree species		Disease presence		Total	Chi-squared	Shade tree species		Disease presence		Total	Chi-squared
		Yes	No					Yes	No		
Maesopsis eminii	Yes	42	11	53		*Eucalyptus globulus*	Yes	6	17	23	
	No	2	20	22	31.55***		No	38	14	52	14.52***
	Total	44	31	75			Total	44	31	23	
Markhamia obtusifolia	Yes	8	4	12		*Pinus sabiniana*	Yes	4	1	5	
	No	36	7	43	0.38		No	42	30	72	0.08
	Total	44	11	55			Total	46	31	77	
Schefflera actinophylla	Yes	5	7	12		*Arecaceae*	Yes	4	7	11	
	No	39	24	63	1.7		No	40	24	64	2.64
	Total	44	31	75			Total	44	31	75	
Cinnamomum tamala	Yes	20	0	20		*Ficus capensis*	Yes	1	1	2	
	No	24	31	55	19.22***		No	43	30	73	0.06
	Total	44	31	75			Total	44	31	75	
Artocarpus heterophyllus	Yes	13	14	27		*Psidium guajava*	Yes	1	1	2	
	No	31	17	48	1.93		No	43	30	73	0.06
	Total	44	31	75			Total	44	31	75	
Triplochiton seleroxylon	Yes	4	3	7		*Citrus X sinensis*	Yes	1	1	2	
	No	42	28	70	0.8		No	43	29	72	1.51
	Total	46	31	77			Total	44	30	74	
Persea Americana	Yes	9	18	27		*Aleurites moluccanus*	Yes	9	0	9	
	No	34	13	47	11.47***		No	35	31	66	7.21***
	Total	43	31	74			Total	44	31	75	
Albizia glaberrima	Yes	0	1	1		*Spathodea campanulata*	Yes	1	0	1	
	No	44	30	74	1.44		No	43	31	74	0.71
	Total	44	31	75			Total	44	31	75	
Glicidia sepium	Yes	3	0	3		*Morinda lucida*	Yes	2	0	2	
	No	42	31	73	2.2		No	42	31	73	1.45
	Total	45	31	76			Total	44	31	75	
Mangifera indica	Yes	6	7	13							
	No	38	24	62	1.02						
	Total	44	31	75							

***, ** and *** stand for significance at 5, 1 and 0.1% error margin, respectively**

Association of cocoa dieback disease with shade tree species

Association between cocoa die back and presence of *Maesopsis eminii*was highly significant for disease incidence ($\chi2$=53.73), (p<0.05); (Table 6). Association of the die back disease and presence of *Cinnamomum tamala*($\chi2$=8.07), (p<0.001);*Persea Americana* ($\chi2$=14.10),

(p<0.05); *Eucalyptus globulus* ($\chi 2$=25.01), (p<0.05); *Schefflera actinophylla*($\chi 2$=4.24),(p<0.001); *Mangifera indica*($\chi 2$=5.45), (p<0.05) showed high significance levels though these trees were planted on few farms. There was a non-significant association between die back with presence of *Markhamia obtusifolia, Artocarpus heterophyllus, Triplochiton seleroxylon, Albizia glaberrima, Glicidia sepium, Arecaceae,Ficus capensis, Psidium guajava, Citrus X sinensis,Aleurites moluccanus, Spathodea campanulate, Morinda lucida*.

Table 8: Cocoa Dieback Disease Prevalence with tree species

Shade tree species		Disease presence Yes	Disease presence No	Total	Chi-squared	Shade tree species		Disease presence Yes	Disease presence No	Total	Chi-squared
Maesopsis eminii	Yes	58	0	58		*Eucalyptus globulus*	Yes	11	13	24	
	No	6	16	22	52.73***		No	53	3	56	25.01***
	Total	64	16	80			Total	64	16	80	
Markhamia obtusifolia	Yes	12	0	12		*Pinus sabiniana*	Yes	3	0	3	
	No	52	16	68	3.53		No	61	16	77	0.78
	Total	64	16	80			Total	64	16	80	
Schefflera actinophylla	Yes	14	0	14		*Arecaceae*	Yes	7	4	11	
	No	50	16	66	4.24*		No	57	12	69	2.13
	Total	64	16	80			Total	64	16	80	
Cinnamomum tamala	Yes	23	0	23		*Ficus capensis*	Yes	2	0	2	
	No	41	16	57	8.07***		No	62	16	78	0.51
	Total	64	16	80			Total	64	16	80	
Artocarpus heterophyllus	Yes	19	7	26		*Psidium guajava*	Yes	2	0	2	
	No	45	9	54	1.15		No	62	16	78	0.51
	Total	64	16	80			Total	64	16	80	
Triplochiton seleroxylon	Yes	4	1	5		*Citrus X sinensis*	Yes	1	1	2	
	No	60	15	75	0		No	63	14	77	5.28
	Total	64	16	80			Total	64	15	79	
Persea Americana	Yes	16	12	28		*Aleurites moluccanus*	Yes	10	0	10	
	No	47	4	51	14.10***		No	54	16	70	2.86
	Total	63	16	79			Total	64	16	80	
Albizia glaberrima	Yes	1	0	1		*Spathodea campanulata*	Yes	1	0	1	
	No	63	16	79	0.25		No	63	16	79	0.25
	Total	64	16	80			Total	64	16	80	
Glicidia sepium	Yes	5	0	5		*Morinda lucida*	Yes	2	0	2	
	No	59	16	75	1.33		No	62	16	78	0.51
	Total	64	16	80			Total	64	16	80	
Mangifera indica	Yes	8	6	14							
	No	56	10	66	5.54*						
	Total	64	16	80							

***, ** and *** stand for significance at 5, 1 and 0.1% error margin, respectively**

4.6 Discussion

Influence of shade tree diversity on disease incidence

The study considered eighty-two respondents with farms which are five acres and above from the four sub counties in Bundibugyo (Table 1).

Results focused on five cocoa diseases and their incidences in relation to the six shade tree diversities. The diseases were, black pod, witch's broom, frost pod rot, cocoa swollen shoot virus and cocoa die back. Cocoa plantations have always been associated with several diseases. (Gabriella Galarza Ferrin. August, 2019)

Shade diversity 1 (one tree species), shade diversity 2 (two tree species), shade diversity 3 (three trees' species), shade diversity 4 (four trees' species), shade diversity 5 (five trees' species), and shade diversity 6 (six trees' species) (Fig. 1-**5**). Cocoa diversity systems have special attention because of their economic, social, and ecological importance. (Hervé Bertin Daghela Bisseleua*et al*., 2014)

Association between diseases and presence of shade diversity varied depending on disease type as indicated in the results, the Parten of the association was not uniform in all diseases and this could have been influenced by several factors not limited to soil fertility, biodiversity issues, age of cocoa plantation,shade characteristics and the cocoa density. Agroforestry is a land use management system in which trees or shrubs are grown with crops and pasture land. It combines agricultural and forestry technologies to create more diverse, productive, profitable, healthy and sustainable land-use systems (James *et al*.,2014).

Shaded cocoa plantations, facilitate dispersal of forest fauna between fragments. Plants and animal biodiversity found within shaded coca systems could augment ecosystem series like pest control, pollination, weed control, fungal disease limitation, and soil fertility. (Hervé Bertin Daghela Bisseleua*et al*., 2014)

The association between pod rot disease and shade diversity presence was non-significant. Disease incidence was reported on all the farms regardless of the type shade diversity present on farm.

Association between witch's broom disease incidence and presence of shade tree diversity was significant. This could have been because of cocoa age, most of the cocoa plantations were above 10 year of existence. The age of the cocoa plantation has a negative significant effect on the witches' broom disease control, low witch's broom incidence is associated with younger cocoa plantations. Spaggiari Souza *et al*. (2009) also found that there is an effect of cocoa age on the incidence of witch's broom disease during a 14- year trial in Brazil. It is argued that older and larger trees have more meristematic fluid which favor the inoculum production and dissemination of witch's broom. The result of this research agrees with the discussion because most of the farms were above 14 years of existence. Reference is made to the study conducted by Spaggiari Souza *et al*. (2009)effect of cocoa age on the incidence of witch's broom disease.

Associations between Black pod, frost, swollen, cocoa dieback and presence of shade diversity was non-significant. The incidence of these diseases had no clear Parten of occurrence on selectedfarms for this research. Marius Wessel et al., (2015) says cocoa swollen virus and *phytophthera* pod rot are common diseases of cocoa, therefore they could have been caused by other factors. This calls for further studies on the specific causes of such diseases within the cocoa plantations but also identifying specific shade tree species of economic importance. Asare (2010) says the occurrence of trees on cocoa farms are as a result of natural regeneration and farmers do not have much to do with selection of specific tree species. During her analysis of shade establishment and management in cocoa farms in Ashanti region of Ghana showed that farmers primarily rely on natural regeneration to include shade trees on farms and this practice allows farmers to establish trees in a cost-effective manner that promotes species already in the land scape. However, these practices limit tree diversification options since it only allows trees already in the system to generate easily and thrive.

Effect of shade tree species on disease incidence

The association between black pod rot disease and presence of all tree species was non-significant. The disease incidence was not influenced by presence of the tree species. The association between witch's broom, swollen shoot virus, die back, frosty pod rot and presence of *Maesopsis eminii*was highly significant. *Maesopsis eminii* is likely to be a host for cocoa diseases and farmers need to care planting it for a shade tree. Witch's broom disease incidence was highly significant with presence of *Maesopsis eminii* ($\chi 2$= 55.41), (p<0.05); there was a significant association between witch's broom disease incidence with presence of *Eucalyptus globulus* ($\chi 2$=16.71), (p<0.05); *Persea Americana* ($\chi 2$=9.79),(p<0.001);*Markhamia obtusifolia* ($\chi 2$=3.95),(p<0.001); *Mangifera indica* ($\chi 2$=6.46),(p<0.001);and*Schefflera actinophylla* ($\chi 2$=4.32),(p<0.001); however, these tree species were planted in limited numbers.

There was a significant association between Frosty rot disease incidence and presence of *Maesopsis eminii with* ($\chi 2$= 25.90), (p<0.05). Association between frost incidence and Eucalyptus *globulus* ($\chi 2$=6.76), (p<0.05); *Mangifera indica* ($\chi 2$=4.85), (p<0.001); is significant despite these tree species being planted in small numbers by farmers.

Association between swollen shoot virus with presence of *Maesopsis eminii*and *Cinnamomum tamala*was highly significant($\chi 2$= 31.55), (p<0.05); ($\chi 2$= 19.22), (p<0.05)was highly significant.Association between die back disease incidence with presence of *maesopsis eminii was highly significant* ($\chi 2$= 52.73), (p<0.05).Marius Wessel et al., (2015) says cocoa swollen virus and *phytophthera* pod rot are common diseases of cocoa, Trees are applied to crops for purposes of shade environment, reduce costs of weeding, control disease attack and increase the quality and taste of cocoa but should be selected trees. (Ngala, 2015). In other studies, some trees have been kept on farm for multipurpose uses in form of timber, fodder, fruit trees and biodiversity services. Abebe Mekoya Kassa, (2008).

Table 1 appendix. indicates a summary of disease incidences with different trees species on selected cocoa farms. There was a non-significant association between diseases under this study with presence of these tree species, *Artocarpus heterophyllus, Triplochiton seleroxylon, Albizia glaberrima, Glicidia sepium, Pinus sabiniana, Arecaceae, Ficus capensis, Psidium guajava, Spathodea campanulate, Morinda*, and farmers need to be encouraged to plant such trees for shade and agroecological purposes. Angelina Sanderson Bellamy, (2017), Horlings. L.G; Marsden, T.K (2011), say practical agroecology is seen as a systemic and holistic approach for the farm's ecosystems. Core techniques and practices include: minimizing and ideally omitting chemical nutrients and high energy use; making use of the properties of the whole farming systems like recycling nutrients, building the soil organic matter, preserving Agro-biodiversity and resources.

Basing on the results, specific shade tree species need to be carefully identified and the technique of inter planting them on the cocoa plantations. These could be multipurpose trees which comprehensively boost the ecosystem services for the farmers' livelihoods. There is a gap on which tree species work better for cocoa shade in Bundibugyo district and this needs to be addressed. It was studied that the diversity of shade and the density of shade are important factors of the structure of cocoa agroforestry systems, which determine the provision of ecosystem services. Gabriela Galarza Ferrín. August, (2019). Table 8 has both botanical and English name of the tree species under study.

CHAPTER FIVE

SUMMARY, CONCLUSION & RECOMMENDATIONS

5.1 Introduction

The study aimed at assessing the impact of different cocoa Agro forestry systems on disease prevalence and yield on small holder farmers in Bundibugyo district. This chapter presents summary findings, conclusions of the study, recommendations of the study and areas for further research.

5.2 Conclusion

A fundamental feature of cocoa agroforestry systems is their variation in complexity. Shade structure complexity is especially important to be characterized. This research therefore, emphasizes the need for specific shade tree diversity to suit the purpose of the cocoa shade needs especially disease control, fertility improvement by recycling biomass, pest and disease management as well other Agro biodiversity services (James et al.,2014).

Specific shade tree species are very paramount in the cocoa plantations for composition of good shade diversity systems and provision of shade, disease control and others services. Care and thorough cautions should be taken in selecting which species to be considered for maximizing the output use of these tree species as opposed to Asare (2010), Osei-Bonsu K, Ameyaw Oduro C. (2003)who say the occurrence of trees on cocoa farms are as a result of natural regeneration and farmers do not have much to do with selection of specific tree species. During her analysis of shade establishment and management in cocoa farms in Ashanti region of Ghana showed that farmers primarily rely on natural regeneration to include shade trees on farms and this practice allows farmers to establish trees in a cost-effective manner that promotes species already in the land scape.

This research identified most diseases being fungal, it therefore, encourages and recommends the farmers to use alternative measures to control these cocoa diseases and these should be ecofriendly measures but not limited to; planting cocoa disease tolerant varieties, pruning, planting non disease host trees, repellant trees, timely weeding, timely harvesting of ready cocoa pods, practicing agroforestry and mulching. Opoku I, Akofia A, Appiah (2002) say some shade trees are alternative hosts of the cocoa pathogens- Phytophthora.

5.3 Ethical considerations and approval

Ethical aspects were highly observed through the process of this research. At university level, an authorization letter was issued allowing the study to proceed. High confidentiality was ensured during the administering of data collection tools. Questionnaire was administered at individual farmer level and their names were reserved not to be indicated on the questionnaire. Observations and photo graphs were taken after seeking authority from the owners of the specific fields in context.

5.4 Areas for Further Studies/ Recommendation

This research recommends that further research should be conducted in the areas of the impact of cocoa Agroforestry systems on prevalence of pests and disease, and their effect on the household income among small holder farmers in Bundibugyo district but also the sustainability of farmers amidst prevalence of cocoa pest and diseases. In addition, knowledge is needed on specific trees species to be used in which specific Agroforestry systems.Farmers seem to be planting any trees of their choices and this is likely to compromise the cocoa performance as well the ecological values.

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APPENDICES

Appendix 1.

Table 1: Disease Association with specific shade tree species

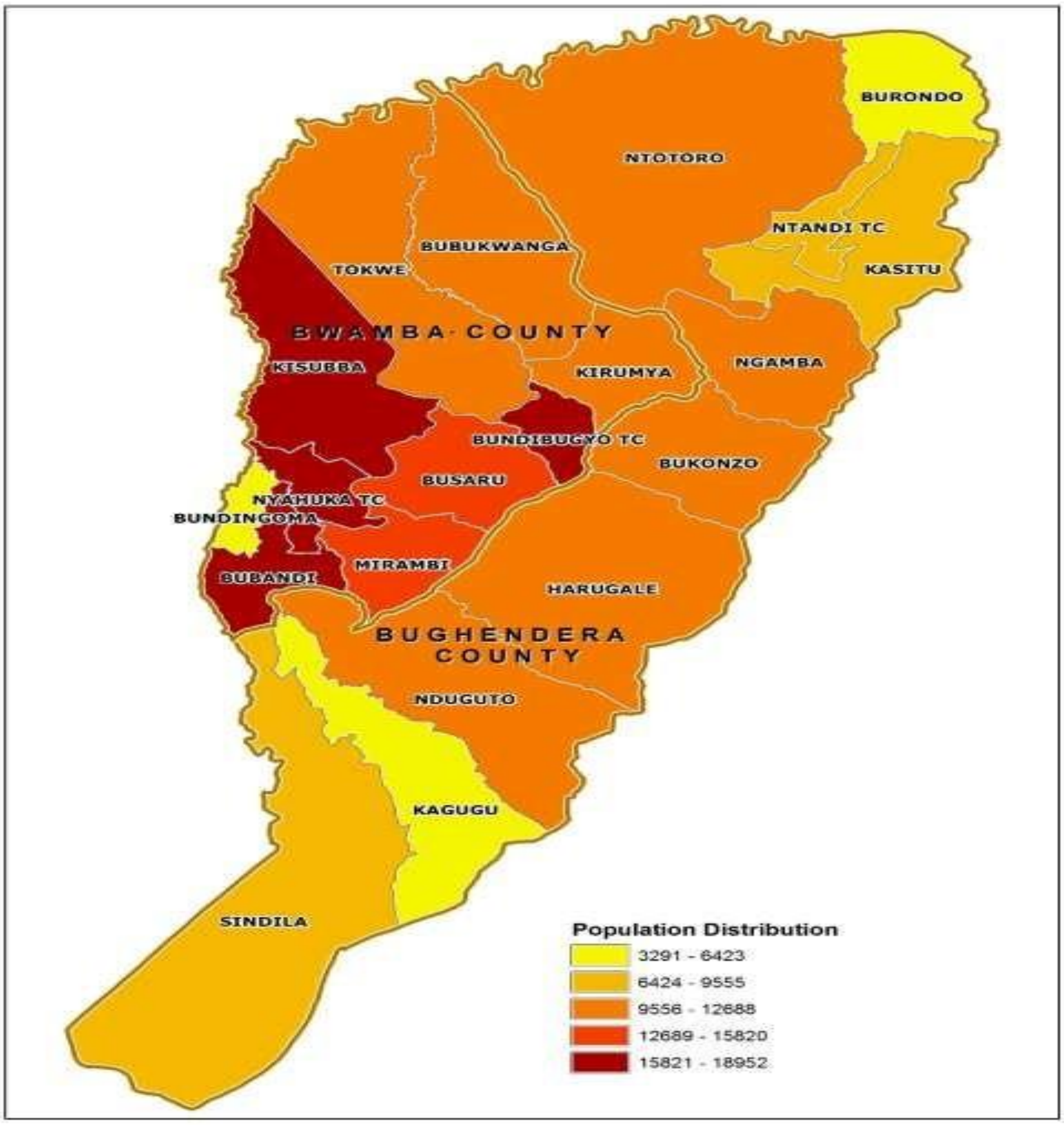
Tree species	Witch's	Frost Pd	Swollen	Die back	Tree species	Witches	Frost Pd	Swollen	Die back
Maesopsis eminii	55.41***	25.90***	31.55***	52.73***	*Eucalyptus globulus*	16.71***	6.76***	14.52***	25.01***
Markhamia Obtusifolia	3.95**	2.04	0.38	3.53	*Pinus sabiniana*	0.79	0.41	0.08	0.78
Schefflera Actinophylla	4.32*	2.23	1.7	4.24*	*Arecaceae*	2.76	0.08	2.62	2.13
Cinnamomum tamala			19.22***	8.07***	*Ficus capensis*	0.53	0.27	0.06	0.51
Artocarpus heterophyllus	2.65	0.01	1.93	1.15	*Psidium guajava*	0.52	0.27	0.06	0.51
Triplochiton seleroxylon	0	0.71	0.8	0	*Citrus X sinensis*	5.19	3.09	1.51	5.28
Persea Americana	9.79***	3.83	11.47***	14.10***	*Aleurites moluccanus*	2.58	1.32	7.21***	2.86
Albizia glaberrima	0.26	1.13	1.44	0.25	*Spathodea campanulate*	0.26	0.31	0.71	0.23
Glicidia sepium	1.36	0.55	2.2	1.33	*Morinda lucida*	0.52	0.27	0.45	0.51
Mangifera indica	6.46*	4.85*	1.02	5.54*					

Appendix 2

Table 2: Tree Species as recorded in the 82 farms of Bundibugyo District, western Uganda

Species name	English name	Species name	English name
Maesopsis eminii	Maesopsis	*Eucalyptus globulus*	Eucalyptus
Markhamia obtusifolia	Markhamia	*Pinus sabiniana*	Pine
Schefflera actinophylla	Umbrella	*Arecaceae*	Palm
Cinnamomum tamala	Tamalia	*Ficus capensis*	Ficus
Artocarpus heterophyllus	Jack fruit	*Psidium guajava*	Guava
Triplochiton seleroxylon	African white wood	*Citrus X sinensis*	Orange
Persea Americana	Avocado	*Aleurites moluccanus*	Candle nut
Albizia glaberrima	Lowveld	*Spathodea campanulate*	African Tulip
Glicidia sepium	Gliricidia	*Morinda lucida*	Brimstone tree
Mangifera indica	Mango		

Appendix 3 Bundibugyo map (UBOS, Report2017)



APPENDIX

Appendix 4: Questionnaire

QN: ……………….

Questionnaire

Dear Respondent,

I am Master of Science in Agroecology student of Uganda Martyrs University. I am aiming at conducting a study on assessment of disease prevalence and shade tree diversity in smallholder cocoa (*Theobroma cacao*) farms in Bundibugyo District.The main objective is this study was to identify shade tree species possessing potential for reducing disease constraints in cocoa farms. Specifically, we aimed at determining the influence of: (i) shade tree species diversity on incidence of diseases in cocoa; (ii) shade tree species on the incidence of diseases in cocoa; and (iii) shade tree species diversity on yield of cocoa.

Therefore, kindly be helpful and respond to questions about cocoa on your farm. The responses will strictly be used for study purposes only and perhaps for further recommendations to improve similar works in the future. Your responses will be treated with confidentiality

I thank you in advance for giving your precious time

Bwambale Blasio Bisereko
20017-MI52-20009

Will you kindly participate in this study? 1. Yes 2. No

If No, reason: ………………………………………………………………….
Name of respondent: ……………………………… Phone No: …………………….
Signature: ………………………………………… Date: …………………………

SECTION A:

0. Farmer location:

Village …………………….. Subcounty ………………………

Longitude (x)…………………….. Latitude (y) …………………………

Altitude………………………

1. Respondents age ……………. years

2. Sex of the respondent

1) Male ☐ 2) Female ☐

3.Age of cocoa farm (years) ………………………. (years)

4.Area of cocoa farm (Acres) …☐……………(acres)

5. Marital status of the respondent

1) Single ☐ 3) Married ☐

2) Divorced ☐ 4) Widowed ☐

6.Highest level of Educational of the respondent

1) No education ☐
2) Primary ☐
3) Secondary ☐
4) Tertiary Institute ☐
5) University ☐

7. Years of cocoa experience for the respondent ☐

<u>SECTION B</u>: Objective one

1.1 Have you ever observed damage on cocoa due to any of the following pests? (*a pestdamage guide is availed to the respondent***)**

	Name of pest	**Yes**	**No**
i.	Cocoa pod borer	( )	( )
ii.	Mirids	( )	( )
iii.	Cocoa beetle	( )	( )
iv.	Thrips ( ) ( )		
v.	Ring bark borers	( )	( )
vi.	Broad mite	( )	( )
vii.	Flower eating caterpillars	( )	( )
viii.	Others (specify)……….		

a. Physical assessment of pests in the cocoa farm (*done by Research team with permission from farmer respondent*)
Cocoa farm area assessed: ……………………. (target is 2 quadrats per farm each of size 20m x 20m

Quadrat 1

Pest	No. cocoa trees damaged	Total no. trees on farm	Damage score scale	Damage score
Cocoa pod borer			1+5-	
Mirids			1+5-	
Cocoa beetle			1+5-	
Thrips			1+5-	
Ring back borers			1+5-	
Broad mite			1+5-	
Flower eating caterpillars			1+5-	
Others (specify)				
			1+5-	
			1+5-	

Scale description:

1 = Healthy
2 = Desired
3 = Infected
4 = Severely infected
5 = Distorted

Quadrat 2

Pest	No. cocoa trees damaged	Total no. trees on farm	Damage score scale	Damage score
Cocoa pod borer			1+5-	
Mirids			1+5-	
Cocoa beetle			1+5-	
Thrips			1+5-	
Ring back borers			1+5-	
Broad mite			1+5-	
Flower eating caterpillars			1+5-	
Others (specify)				
			1+5-	
			1+5-	

2.1Have you ever observed symptoms on cocoa due to any of the following diseases?
(*aidentification guide is availed to the respondent***)**

Name of disease	**Yes**	**No**
i. Black pod disease	( )	( )
ii. Witches Broom	( )	( )
iii. Frosty pod rot	( )	( )
iv. Cocoa swollen shoot virus	( )	( )
v. Dieback disease	( )	( )
vi. Others (specify)……….		

b. **Physical assessment of diseases in the cocoa farm** (*done by Research team with permission from farmer respondent*)

Quadrat 1

Disease	No. cocoa trees infected	Total no. trees on farm	Disease severity score scale	Severity score
Black pod disease			1+5-	
Witches Broom			1+5-	
Frosty pod rot			1+5-	
Cocoa swollen shoot virus			1+5-	
Dieback disease			1+5-	
Others (specify)				
			1+5-	
			1+5-	

Scale description:

1 = Healthy
2 = Desired
3 = Diseased
4 = Severely diseased
5 = Distorted

Quadrat 2

Disease	No. cocoa trees infected	Total no. trees on farm	Disease severity score scale	Severity score
Black pod disease			1+5-	
Witches Broom			1+5-	
Frosty pod rot			1+5-	
Cocoa swollen shoot virus			1+5-	
Dieback disease			1+5-	
Others (specify)				
			1+5-	
			1+5-	

2. How often do cocoa pests and diseases attack your farm?

5.1 Pests (*Tick* as appropriate basing on farmer response)

Pest	Rainy season	Dry season	Rainy and dry seasons
Cocoa pod borer			
Mirids			
Cocoa beetle			
Thrips			
Ring back borers			
Broad mite			
Flower eating caterpillars			
Others (specify)			

5.2 Diseases (*Tick* as appropriate basing on farmer response)

Disease	Rainy season	Dry season	Rainy and dry seasons
Black pod disease			
Witches Broom			
Frosty pod rot			
Cocoa swollen shoot virus			
Dieback disease			
Others (specify)			

3. What are the impacts of pest and diseases attack on Cocoa production?
   The damage done by this pest or disease affects the following (give a tick if it is a Yes)

	Yes	No	Describe negative impact
- Quantity of cocoa produce	( )	( )	______________
- Quality of cocoa product	( )	( )	______________
- Price of product	( )	( )	______________
- Health of the cocoa plant	( )	( )	______________
- Livelihood of the farmer	( )	( )	______________

4. What are the management strategies that can be used to control pests and disease?

Method	**Yes**	**No**
Planting shade trees	( )	( )
Clearing (weeding)	( )	( )
Regular spraying	( )	( )
Pruning	( )	( )
Field hygiene	( )	( )
Selected and cutting off infected plants	( )	( )
Killing of insects with hands or stickers when seen	( )	( )

5. What problems are faced in ensuring quality cocoa beans

Problems	**Yes**	**No**
Financial constraint	( )	( )
Pest and Diseases	( )	( )
High cost of spraying	( )	( )
Unavailability of drying facilities	( )	( )
Problem of weeds	( )	( )
High cost of labour	( )	( )
Erratic rainfall	( )	( )

Poor health of farmer	( )	( )
Unavailability of good variety	( )	( )
Long distance of cocoa farms	( )	( )

6. Measures to fight against pest and disease and ensure high quality cocoa beans

Method	**Yes**	**No**
Access to credit	( )	( )
Training on post-harvest management	( )	( )
Training of pest & disease management	( )	( )
Formation of farmers' cooperative	( )	( )
Use of clean planting materials	( )	( )

<u>SECTION C</u>: Objectives two

1. What type of shade tree species do you grow on your farm?

Tree species		Number of trees
i)	………………………..	…………………….
ii)	………………………..	…………………….
iii)	………………………..	…………………….
iv)	………………………..	……………………..
v)	………………………..	……………………..
vi)	………………………..	……………………..

Size of cocoa farm assessed (acres): ………………………………………

2. What was the total produce of cocoa beans for the last three years?

Years	**Season A (March-June) -Basins**	**Season B (Sept-Jan) - Basins**	**Total (kg)**
2016			
2017			
2019			

3. In case of any differences in cocoa bean produce between years, what could have been the cause?

Physical counting of cocoa pods and pod size measurement along two diagonals per quadrat

Quadrat 1 (systematic sampling based on distance is applied).

Diagonal 1	No. pods	Pod length (cm)	Pod diameter (cm)	Weight of sample pod (grams)
Cocoa tree 1				
Cocoa tree 2				
Cocoa tree 3				
Cocoa tree 4				
Cocoa tree 5				
Diagonal 2				
Cocoa tree 1				
Cocoa tree 2				
Cocoa tree 3				
Cocoa tree 4				
Cocoa tree 5				

Quadrat 2 (systematic sampling based on distance is applied).

Diagonal 1	No. pods	Pod length (cm)	Pod diameter (cm)	Weight of sample pod (grams)
Cocoa tree 1				
Cocoa tree 2				
Cocoa tree 3				
Cocoa tree 4				
Cocoa tree 5				
Diagonal 2				
Cocoa tree 1				
Cocoa tree 2				
Cocoa tree 3				
Cocoa tree 4				
Cocoa tree 5				

Appendix5
Pests and disease guide
Cocoa stem borers


Flower eating caterpillars


Cocoa Thrips


Cocoa mirids

Cocoa beetles

Cocoa mealybugs

Cocoa mirid

Diseases

Cocoa pod rot disease

Witches Broom



Cocoa swollen shoot virus


Cocoa dieback


Frosty pod rot

Research team collecting data on quadrats

Counting cocoa pods and taking pod measurement

Caterpillars found on cocoa trees

Taking measurements for quadrats

Taking measurements for cocoa pod diameter

Coco tree plantations

Coco tree plantations