

ASSESSMENT OF THE ECONOMIC IMPACT OF AGROBIODIVERSITY  
INTERVENTIONS ON FARMER FIELD SCHOOL HOUSEHOLDS IN BONDO  
DISTRICT, KENYA

ACHONGA BONVENTURE OKOMOLI



A thesis submitted to Graduate School in partial fulfillment for the requirements of the  
Master of Science Degree in Agricultural Economics of Egerton University.

EGERTON UNIVERSITY LIBRARY

EGERTON UNIVERSITY

APRIL, 2011

X  
EULIB



026 120



## DECLARATION AND RECOMMENDATION

### Declaration

This is my original work and has not been presented for a degree in this or any other University

Achonga Bonventure Okomoli.

KM 15/1978/07



Signature.


26<sup>th</sup> April, 2011

Date

### Recommendation

This thesis has been submitted with our approval as University Supervisors.

1. Dr. Job Kibiwot Lagat.



Signature.

4<sup>th</sup> May 2011


Date

Department of Agricultural Economics and

Agribusiness Management.

Egerton University, Njoro.

2. Prof. Thomas E. Akuja.



Signature.

27. 4. 11

Date

Department of Crops, Horticulture and Soil Science

Egerton University, Njoro.

## **COPYRIGHT**

No part of this thesis may be produced, stored in any retrieval system or transmitted in a form or means, electronic, mechanical, photocopying, recording or otherwise without prior written permission of the Author or Egerton University.

Achonga Bonventure Okomoli ©2011.

All rights reserved.

## DEDICATION

This thesis is dedicated to my daughter Daphy Taka, who missed out on Daddy's company as I devoted time to the development of this work.

EGERTON UNIVERSITY LIBRARY

## ACKNOWLEDGEMENT

I wish to acknowledge the efforts of my University Supervisors, Dr. J.K. Lagat and Prof. E.T. Akuja, other members of the Department of Agricultural Economics and Agribusiness Management of Egerton University, who guided me in every step of this research. I am particularly gratefully to Dr. J.K. Lagat who guided me in formulation of the research proposal, analysis of data and writing of the thesis. Further, I am very grateful to Prof. E.T. Akuja for the guidance he provided to me in writing of a Journal paper, which was published in the Journal of Applied Biosciences as an output from my research work.

Funding for my research work was provided by Graduate School of Egerton University and Food and Agriculture Organization (FAO) of the United Nations and I am indeed very grateful to the two organizations. I would like to extend my sincere gratitude to Dr. Michael Makokha who was the National Coordinator of the FAO - Netherlands Partnership Programme (FNPP) Agrobiodiversity Project for providing technical and logistical support during my research work in Bondo district.

I thank my employer, Ministry of Agriculture for providing a study leave which enabled me to accomplish my study.

The support I was accorded by my colleagues and family was quite valuable, and I would like to express to them my heartfelt thanks.

## ABSTRACT

Smallholder farmers, especially those in agriculturally marginal areas such as Bondo district where some high-yielding crop varieties and livestock breeds do not prosper, have relied on a wide range of crop and livestock types. This coping strategy has helped them to maintain their livelihoods in the face of unfavorable circumstances such as disease attack, uncertain rainfall, and fluctuation in the price of farm inputs and outputs. However, intensification and commercialization of agriculture over the years has led to a continual decline in crop and livestock diversity, increasing vulnerability of smallholder farmers to food insecurity. FAO-Netherlands Partnership Programme promoted interventions in Bondo district aimed at enhancing agrobiodiversity through diversification of crop and livestock enterprises. The objective of this study was to determine the impact of agrobiodiversity interventions on crop and livestock diversity, smallholder farmers' food security and income using comparison groups composed of project participants and non-participants. Data for the study was obtained from a random sample of 150 households using a Single Household Survey (SHS). Shannon's index was used to determine crop and livestock diversity in the comparison groups. Multinomial Logit (MNL) and Ordinary Least Square(OLS) regression models were used to determine the impact of crop and livestock diversity on food security and income, respectively, while optimal level of farm enterprise diversification was determined using a linear programming model.

The analysis showed that crop diversity was significantly higher for ABD – FFS farmers compared to NABD-FFS farmers. Further the study showed that Crop diversity significantly increased farm income as well as the probability for the smallholder farmers to be food secure. The study also showed that to achieve an optimal enterprise combination that would be able to meet household food security requirements and income, farmers need to reduce on enterprises with negative gross margins in their farm plans either by bringing in new enterprises or by improving on the productivity of the existing enterprises. Agrobiodiversity therefore is an important strategy in improving smallholder farmers' food security and income. The knowledge generated through this study especially on assessment of the economic impact of agrobiodiversity on smallholder farmers will be useful to policy makers in the development of appropriate food security and income strategies for smallholder farmers.

## TABLE OF CONTENTS

<b>DECLARATION AND RECOMMENDATION .....</b>	<b>II</b>
<b>COPYRIGHT.....</b>	<b>III</b>
<b>DEDICATION.....</b>	<b>IV</b>
<b>ACKNOWLEDGEMENT.....</b>	<b>V</b>
<b>ABSTRACT.....</b>	<b>VI</b>
<b>LIST OF TABLES .....</b>	<b>IX</b>
<b>LIST OF FIGURES .....</b>	<b>X</b>
<b>ABBREVIATIONS AND ACRONYMS .....</b>	<b>XI</b>
<b>CHAPTER ONE .....</b>	<b>1</b>
<b>INTRODUCTION .....</b>	<b>1</b>
1.1 Background to the problem.....	1
1.2 Statement of the problem.....	3
1.2. Research Objectives.....	3
1.3. Research Questions.....	4
1.4. Justification of the study.....	4
1.5. Definition of terms.....	4
1.6. Scope and Limitations of the study .....	6
<b>CHAPTER TWO .....</b>	<b>7</b>
<b>LITERATURE REVIEW .....</b>	<b>7</b>
2.1. Agrobiodiversity interventions.....	7
2.2. Economic impact of Agrobiodiversity.....	7
2.3. Determinants of Agrobiodiversity .....	8
2.4. Farm enterprise and Food security optimization .....	9
2.5. Conceptual framework.....	9
<b>CHAPTER THREE .....</b>	<b>12</b>
<b>METHODOLOGY .....</b>	<b>12</b>
3.1. Study area .....	12
3.2. Data types and Sources.....	14
3.3. Sampling design and techniques.....	15
3.4. Data Analysis.....	16

3.4.2. Econometric analysis model .....	17
<b>CHAPTER FOUR.....</b>	<b>24</b>
<b>RESULTS AND DISCUSSIONS .....</b>	<b>25</b>
4.1. Descriptive analysis .....	25
4.1.1. Household Agrobiodiversity Characteristics .....	25
4.1.2. Agrobiodiversity Analysis .....	26
4.1.3. Household food security characteristics .....	29
4.2. 1. Impact of crop and livestock diversity on farm income .....	30
4.2.2. Impact of Crop and Livestock diversity on food security.....	32
4.3. Optimum farm enterprise mix for Agrobiodiversity farmer field school households in Bondo district.....	35
<b>CHAPTER FIVE.....</b>	<b>42</b>
<b>CONCLUSIONS AND POLICY IMPLICATIONS .....</b>	<b>42</b>
5.1. Conclusions.....	42
5.2. Policy Implications .....	43
<b>REFERENCES.....</b>	<b>44</b>
<b>APPENDICES .....</b>	<b>50</b>
Appendix 1: Questionnaire.....	50
Appendix 2: World Health Organization Nutritional Requirements.....	62
Appendix 3: Nutritional Values of Food Commodities.....	63
Appendix 4: Scatter Plot for Income Regression Model.....	65
Appendix 5: Gross Margins for Main Enterprises (Gm/Unit/Year).....	66

## LIST OF TABLES

Table 1: Income Model Variables .....	18
Table 2: Food Security Model Variables .....	20
Table 3: Number of Crop Enterprises per Household .....	25
Table 4: Number of Livestock Enterprises Per Household .....	26
Table 5: Crop and livestock diversity mean difference.....	27
Table 6: Significance of Mean Difference of Crop and Livestock Diversity between ABD-FFS and NABD-FFS Farms.....	28
Table7: Household food security characteristics.....	29
Table 8: Analysis of the Impact of Crop and Livestock Diversity on Farm Income.....	31
Table 9: Impact of Crop and Livestock Diversity on Food Security .....	34
Table10: Household Categorization Parameters.....	35
Table 11: The Linear Programming (LP) Model Analysis Results .....	37

## LIST OF FIGURES

Figure 1: Conceptual framework .....	11
Figure 2: The Map of Bondo District, Kenya .....	13

## ABBREVIATIONS AND ACRONYMS

FFS	-	Farmer Field Schools
HH	-	Household
HA	-	Hectare
FNPP	-	FAO- Netherlands Partnership Programme
FAO	-	Food and Agriculture Organization
G.O.K	-	Government of Kenya
ABD	-	Agrobiodiversity
ABD-FFS-	-	Agrobiodiversity Farmer Field Schools
NABD-FFS-	-	Non-Agrobiodiversity Farmer Field Schools
CRSP	-	Collaborative Research Support Project
SPSS	-	Statistical Package for Social Sciences
TLU	-	Tropical Livestock Unit
IPM	-	<i>Integrated Pest Management</i>
DSA	-	Daily Subsistence Allowance
KM	-	Kilometers
Kshs	-	Kenya Shillings
I.R.	-	Incremental Return
WHO	-	World Health Organization
YRS	-	Years
MD	-	Man day
No.	-	Number

## CHAPTER ONE

### INTRODUCTION

#### 1.1 Background to the problem.

Agrobiodiversity is the result of the interaction between the environment, genetic resources and management systems and practices. Thus, agrobiodiversity encompasses the variety and variability of animals, plants and micro-organisms that are necessary for sustaining key functions of the agro-ecosystem, including its structure and processes in support of food production and food security (FAO, 1999a).

Agrobiodiversity requires our attention for two reasons. First, it provides a wide range of direct and indirect benefits to humans in form of goods and services. Secondly, human activities have been contributing to unprecedented rates of biodiversity loss, which threatens the stability of ecosystems in terms of their provision of goods and services to humans (Nijkamp *et al.*, 2008). It has been noted globally that the world's food and agriculture depends on increasingly fragile agrobiodiversity. Since the 1900s, seventy percent of plant genetic diversity has been lost and 30 percent of the livestock breeds are on the verge of extinction (FAO, 1999b). Farmers worldwide have left their multiple local varieties and breeds for genetically uniform, high yielding varieties and breeds that are limited in resilience to adverse environmental conditions. Today, seventy percent of the world's food is generated from twelve plants and five animals' species only (FAO, 1999b). Factors like poverty and lack of knowledge have accelerated the rate of agricultural biodiversity loss (FNPP, 2005). Increased loss of agrobiodiversity reduces community's resilience to adverse environmental, climatic and economic conditions like fluctuations of agricultural commodity prices (FAO, 2005).

Many farmers, especially in marginal areas such as Bondo where most high-yielding crop varieties and livestock breeds do not prosper, rely on a diversity of crop and livestock enterprise. Farmers in Bondo district are mainly mixed crop and livestock subsistence farmers. Their major crop and livestock enterprises are maize, beans, sorghum, cassava, cotton, indigenous cattle, goats, sheep and poultry. A few people are involved in fishing along the lake shore and rivers. More than 80% of the households in Bondo district are food insecure at least in some months of the year in both crop and livestock products (Mungai *et al.*, 2008). To deal with food shortages

92% of the households buy food from the market (Mungai *et al.*, 2008). Food insecurity has been aggravated by frequent crop failure as result of over reliance on crops that are ecologically unsuitable for the area such as maize. Farm enterprise diversification would help them maintain their livelihoods in the face of unfavorable circumstances such as disease infestation, uncertain rainfall, fluctuation in the price of farm inputs and outputs. Crops considered as minor such as cowpeas, sweet potatoes and green grams play an important role in food and livelihood security within the production systems at the local level. Plants that grow in infertile or eroded soils, and livestock that feed on scarce vegetation found on degraded land, are often crucial to household nutritional strategies (FAO, 2005).

Agrobiodiversity interventions were implemented in Bondo district by FAO-Netherlands Partnership Programme from 2005 to 2007. The programme worked with Farmer Field Schools (FFS) to raise awareness on agrobiodiversity issues. It used learn by doing processes with a view to enhancing the conservation and sustainable use of agrobiodiversity. The agrobiodiversity interventions implemented through FFS to enhance crop and livestock diversity were bulking of cassava, sweet potatoes, arrow roots, pumpkins and local vegetables to provide planting materials for the farmer's crop diversity. Other interventions were, intercropping, beekeeping, fish farming, rearing of indigenous goats and poultry, planting of medicinal plants and seed banking. A few commercial crops were introduced to the farmers such as tissue culture bananas, onions, tomatoes, chick peas and water melon (G.O.K, 2007a; Mungai *et al.*, 2008). The agrobiodiversity interventions were expected to generate increased opportunities for enterprise diversification and benefits for farmers and fisher folks in terms of income, food security and sustainable natural resource management (FNPP, 2005). FFS had implemented food security related activities in Bondo district since 2002. Ten of these FFS comprising an average of 20 farmers each were selected to implement agrobiodiversity activities (G.O.K, 2007a). The purpose of this study was to assess the impact of Agrobiodiversity interventions on crop and livestock enterprise diversity, food security and farm income by evaluating the Agrobiodiversity Farmer Field School (ABD-FFS) farmers in relation to Non – ABD-FFS farmers (Erbaugh *et al.*, 2002).

## **1.2 Statement of the problem**

Farmers in Bondo have carefully selected and raised many different animals and plants adapted to their local environments and needs over the years. However, intensification and commercialization of agriculture, particularly over the last 30 years has led to a continual decline in agrobiodiversity among Smallholder farmers (Kooten *et al.*, 2000; Nijkamp *et al.*, 2008). Loss of agrobiodiversity has undermined the ability of agriculture to provide food and income leading to food insecurity. FAO-Netherlands partnership Programme (FNPP) in 2005 to 2007 implemented agrobiodiversity interventions to encourage Smallholder Farmers in Bondo to diversify their crop and livestock enterprises as a strategy to enhance agrobiodiversity, food security and income. However, the impact of agrobiodiversity interventions on crop and livestock diversity as well as household food security and farm income among the small holder farmers in Bondo district had not been studied and documented. This study aimed at filling this knowledge gap.

### **1.2. Research Objectives**

The general objective of the study was to assess the economic impact of agrobiodiversity interventions on crop and livestock enterprise diversity, household food security and farm income among Farmer Field School households in Bondo District, Kenya.

The specific objectives are to:

1. Assess crop and livestock diversity among agrobiodiversity farmer field school (ABD-FFS) and Non- ABD-FFS households in Bondo District.
2. Assess the impact of crop and livestock enterprise diversity on household food security and farm income among ABD-FFS and Non-ABD-FFS households
3. Determine the optimum farm enterprise mix for agrobiodiversity Farmer Field School households in Bondo District.

### **1.3. Research Questions**

The study set to answer the following research questions:

1. What is the extent of crop and livestock diversity among Agrobiodiversity Farmer Field School (ABD-FFS) and Non- ABD-FFS households in Bondo District?
2. What is the impact of crop and livestock enterprise diversity on household food security and farm income?
3. What is the optimum farm enterprise mix for Agrobiodiversity Farmer Field School households in Bondo district?

### **1.4. Justification of the study**

Smallholder farmers depend on agrobiodiversity for the supply of direct and indirect benefits (food, fuel wood, fiber and income). Conservation and sustainable use of agrobiodiversity by smallholder and commercial farmers is important to enhancement of the genetic resource base, and to the productive and resilient agro-ecosystems. If the impact of agrobiodiversity interventions is positive there would be an incentive for farmers to mitigate the effects of agrobiodiversity loss. Increased crop and livestock diversity has been emphasized as one of the strategies for enhancement of agrobiodiversity and food security (FAO, 2005). It is therefore important to assess the impact of this strategy on smallholder farmers' income and food security. Given that smallholder farmers have limited resources and multiple objectives to satisfy, it's necessary to determine the optimal level of enterprise diversification. This study will contribute to existing limited body of knowledge on economic impact of crop and livestock diversity on household food security and farm income among small holder farmers. The study will further provide useful information for improvement of agrobiodiversity interventions and policy formulation.

### **1.5. Definition of terms**

**Agrobiodiversity-** Agrobiodiversity comprises of crop varieties, livestock breeds, fish species, wild species that are harvested and those that are not harvested that support production systems (FAO, 2005). In this study agrobiodiversity was limited to crop and livestock enterprise diversity

**Tropical livestock unit (TLU)** – One TLU is the equivalent of 250 kg of tropical animal live weight

**Impact** – In the context of this study impact implied the change brought about as result of  agrobiodiversity interventions

**Economic impact-** In this study economic impact implied the change caused on an economic response variable (farm income, food security) as a result of a unit change in explanatory variables.

**Food security** – Food security exists when all people, at all times, have physical and economic access to enough, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy lifestyle (FAO, 1996b). Food security (FDSEC) in this study implies food from the farm plus food purchased from the market meeting the World Health Organization (WHO) minimum protein and energy dietary requirements

**Net Farm income** – In this study Net Farm income (Y) implied Total farm gross margin in the year of study after deducting monthly food consumption, farm inputs and hired labour valued at market prices

**Non – Farm income (NFI)** – In this study refers to income from sources other than farm produce (Non-farm business, wages, salary, gifts)

**Working Capital** – Working Capital in this study implied Total Variable Cost less Labour Cost

**Diversification** – Adjustment to the farm enterprise pattern in order to increase farm income or to reduce income variability. It may involve bringing in new enterprises or expansion of the existing ones (Dixon *et al.*, 2001)

**Farming system** – A group of farms that have similar resource base, enterprise patterns, household livelihoods and constraints and for which similar development strategies and interventions would be appropriate (Dixon *et al.*, 2001)

**Farmer field school** – A Farmer field school is a group of farmers (20-30 farmers) who meet regularly in the course of the enterprise production season to learn and experiment with new production options.

**Smallholder Farmer**- smallholders in this study refers to farmers owning a farming unit usually less than two hectares with one or more farm enterprises managed mainly for subsistence and limited production for the market.

**Household** – A social unit characterized by sharing of resources and decision making.

**Incremental Return** – The incremental return in this study refers to the incremental income accrued to the optimization plan in relation to the farmers plan.

**Man days** – Man day in this study refers to the amount of work performed by an average worker during one day of 8 hrs

### **1.6. Scope and Limitations of the study**

The study was limited to crop and livestock enterprise inter diversity as a strategy of enhancing agrobiodiversity and determination of its impact on farmer field school households' food security and income in Bondo district. Crop and livestock diversity was analysed at species level based on whole farm approach (Frank, 2001). Also to be explored was the whole farm analysis of optimal enterprise mix among the agrobiodiversity farmer field school participants in Bondo district.

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1. Agrobiodiversity interventions

Agrobiodiversity (ABD) theme of the FAO – Netherlands Partnership Program (FNPP) was developed to address the challenge of ABD loss. The theme aims to have impact on mobilizing inter-sectoral and systematic approaches for addressing agricultural biodiversity issues and possible integration into policy processes. The Kenya agrobiodiversity programme had one of its main interventions as, Promotion of farmer innovation and indigenous knowledge on agrobiodiversity through farmer field schools approaches with a view to improving food and livelihood security. Farmer Field Schools were meant to identify and promote farmer initiatives, innovations and indigenous knowledge in relation to agrobiodiversity. The main purpose was to test and adapt selected management practices in specific agro-ecological areas and to incorporate topics on fisheries, habitat protection, alien species, diversified and sustainable agro-silvo-pastoral systems and land and water management (FNPP, 2005).

#### 2.2. Economic impact of Agrobiodiversity

Research has shown that agrobiodiversity can increase productivity, food security and economic returns (Thrupp, 1977). Agrobiodiversity can also lead to diversity of products and improve income opportunities, human nutrition and contribute to sustainable agricultural production (Thrupp, 1977). Studies in western Kenya by Waithaka *et al.* (2003) showed that manure and fertilizers complemented each other in boosting cash and food crop yields in smallholders farming systems. Place *et al.* (2003) showed that 70% of the smallholder households used manure while 41% used compost indicating the importance of manure in mixed farming system. The significance of manure in improving productivity suggests importance of agrobiodiversity in enhancing food security and income.

Erbaugh *et al.* (2002) studied the impact of integrated pest management-collaborative research project (IPM –CRSP) activities in Uganda and the results indicated that more active participation increased integrated pest management (IPM) knowledge and skills. Project beneficiaries were slightly better off socio- economically than non- beneficiaries, implying the project had a positive economic impact. Though the study used statistical analysis to assess mean difference to attribute outcomes to the project interventions, it did not involve econometric

analysis which is important for policy inferences to determine the significance of the attribution. This study employed econometric analysis to determine the economic impact of agrobiodiversity on household food security and farm income. However the approach used by Erbaugh *et al.* (2002) in sampling, data collection and analysis was important to the agrobiodiversity research. Morris *et al.* (1999) studied adoption and impact of improved maize production technologies among maize farmers in Ghana in terms of productivity, income and nutrition. The study revealed that uptake of improved maize technologies was determined by four main factors, farmers' characteristics, resource ownership, commercial orientation and accessibility of the technology, and that the improved maize production technologies improved productivity, nutrition and farmers income. However the study was mainly based on descriptive analysis hence not able to provide a strong basis for policy recommendation. The factors outlined in this study as determinants of technology adoption and approach used to address lack of baseline data was of important consideration in the Bondo agrobiodiversity study.

Roth *et al.* (1994) studied Costa Rican Ant diversity to assess the impact of different levels of disturbance on biological diversity. The author measured diversity in four different habitats ranging from very low levels of human disturbance (primary rain forest) to very high levels of human disturbance (banana plantations) using Shannon's index. The results showed that the diversity and evenness from the undisturbed habitat (primary rain forest) were much higher than from the highly disturbed habitat (banana plantation). The author concluded that different levels of disturbance have different effects on Ant diversity. Therefore, if the goal is to preserve biodiversity in a given area, there is need to understand how diversity is impacted by different management strategies. The methodology in evaluating the impact of different management strategies on biological diversity was of important relevance to the Bondo agrobiodiversity study.

### **2.3. Determinants of Agrobiodiversity**

Benin *et al.* (2004) studied determinants of cereal crop diversity on farms in Ethiopian highlands using farm household model. The study revealed that factors like age, education, land size, household income, access to seed markets, stock of labour, soil conditions and livestock assets were significant determinants of cereal crop diversity. There was no evident trade-off between seeking to enhance productivity through the use of modern varieties and the spatial diversity among maize and wheat varieties studied. However the study did not assess the effect

of crop diversity on food security and income. The study did not also take into account the impact of synergistic interaction in a mixed farming system which incorporates crops and livestock, an aspect which the Bondo agrobiodiversity study will endeavor to address. Oakley and Momsen, (2004) studied the relationship between Gender and agrobiodiversity in Smallholder farms in Bangladesh in a case study of two villages. The authors looked at the interrelationships between gender, agrobiodiversity, the use and preferences for improved and local crop varieties. The researcher evaluated agrobiodiversity using the number, types, and varieties of crops grown in the fields and home gardens. Local geography and gender were found to be the two major factors determining which crop varieties are cultivated in the two villages studied. The approach used in this study in evaluation of agrobiodiversity was of important consideration.

#### **2.4. Farm enterprise and Food security optimization**

Calkins (1981) indicated that the farm family in developing countries must be both an efficient producer and consumer of food. He studied four subsistence farms in Nepal Hill region to determine the most nutritious and profitable production pattern using linear programming (LP) model. The objective was to maximize income subject to meeting minimal dietary requirements. The study showed that inclusion of food security objective in the model as a constraint reduced net farm income although it was more realistic to small scale subsistence farmers' circumstances. The approach of this study was adopted by the Bondo agrobiodiversity study in determining optimal enterprise combination taking into consideration the food security objective of the small scale semi-subsistence farmers

#### **2.5. Conceptual framework**

The study was based on the conceptual framework of static spatial model for land use and crop management decisions. Production factor method was used to estimate the economic value of an environmental commodity through the input–output relationship of such a commodity in a production function. For example, the economic value of a healthy soil is related to the value of the increased agricultural output through a response method (Nunes *et al.*, 2004). Change in the environment and management practices will cause change in natural assets that have value in production of market and non – market goods. Smallholder farmers are assumed to be optimizers whose main objective is food security and income. Given biophysical parameters, economic factors and production technology, they make land use and enterprise choice decisions on each

unit of land under their management. Then conditional on land use and enterprise choice decisions, farmers make other management decisions (seeding, fertilizer use, and pesticides use and cultivation practices). These decisions if implemented affect agrobiodiversity which in turn affect food security and income. The agrobiodiversity situation in the long run affects biophysical factors such as Soil quality, surface and ground water quality on and off the farm, pest and diseases. Figure 1 explains the factors that influence the process of farm household land use decision making. They can be categorized as biophysical, socio-economic and technological. The biophysical factors are mainly exogenous and tend to define the type of production system the farmers will operate. The socio economic environment offers both incentives and disincentives, which can influence the choice of enterprise mix and techniques. The diversity of enterprises and production techniques undertaken by farmers has an impact on agrobiodiversity. The socio economic factors include prices of inputs and outputs, economic policies, infrastructure, access to markets of inputs and outputs, off farm opportunities and household characteristics. Poorly functioning credit system, inputs and output markets lead to inadequate investment in agricultural production and great dependence on production on food crops and less of cash crops (Holden and Binswanger, 1998). The availability of off- farm opportunities provides income for use in the farm activities which affects production, investment and savings decisions (Argwings-Kodhek *et al.*, 1999). Decisions made by households are subject to availability of resources (land, labour and capital). Low resources endowment leads to inadequate investment in high yielding technologies, poor disease and pest management practices (Pretty *et al.*, 2003). Education has been shown to have significant effects on adoption of decisions that improve management practices and production (Odulaja and Kiros, 1996). The educated members of a household are more likely to adapt agrobiodiversity (Mungai *et al.*, 2008). Technologies determine the nature of production (Ehui and pender, 2003). Biophysical factors include soil quality, breeds of livestock, types of crops, livestock and crop diseases (Rosegrant *et al.*, 2001). Land quality and natural resources endowment affect production decisions (Binswanger and Townsend, 2000).

Farmers manage agrobiodiversity, hence the land use and production management decisions they make affect agrobiodiversity positively (gain) or negatively (loss). Good decisions will enhance agrobiodiversity (soil health, pollination, variety and variability of plants, animals, and microorganisms) which in turn will have impact on productivity, food security and income.

In the long run household food security and income will have an impact on household socio-economic factors and production technology.

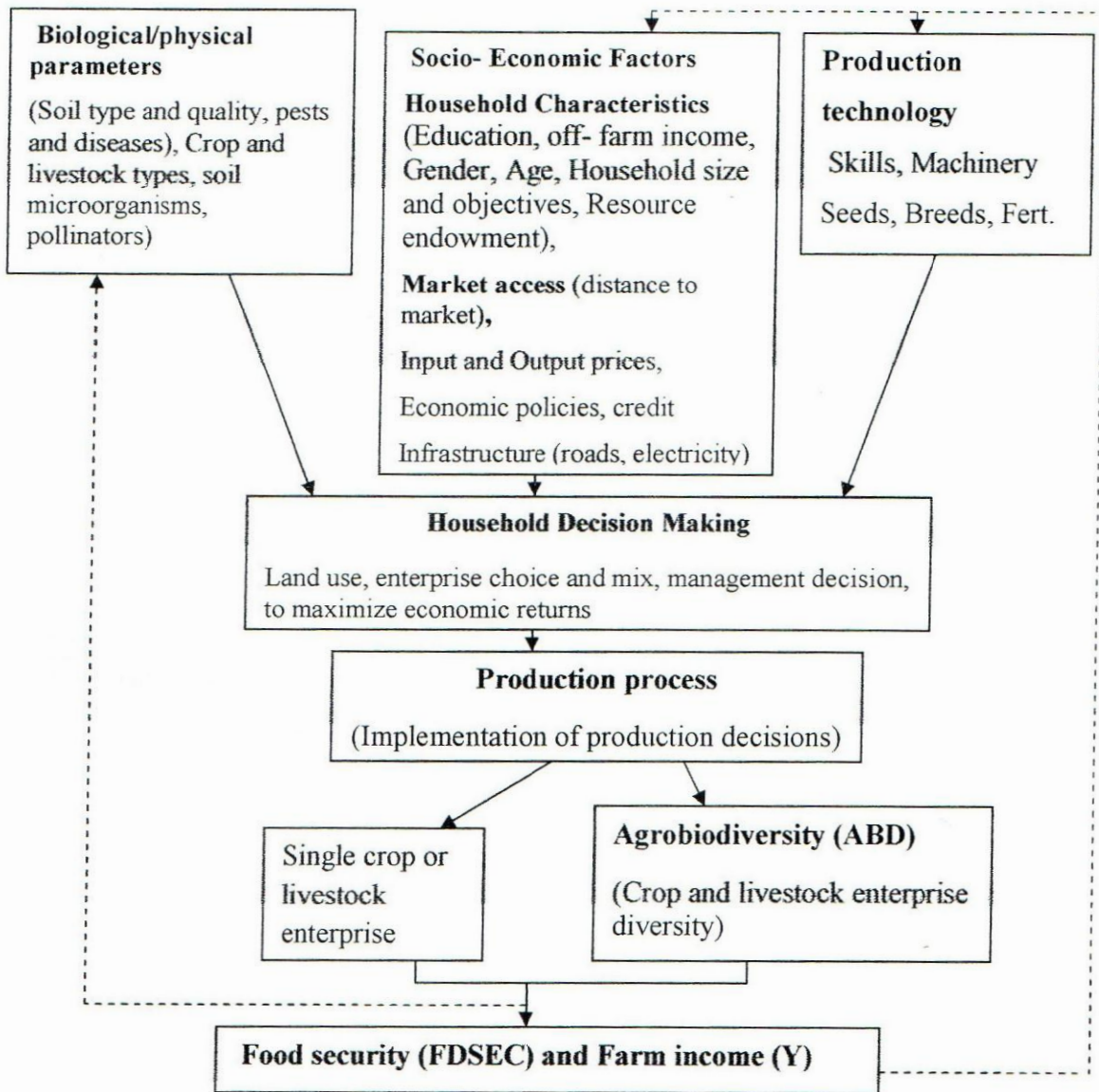


Figure 1: Conceptual framework (Source: Adapted from Antle, 1995)

## CHAPTER THREE

### METHODOLOGY

In this chapter, the methods used to obtain the sample size, collect data for analysis and the analysis techniques are discussed.

#### 3.1. Study area

The study was conducted in the greater Bondo District which comprises of the current Bondo and Rarieda districts in Nyanza province, Kenya. Bondo district was selected because it is one of the two districts in Kenya where the FAO-Netherlands Partnership Programme (FNPP) - agrobiodiversity project activities were implemented. Bondo district presents a wide cross section of aquatic and terrestrial biodiversity, which provides a good opportunity for farmers to adopt enterprise diversification as a strategy to enhance Agrobiodiversity. The district lies between longitude 34°E and 34°30'E and latitude 0° and 0°30'S. The entire South-West boundary is delineated by Lake Victoria while the northern boundary is marked by River Yala. The district has a population of 275,543 (projected based on 1999 census (Bondo district development report, 2007). Bondo district covers a total of 1,972 km<sup>2</sup> out of which 972 km<sup>2</sup> is dry land and 1,000 km<sup>2</sup> is water surface. The total arable land is 796 km<sup>2</sup>. The district receives 800-16000mm of rainfall per annum with a bimodal distribution pattern. The soils are mainly Luvisols with low – moderate fertility except Madiany division which has black cotton soils (Vertisols) of relatively high fertility. The district is divided into four agro ecological zones namely Lower Midland Two (LM<sub>2</sub>), LM<sub>3</sub>, LM<sub>4</sub>, M<sub>5</sub> of which LM<sub>3</sub> and LM<sub>4</sub> covers 96 percent of the total area (Jaetzold and Schmidt, 1982). The major farming system was mixed crop and livestock subsistence farming. The major crops were maize, sorghum, cassava, cotton and beans while livestock kept were zebu cattle, indigenous goats, sheep and poultry. Farmers living along the lake shore were involved in fishing and small scale vegetable production which forms a relatively important source of income to the district.

### 3.2. Data types and Sources

Both primary and secondary data was used for this study. Primary data was collected from the Agrobiodiversity Farmer Field Schools (ABD-FFS) Farmers and Non- ABD-FFS farmers in Bondo District through a single household survey. The household survey covered farmers selected from the ABD-FFS groups in the district and Non- ABD – FFS farmers. A structured questionnaire was used to collect information from the households on farm enterprise input – output data, household characteristics, socio- economic, household food consumption, household expenditure, farm and Non- farm income and technological factors. Farm income covered commodity sales and subsistence production, valued at local market prices. Data especially on prices of inputs and outputs was collected from the local markets.

Respondents were asked to specify in detail all inputs used, outputs obtained, and prices for the different crop and livestock activities over the period January-December, 2008. Non – farm income included agricultural wages, non-agricultural wages, self-employed income, remittances, pensions, house rent, land leases and other incomes from sell of value added products. These were recorded separately for all household members, also covering January-December, 2008, in order to avoid a seasonality bias.

Food consumption data was elicited at the household level covering various food items. Quantities consumed included food from own production, market purchases, and out-of-home sources. Data was captured from daily consumption, monthly and converted into annual data. Attempt was made to capture the household food consumption month by month to avoid the seasonality bias in food consumption. Capturing data from daily, weekly then to monthly consumption was an attempt to address the weakness of memory recall. The interviews were carried out in June -July, 2009.

Input – output and household food consumption data was constrained by the fact that most smallholder farmers did not keep records hence depended on memory recall which is not very reliable. However month to month approach and field observation were adopted to reduce the limitations of memory recall. Field estimations were conducted to establish enterprise sizes especially for perennial crops. The questionnaire was design with an inbuilt systematic data triangulation mechanism in which the preceding question crosschecked the next. This approach was adopted to assist in enhancing accuracy of the household data (Sharon, 2006). Secondary

data was collected from various reports at Divisional, District Agriculture offices. Other data sources were Livestock, Fisheries and District Development offices in Bondo district.

### 3.3. Sampling design and techniques

A sample of 150 farmers was selected for the study based on comparison groups' approach of Agrobiodiversity (ABD-FFS) participants and Non-ABD-FFS (NABD-FFS) participants (Erbaugh *et al.*, 2002; Lifeng *et al.*, 2007; Mungai *et al.*, 2008). The total sample was then subdivided into two equal Sub-samples of ABD-FFS and NABD-FFS farmers. The Sub-sample of 75 ABD-FFS farmers were selected from the 10 Agrobiodiversity- Farmer Field Schools (ABD-FFS) groups in Bondo district. The ten (10) ABD-FFS groups had an average of 20 farmers. The ten groups, distributed all over the district were purposively selected for the study. Purposive selection was necessary to get groups that would provide adequate coverage of the district. A list of members for the ten groups was developed. Farmers to constitute the ABD – FFS sub-sample of 75 farmers were selected from the population of ABD – FFS members by systematic random sampling method.

The ABD – FFS sub-sample size of 75 farmers was determined using the formula below:

$$n = z^2 \cdot p \cdot q \cdot N / [e^2(N-1) + z^2 \cdot p \cdot q] \quad (\text{Kothari, 2004}) \dots\dots\dots(1)$$

Where n = desired sample size,

Z= 1.96 the value of the standard variate at 95% confidence interval under normal curve

P = 0.5 sample proportion, assuming a conservative sample, q = 1-p = 0.5,

e = 9% acceptable margin of error

N= 200 the estimated population of farmers comprising the 10 ABD-FFS

An equivalent sub-sample of 75 Non – ABD – FFS (NABD-FFS) farmers was selected from three villages in the neighbourhood of ABD-FFS farmers by proportionate stratified sampling. First the district was stratified into three Zones, Lake Zone (LZ), Hinterland (HL) and Riverine (RZ) Zone (Figure 2). Then three villages were purposively selected where one village represented each zone to capture the varied agrobiodiversity situations. Each village was separated from an ABD-FFS Village by at least one Non-ABD-FFS village to reduce the effect of diffusion (Erbaugh *et al.*, 2002, Lifeng *et al.*, 2007). The list of farmers in each village was developed and a proportionate sample selected by systematic random sampling from each

stratum to constitute the Sub-sample for Non-ABD FFS farmers. The ABD-FFS and NABD-FFS Sub-samples cut across the three ABD Zones namely the Lake (LZ), Hinter Land (HL) and Riverine (RZ) Zones (Figure 2). The zones were demarcated at an estimated uniform cross-sectional distance of 10 kilometers from Lake Victoria to the south to River Yala at the North of the district. The two sub samples were assumed to be fairly homogenous having been drawn from the same population and therefore the differences would be majorly due to the factors under investigations. Socio-economic factors like education (EDUC), age, farm size, household non-farm income (NFI), household size and household non- food expenditure (NFE) were evaluated for heterogeneity by regressing them against Participation (ABD-FFS/NABD-FFS) as an independent variable and no significant difference was noticed. This implied that the two sub-samples were fairly homogenous.

**3.4. Data Analysis**

Descriptive and econometric analysis was done using Microsoft Excel and Statistical Package for Social Sciences (SPSS) while the linear programming model analysis was done using LINDO 11.0 for Windows computer package

**3.4.1. To determine crop and livestock diversity among Agrobiodiversity FFS and Non-ABD-FFS Farmers**

Descriptive analysis using Shannon index was used to determine impact of agrobiodiversity interventions on crop and livestock diversity among ABD-FFS and Non-ABD-FFS farmers in Bondo district. The analysis was based on crop and livestock species diversity (Benin *et al.*, 2004; Roth *et al.*, 1994). The crop and livestock diversity index was analysed using the Shannon index diversity model. In Shannon’s index:

$$\text{Crop diversity (CD)} = - \sum_{i=1}^n \alpha_i \ln \alpha_i \dots\dots\dots (2)$$

Where:  $Cd \geq 0$ ,  $\alpha_i$  = Area (A) Share Occupied by Crop enterprise up the  $i^{\text{th}}$  Crop.

$$\text{While livestock diversity (LVD)} = - \sum_{i=1}^n \theta_i \ln \theta_i \dots\dots\dots (3)$$

Where:  $\theta_i$  = Share of the Total Livestock Unit ( $TLU_i / \sum_{i=1}^n TLU_i$ ),  $TLU \geq 0$  where  $TLU_i$  = the Total livestock unit up the  $i^{\text{th}}$  livestock type. The outcome of both crop and livestock indices were used to make descriptive statistical inference on crop and livestock enterprise diversity of

Agrobiodiversity Farmer field school (ABD-FFS) and Non-ABD – FFS farmers. The statistical significance of the mean difference was tested using a t- test (Erbaugh *et al.*, 2002; Roth *et al.*, 1994). Further the crop and livestock diversity indices were used in determining the impact of crop and livestock diversity on household food security and farm income.

**3.4.2. Econometric analysis model**

Econometric analysis was conducted to determine the impact of crop and livestock diversity on income and food security of smallholder farmers in Bondo district. The analysis was done in two parts using ordinary least square and multinomial logit. Ordinary least square analysis was used to determine impact of agrobiodiversity on income while multinomial logit was used to analyse the impact on food security.

**(b). Impact of crop and livestock diversity on farm income and food security**

This objective was analysed in two parts:

**(i). Impact on Net Farm Income**

Ordinary Least Square (OLS) multiple regression model was specified to determine the impact of crop and livestock diversity on farm income(Y) (Lifeng *et al.*, 2007; Thi Mai *et al.*,2007). The OLS model was specified as:

$$Y_i = \lambda_0 + \sum_{k=1}^n \lambda_{ik} X_{ik} + \varepsilon_i \dots\dots\dots (4)$$

Where:  $Y_i$  = farm income,  $\lambda_0$  = the mean farm income difference between participating and non participating group,  $X_{ik}$  = a vector of independent variables affecting farm income ( $Y_i$ ),  $\lambda_{i,s}$  = parameters to be determined and  $\varepsilon_i$  = the unobserved factors affecting farm income. The variables used in the model are shown in table 1.

**Table 1: Income model variables**

Variable	Description	Measurement	A priori assumptions
Y	Net Farm Income	Kshs	
CD	Crop diversity	Shannon Index	+
LVD	Livestock diversity	Shannon Index	+
FARMSIZE	The size of the Farm in Hectares	HA	+
TECH	Technology	K/L Ratio	+
HHSIZE	Household size	No.	-
GENDER	Gender	(Male=1 Female= 0)	indeterminate
NFI	None farm income	Kshs	+
NFE	Non- food items Expenditure	Kshs	+
PART	Participation	PART=1,Non PART=0	indeterminate
AGHED	Age of Household Head	Years	+
EDUCLEV	Education Level (Years of Schooling)	Years	+
DMKT	Distance of Household to nearest major Market (km)	Km	+

K =Working capital, L= Labour

### (ii) Impact on Food Security

To determine the impact of crop and livestock diversity on food security (FDSEC), Multinomial Logit (MNL) regression model was used. Given  $X_i$  is a vector of explanatory variables,  $\beta_j$  is the matrix of parameters to be estimated and  $Z$  is the response variable, the general MNL model can be stated as:

$$\Pr(Z=j/x) = \frac{e^{\beta_j X_i}}{\sum_{K=1}^4 e^{\beta_K X_i}}, \quad j= 0,1,2,3 \dots \dots \dots (5)$$

Where: Pr is the probability of a household falling in a food security category j and  $x_i$  is a vector of exogenous variables affecting the probability of a household falling in a food security category j,  $j = (1)$  when a household is food insecure in dietary energy consumption,  $j = (2)$

when a household is food secure in dietary protein and Energy consumption,  $j = 3$  when a household is food secure in dietary protein and energy consumption.  $Z =$  Food security, was estimated first from the food security equations (12 and 13) before being used in the food security regression equation 6. Food security was estimated in terms of annual dietary energy (De) and dietary protein (Dpr.) consumption by the household and compared to the world health organization food consumption tables for minimum dietary energy and protein consumption (Jaswant, 1993). This was used to determine the food security categories for the households:  $j=1, 2,$  and  $3$  stated above.

The empirical model is specified as:

$$Z_{ji} = \beta_j + \sum_{k=1}^k \beta_{jk} v_{ik} + \mu \dots \dots \dots (6)$$

Where:  $Z_{ij}$  is the logs odd ratio,  $\beta_{jk}$  is the parameters to be estimated,  $V_{ik}$  a vector of independent variables affecting the probability of a household falling in a food security category  $j$ ,  $\mu =$  other factors affecting the probability of a household falling in a food security category  $j$ . The response of food security to agrobiodiversity was compared for ABD-FFS Farmers and Non- ABD-FFS Farmers (Lifeng *et al.*, 2007; Khan, 2007). The variables that were included in the model are as shown in Table 2.

**Table 2: Food security model variables**

Variable	Description	Measurement	A Priori Assumptions
FDSEC(Z)	Food security	(Energy Secure=1, Protein and Energy secure=2,protein and energy insecure=3)	+
CD	Crop diversity	Shannon Index	+
LVD	Livestock diversity	Shannon Index	+
FARMSIZE	The size of the Farm (Hectares)	HA	+
HHSIZE	Household size	No.	-
GENDER	Gender of Household Head	(Male=1 Female= 0)	indeterminate
PART.	Participation in ABD-FFS	PART=1,Non PART=0	indeterminate
AGHED	Age of Household Head	Years	+
EDUCLEV	Education Level (Years of Schooling)	Years	+
DMKT	Distance of Household to nearest major Market (km)	Km	+

### (c). Testing the explanatory power of the parameter estimates

#### (ii). The income model

The empirical income (OLS) model was subjected to a test for multicollinearity and the explanatory power of the parameter estimates. It was necessary to test for multicollinearity since it is commonly experienced problem in cross-sectional data using ordinary least square regression (OLS). The rule of the thumb in testing for multicollinearity is that a correlation coefficient between two explanatory variables greater than 0.8 indicates a strong linear association and a potentially harmful collinear relationship. Further, multicollinearity is exhibited in an ordinary least square (OLS) regression model by a high coefficient of determination ( $R^2$ ), few significant t-values coupled with a significant F-value. Another indicator of multicollinearity

is condition index (CI) > 30 which indicates severe multicollinearity (Gujarat and Porter, 2009). The Income model ordinary least square regression analysis in this study did not violate any of the aforementioned tests hence ruling out the presence of serious multicollinearity in the model. The F - Value for the income model was significant ( $p < 0.05$ ) which was an indication that the explanatory variables had a significant impact on the regressand variable, income (Gujarat and Porter, 2009).

### **(ii). Food Security Model**

The multinomial (MNL) logit regression model was used to estimate the impact of crop and livestock diversity on food security. The explanatory power of the model was measured in terms of the Chi-Square value which was significant. Further Pseudo R- Square indicators namely Cox and Snell, Nagelkerke and McFadden were also considered in assessing the explanatory power of the model. The Pseudo R-Square values range from Zero (0) to One (1) and the higher the value the better the model (Table 9). However the consistence of the variables coefficients with the economic theory and priori expectations was given serious consideration in determining usefulness of the results (Gujarat and Porter, 2009).

### **3.4.3. Determination of the optimum farm enterprise mix for agrobiodiversity Farmer Field School households in Bondo district.**

#### **(a) Optimization Model**

The Linear programming Model (LP) was used to determine optimum enterprise mix. The optimization model adopted is the short run model with nutritional constraints, unlimited use of the market to meet consumption demands. In this model, the family can purchase food from the market and sell the surplus production. The objective function in the model is to maximize farm net farm income over consumption subject to land, capital, labour and food security constraints. Net farm income in the model is defined as the net return of all commodities produced and sold minus all monthly costs incurred in purchase of household foodstuffs, crop and livestock inputs, hiring labor and all variable other costs incurred in crops and livestock enterprises. This definition ensures that household maximizing an income objective do so after all basic costs incurred in production and food security have been achieved which is usually the case with smallholder farmers. Dietary requirements are based on World Health Organization (WHO) requirements (WHO, 1985). Labour constraint is based on hired labour and household

labour. The household labour is based on the number of people in the household available for farm work, the number of hours they are available per day and number of days in a month. Sensitivity analysis was conducted to determine optimal farm plans for various farm and household scenarios.

The general Linear programming Model (LP) is formulated as:

$$\text{Max } Z = \sum_{j=1}^n c_j x_j \quad \text{Objective function} \dots\dots\dots (7)$$

Subject to Constraints:

$$\sum_{j=1}^n a_{ij} x_j \leq b_i \quad \text{all } i = 1 \text{ to } m \quad \text{Resource constraints} \dots\dots\dots (8)$$

$$X_j \geq 0 \quad \text{all } j = 1 \text{ to } n \quad \text{Non negativity of activity}$$

Z is the sum of enterprise gross margins ( $c_j x_j$ ),  $x_j$  = the level of  $j^{\text{th}}$  farm activity for n possible activities,  $c_j$  = per unit gross margins of  $j^{\text{th}}$  activity,  $a_{ij}$  = the quantity of  $i^{\text{th}}$  resources required to produce one unit of  $j^{\text{th}}$  activity up to m possible resources and  $b_i$  the amount of the  $i^{\text{th}}$  resource available (resource constraint levels). The empirical model is specified as:

$$\text{Max } Y = \sum_{m=1}^{12} \sum_{j=1}^n b_j^s p^s - \sum_{m=1}^{12} \sum_{j=1}^n b_j^b p^b - \sum_{m=1}^{12} \sum_{j=1}^n L_h - \sum_{m=1}^{12} \sum_{j=1}^n cp_h - \sum_{m=1}^{12} \sum_{j=1}^n cp_x \dots\dots\dots (9)$$

Where: Y = Net farm income, m = months of the year,  $b_j^s$  = quantity of good j sold,  $b_j^b$  = quantity of goods j bought,  $P^s$  = price of good j sold and  $P^b$  = price index of good j bought,  $cp_h$  = cost of production of h crop enterprises.  $cp_x$  = cost of production of x livestock enterprises,  $L_h$  = labour hired. Subject to:

$$(i). \text{ Land constraint } \sum_{k=1}^k C_k + \sum_{j=1}^j C_j \leq \text{TLD} \dots\dots\dots (10)$$

TLD = Total land resource available for cultivation.  $C_k$  = quantity of land c planted with k crops,  $C_j$  = quantity of land c set for pasture or fodder for livestock j

$$(ii). \text{ Labour Constraint Equation } \sum_{m=1}^m l_{km} c_k + \sum_{m=1}^m l_{xm} z_x + \sum_{m=1}^m l_{jm} c_j \leq \sum_{i=1}^m l_n^f + \sum_{i=1}^m l_m^{hi} \dots\dots\dots (11)$$

$l_{km}$  = labour requirement per acre of crop k in m months,  $l_{xm}$  = labour requirement per unit of x livestock in m months,  $l_{jm}$  = labour requirement per acre j pasture or fodder in m months

$c_k$  = size of  $k$  crop enterprise,  $z_x$  = size of  $x$  livestock enterprise,  $c_j$  = size of  $j$  fodder or pasture enterprise,  $I_m^f$  = quantity of family labour used in  $m$  months,  $I_m^{hi}$  = quantity of hired labour used in  $m$  months

(iii). *Food security constraint*

The second objective, which is to maximize food security, was accommodated in the model as a binding constraint and set as an inequality (Hazell and Norton, 1986). Thus farm income ( $Y$ ) is maximized subject to a food security constraint. Food security constraint comprises of dietary energy constraint and dietary protein constraint with respect to household members. Dietary energy constraint ( $D_e$ ) is expressed as:

$$\sum_{i=1}^m Q_1 + \sum_{i=1}^m Q_2 + \sum_{i=1}^m Q_3 + \dots + \sum_{i=1}^m Q_n \geq D_e \dots \dots \dots (12)$$

Where:  $Q_n$  = minimum consumption of  $n$  energy sources in  $m$  months.  $D_e$  = Minimum dietary energy requirement. Protein dietary requirement is given by:

$$\sum_{i=1}^m Q_1 + \sum_{i=1}^m Q_2 + \sum_{i=1}^m Q_3 + \dots + \sum_{i=1}^m Q_p \geq D_{pr} \dots \dots \dots (13)$$

Where:  $Q_p$  = Minimum consumption of  $p$  protein source in  $m$  months,  $D_{pr}$  = Minimum dietary protein requirement

(iv). *Capital constraint*  $\left[ \sum_{m=1}^{12} \sum_{j=1}^n cp_h + \sum_{m=1}^{12} \sum_{j=1}^n cp_x \right] \leq WP \dots \dots \dots (14)$

Where:  $cp_h$  = cost of production of  $h$  crop enterprises (family labour excluded).  $cp_x$  = cost of production of  $x$  livestock enterprises (family labour excluded),  $WP$  = Working capital cost. Working Capital cost was taken as Total Variable Cost (TVC) less Labour cost. The model was analysed in the form of a simplex problem matrix using LINDO for Windows LP Programme.

**(b). Household Categorization**

In the analysis, households were divided into three categories based on the size of their farms. The mean farm size was 1.64 hectares with a mode of 0.8 hectares and a range of 0.2 to 12 hectares (Table 10). The households were divided into three categories namely (I) small (0.2 < 1.2 hectares), (II) medium (1.2 hectares < 2 hectares) and (III) large (> 2 hectares). The representative farms for modeling were selected purposively based on land size, household size, labour employed and own capital endowment which were close to the mean values of the

category (Table 10). The farmer's current plan was used as a base for modeling. The plan was then adjusted either by dropping or bringing in new enterprises and response in terms of income and food security observed. Four plans were developed where, plan A was farmers plan, plan B was optimization of plan A, Plan C was optimization of plan B while plan D was as a result of optimization of plan C. Optimal plan for each category was determined from the four plans based on the highest incremental returns and whether it met the minimum annual dietary requirements for the household in terms protein and energy. In each category the farm size of the selected farm was kept constant. The analysis assumed a short run model with nutritional constraints and unlimited use of the market to meet the household consumption needs (Calkins, 1981). The model allows the family to purchase food from the market and sell surplus production. Land and labour can be hired while capital is limited to internal sources. The internal sources expected to provide capital are profits from sell of surplus produce, farm assets and Non-farm income.

## CHAPTER FOUR

### RESULTS AND DISCUSSIONS

This Chapter is divided into three sections. The first section discusses the results of the descriptive analysis of the household and farm Characteristics using descriptive statistics and the results of the agrobiodiversity analysis using Shannon index to determine the impact of agrobiodiversity interventions on crop and livestock diversity among ABD-FFS and Non-ABD-FFS farmers in Bondo district. The second section discusses the results of econometric analysis on the impact of Agrobiodiversity on income and food security of Smallholder households in Bondo district. The third section discusses the results of linear programming analysis which assesses the optimal enterprise diversification plan which takes into account the food security demands of the household and farm income.

#### 4.1. Descriptive analysis

##### 4.1.1. Household Agrobiodiversity Characteristics

**Table 3: Number of Crop enterprises per household**

Number of enterprises	Frequency	Percent
One crop enterprise	4	2.7
More than one crop enterprise	146	97.3
<b>Total</b>	<b>150</b>	<b>100.0</b>

Farmers in Bondo typically grow more than one crop enterprise on their farms with an almost absolute proportion of 97.3% (Table 3). It is apparent that households make deliberate decisions to diversify so as to meet certain objectives, probably to provide a variety of food for their families (Miyuki, 2006).

**Table 4: Number of Livestock enterprises per household**

Number of livestock types per Household	Frequency	Percent
Number of livestock enterprises		
0	5	3.3
1	28	18.7
>1	117	78.0
<b>Total</b>	<b>150</b>	<b>100.0</b>

Just like crop enterprises, many farmers in Bondo (78%) kept diversified livestock types such as Cattle, Goats, Sheep, donkey and Chicken (Table 4). Such diversification tend to lead to better utilization of farm resources such as forage, labour and encourages crop-livestock integration (Miyuki, 2006). Further it permits complementary relationships where crop enterprises utilize livestock manure and livestock, crop residues. This interaction in a mixed farming system leads not only to increased yields and income but a stable and sustainable farming system (Waithaka *et al.*, 2003)

#### 4.1.2. Agrobiodiversity Analysis

Agrobiodiversity analysis was done to determine the diversity of crop and livestock enterprises among ABD-FFS farmers and NABD – FFS farmers in Bondo district. The outcome of the analysis showed the relative difference in crop and livestock diversity hence forming a basis for making inference on the impact of FAO-Netherlands Partnership Programme-Agrobiodiversity project interventions on agrobiodiversity among the participating farmers.

##### 4.1.2.1. Crop and Livestock Diversity among Agrobiodiversity FFS and Non-ABD-FFS Farmers

Shannon index was used to determine the individual household farm crop and livestock diversity indices among ABD –FFS and NABD-FFS farms. The mean values of crop and livestock diversity of ABD and NABD farms (Table 5) were determined from the individual household crop and livestock diversity indices using statistical analysis of comparison of means.

**Table 5: Crop and livestock diversity mean difference**

Participation in ABD-FFS	Mean		N	
	Crop	Livestock	Crop	Livestock
NABD	.386	.129	75	75
ABD	.499	.101	75	75
Total Respondents			150	150

Results in table 5 show that there is a mean difference in crop diversity between ABD-FFS farms and NABD-FFS farms. The difference in the mean values for ABD-FFS farms (0.499) and NABD farms (0.386) is 0.113. This implies that the mean crop diversity value for ABD-FFS farms is 0.113 or 11.3% higher than NABD-FFS farms.

Mean value for Livestock diversity for NABD-FFS (0.129) is higher than ABD-FFS (0.101) by 0.028 or 2.8% (Table 5) though not significant. This is probably due to the trade – off in diversity between livestock and crops in a mixed farming system. Miyuki (2006) found similar results, that farmers specializing in crop production were less likely to keep more livestock. Livestock require 0.6 hectares per livestock unit of unimproved grazing pasture (Jaetzold and Schmidt, 1982) which is the common source of livestock feeds in Bondo district. In this circumstance, integration of livestock and crop diversity in a mixed farming system can be enhanced when the productivity of crops, livestock and pasture is improved. Simple linear regression analysis was used to test the statistical significance of the mean difference of crop and livestock diversity between ABD-FFS farms and NABD-FFS farms (Table 6)

### 4.1.3. Household food security characteristics

**Table 7: Household food security characteristics**

Household Food security status	Age of Household Head			Participation in ABD-FFS		Gender of Head of Household (Male/Female)		Total (No.)	% of Total HH
	18-30 Years	30-60 Years	Above 60 YRS	NABD	ABD	Female (No.)	Male (No.)		
Number of Households									
Energy insecure	3	33	10	28	16	16	30	46	30.7
Both protein and Energy secure	5	61	27	36	53	40	53	93	62
Both Protein and Energy insecure	0	9	1	8	3	6	5	11	7.3
<b>Total</b>	<b>8</b>	<b>103</b>	<b>38</b>	<b>72</b>	<b>72</b>	<b>62</b>	<b>88</b>	<b>150</b>	<b>100</b>

The results in Table 7 shows that (93) 62% of the households in Bondo district were food secure, 30.7% were energy insecure and 7.3% were both protein and energy insecure being completely malnourished. Among the food secure households, 66.3% were ABD-FFS households, 40.9% were households whose heads were in the age bracket of 30-60years, 35.3% male headed and 26.7% female headed households. More ABD-FFS households were food secure (66.3%) than NABD –FFS households (34.7%). Slightly more male headed households (35.3%) were food secure than female headed households (26.7%). This is probably the case because female headed households tend to be widows who are culturally deprived of basic resources of production especially absolute ownership of land.

#### 4.2. 1. Impact of crop and livestock diversity on farm income

Ordinary Least Square (OLS) multiple regression model was used to determine the impact of crop and livestock diversity on farm income(Y). The variable Participation (PART) is a dichotomous proxy variable for participation in ABD-FFS and Non Participation in ABD-FFS where participation is denoted by (1) and non-participation by (0). Non ABD-FFS represents the comparison group consisting of households that did not participate in Agrobiodiversity Farmer Field Schools (ABD-FFS). Participation being a categorical variable and non-participation being chosen as the reference category in the analysis its value was given by the value of the intercept. The results of the analysis of the impact of crop and livestock diversity on farm income(Y) are indicated in Table 8.

The Results in Table 8 show that crop diversity has a significant positive impact on net farm income. A 1% change in crop diversity would increase net farm income by Kshs 75152.6 per annum. The farmers will need to enhance the impact of crop diversity on income by applying productivity improvement technologies on their farms. The results show that technology significantly increases farmers' net income. Technology significantly enhances productivity of the diversified crop enterprises. Therefore strategies to enhance crop diversity and farmers income will need to integrate use of improved technology to have a significant income.

Household size had a significant negative impact on net farm income (Table 8). This is plausible given that the determination of net farm income took into account the food security demand of the household. Large households had high food security requirements hence reducing the net farm income. Strategies to enhance smallholders' net farm income will need to be implemented in conjunction with interventions on reduction of fertility rate in order to be successful.

Education level of the household head had a significant positive impact on net farm income (Table 8). This is acceptable because farmers' level of education can be associated with better farm management. The more educated farmers are also likely to have better non - farm income which they use as capital to better their farm enterprise productivity. Results are in congruence with earlier research findings that with increased years of education households are more likely to go into more diversified livelihood options and enhance their farm income (Khan, 2007).

**Table 8: Analysis of the impact of crop and livestock diversity on farm income**

Independent Variables	Unstandardized		Standardized	t	Sig.
	Coefficients		Coefficients		
	B	Std. Error	Beta		
(Constant)	-33591.636	16172.729		-2.077	.040**
Participation ( ABD- FFS/NABD-FFS)	8922.346	7445.048	.096	1.198	.233
Crop diversity index	75152.596	19301.698	.301	3.894	.000**
Livestock diversity index	33161.898	29057.788	.086	1.141	.256
Household Size of the Respondent(HH members)	-3459.638	1539.104	-.186	-2.248	.026**
Age of Household Head	-11781.405	6773.780	-.136	-1.739	.084*
Distance of Household to nearest major Market(km)	417.403	2732.401	.011	.153	.879
Gender of Head of Household(Male/Female)	-12647.787	7603.359	-.135	-1.663	.099*
The size of the Farm in Acres	1320.281	919.985	.112	1.435	.154
Education Level(Years of Schooling)	2160.849	1215.640	.160	1.778	.078*
Household Non-Food Expenditure	-.246	.154	-.134	-1.596	.113
Household Non - Farm Income	.111	.042	.205	2.631	.010**
Household Agric. Prod. Technology Level	80.391	36.612	.160	2.196	.030**

**Dependent Variable:** Household Net Farm Income,  $R^2 = 0.353$ .  $F= 5.91(0.000)$ , condition index (CI) = 16.7, \*\*Significant at ( $p < 0.05$ ), \*Significant at ( $p < 0.1$ )

Household non - farm income (NFI) had a significant positive impact on farm income. This could be probably because household none farm income supplements family food expenditure and also provides capital for improvement of the farm. Therefore, policies aimed at

improving smallholder farmer' income should consider integrating Non- farm income interventions.

ABD-FFS farmers had a significantly higher net farm income of Kshs 8922.4 per annum than NABD-FFS farmers. This is an indication that the agrobiodiversity interventions undertaken by ABD-FFS farmers had a positive impact on farmers' net farm income. These findings are in line with FNPP-Agrobiodiversity project objectives which aimed at improving farmers' income through agrobiodiversity interventions (FNPP, 2005).

The smallholder farmers in Bondo district will need to enhance the impact of crop and livestock diversity on their farm income by applying productivity improvement technologies on their farms. The results in Table 8 show that increase in technology use has a significant positive impact on net farm income. Technology use includes the use of fertilizers, farm yard manure, quality seeds and livestock breeds, pesticides, farm machinery and farming skills.

#### 4.2.2. Impact of Crop and Livestock diversity on food security

To determine the impact of crop and livestock diversity on food security (FDSEC), Multinomial Logit (MNL) regression model was used since the dependent variable food security had three categories. Food quantities consumed at the household level were converted to kilocalories and gram protein using the food composition table (Jaswant, 1993). The household energy and protein dietary requirements were determined using the World Health Organization (WHO) recommendations for various age groups and sex (WHO, 1985). Household annual energy and protein dietary food consumption was compared with the WHO minimum energy and protein dietary recommendations to determine the food security categories for the analysis. The three (3) categories included the probability of the household being Energy secure(1), both protein and energy secure (2), both protein and energy insecure (3). The three (3) categories of household food security status were analysed, of which Energy insecure was the reference category while protein and energy secure was taken as the category of interest. Protein and energy secure category represents the status of the household being food secure. Table 9 shows the results of multinomial logistic regression to examine which variables affect the probability for a household being in a particular food security category. The Variables included those representing household characteristics Age of household head (AGHED), Gender of household head (Gender), Education years of the household head (EDUC), Household Size (HHSIZE),

Participation in ABD-FFS (PART), Crop diversity (CD), Livestock Diversity (LVD), Farm Size (FARMSIZE), Distance to market (DMKT).

The result in table 9 shows that the coefficients for Crop Diversity (CD) and Participation in ABD-FFS (PART) were positive for Both Protein and Energy secure, food security category. It implies households with high Crop and Livestock diversity and who Participated in ABD-FFS had a high probability of being food secure (Table 9). The coefficient for crop diversity and participation ABD-FFS are significantly positive for both protein and energy secure, food security category. Crop diversity is significantly negative for both protein and energy insecure food security category. This suggested that crop diversity had a significant positive impact on food security. This is plausible because increase in crop diversity enhances the probability of a household being food secure. Households with diverse crop enterprises are cautioned against crop failure due to drought or pest and disease infestation (FAO, 2005). These findings are in line with the aspirations FAO Netherlands Partnership Programme (FNPP) – Agrobiodiversity project. The project aimed at sensitizing the smallholder farmers in Bondo district to enhance agrobiodiversity on their farms so as to reduce vulnerability to food insecurity (FNPP, 2005).

Household size has a significant negative coefficient implying large households are less likely to be food secure despite diversifying their crop and livestock enterprises due to their high food security demand (Table 9). This study found that in Bondo district the mean household size was six (6) people with a mode of five (5) people per household. A policy targeting crop diversity as a strategy to increase smallholder farmers' household food security in order to be effective has to address the need to maintain small households (Alemayehu *et al.*, 2005)

**Table 9: Impact of crop and livestock diversity on food security**

Independent Variables	Food Security Status of the Households							
	Both Protein and Energy secure				Both Protein and Energy insecure			
	B	Std. Error	Sig.	Exp(B)	B	Std. Error	Sig.	Exp(B)
Intercept	-.897	.972	.356		.802	1.798	.542	
PART	1.011	.436	.020**	2.748	-.144	.956	.522	.542
CD	2.827	1.283	.028**	16.902	-7.617	2.576	.011**	.001
LVD	1.251	1.771	.480	3.495	-1.443	4.072	.678	.184
HHSIZE	-.184	.094	.050**	.832	.424	.210	.368	1.208
AGHED	.036	.399	.929	1.036	.138	.712	.560	1.515
DMKT	.141	.178	.429	1.151	.365	.344	.526	1.243
GENDER	-.165	.444	.711	.848	-1.539	.942	.317	.390
FARMSIZE	.166	.090	.067*	1.180	-.291	.289	.175	.676
EDUCLEV	.012	.069	.856	.988	-.007	.143	.489	.906

Reference category – Energy insecure

-2Log Likelihood = 205.4, \*Chi-Square = 49.7, Cox and Snell =0.282, Nagelkerke = .345, McFadden = 0.195, Number of observations = 150, Energy insecure = 46, Both protein and energy secure =93, Both protein and energy insecure = 11, \*\*Significant at (p<0.05), \*Significant at (p<0.1), B = Variable coefficient (Log odds ratio), Exp (B) = Exponential of B.

Farm size had a significant positive impact to food security (Table 9). Implying that households with large farm size are most likely to be food secure. This is plausible because large farm size allows farmers to diversify their enterprises especially in mixed farming system and also produce on large scale compensating for low productivity. However farm sizes are shrinking with population growth hence farmers will need to increase productivity to sustain food security in future.

### 4.3. Optimum farm enterprise mix for Agrobiodiversity farmer field school households in Bondo district.

#### 4.3.1. Households Categorization Parameters

Households in the sample were divided into three categories based on their resource endowment level in terms of basic factors of production namely working capital, Labour (Family&Hired), farm size and house hold size. Table 10 below shows the farm characteristics used for the selection of farms for modeling. Up to 83% of the households owned less than 2 hectares of land implying land was limited and likely to be a constraint to diversification. Therefore the farmers to attain food security they would need to increase productivity of their enterprises by adoption of yield enhancing technology (Nyaribo, *et al.*, 1989)

**Table 10: Households' Categorization Parameters**

Factors of Production	Household Category	No of Households	Mean	Minimum	Maximum	
Working capital used by the farmer	0.2<I<1.2 HA	I	55	1776	0	11580
	1.2<II<2 HA	II	63	5460	45	43360
	III ≥2 HA	III	26	6496	0	36450
Household Labour (Family&Hired) in Man days	0.2<I<1.2 HA	I	56	196	7	579
	1.2<II<2 HA	II	63	292	4	876
	III ≥2 HA	III	26	241	21	607
The size of the Farm in Hectares	0.2<I<1.2 HA	I	54	1.792	.5	3.0
	1.2<II<2 HA	II	63	3.770	3.0	5.0
	III ≥2 HA	III	26	9.885	6.0	30.0
Household Size of the Respondent (HH members)	0.2<I<1.2 HA	I	55	6	2	11
	1.2<II<2 HA	II	63	6	2	14
	III ≥2 HA	III	26	8	3	12

Linear programming model was used to determine the optimum enterprise mix for the small holder farmers in Bondo district. The objective here was to determine an enterprise combination that provides a diverse, nutritious as well as profitable and affordable plan to the farmers. Linear programming (LP) model was used to maximize net farm income with food security as a constraint. Smallholder farmers maximize income after meeting their household food security needs (Calkins, 1981). The households were divided into three categories namely I, II, III, based on farm size and analysed based on four farm plans A, B, C and D with farmers plan as the reference plan. The plan was deemed feasible if it maximized net farm income above food security requirements of the household without violating the resource constraints of the category. The result of the linear programming analysis is shown in Table 11.

**Table 11: The Linear Programming (LP) model analysis results**

HH Category	Farm Plan	NFI (Kshs)	I.R (Kshs)	HH Food Security Requirements p.a		Farm size (HA)	Labour (MD)	Own Capital (Kshs)	House hold size (No.)
				Dietary Energy (DE) (Kcl) (00,000)	Dietary Protein (DP) (Pg) (00,000)				
I	A	-29999		47.4 (43.4)	1.7 (0.78)	0.8	410	7079	5
	B	5601	35600	91.6 (43.4)	1.7 (.78)	0.8	410	8799	5
	C	15440	45439	91.6 (43.4)	7.9 (0.78)	0.8	489	8796	5
	D	24620	44780	90.7 (43.4)	7.5 (0.78)	0.8	479	8796	5
II	A	123260		50.14 (61.1)	2.26 (1.2)	1.6	481	12080	7
	B	67548	-55712	61.14 (61.1)	2.39 (1.2)	1.6	457	10640	7
	C	87442	-35818	68.71 (61.1)	2.66 (1.2)	1.6	484	15453	7
	D	31008	-92252	73.01 (61.1)	2.81(1.2)	1.6	484	18043	7
III	A	-81400		102.2 (76.1)	6.6 (1.2)	1.2	237	2887	10
	B	-74540	6860	113.7 (76.1)	4.3 (1.2)	2.6	277	2887	10
	C	38784	120184	100.7 (76.1)	3.96 (1.2)	2.0	423	35347	10
	D	29985	111385	100.7 (76.1)	3.96 (1.2)	2.6	423	3547	10

The values in parenthesis are the minimum household food security requirements, NFI = Net Farm Income, I.R. = Incremental Return, Kcl = kilocalories, Gp = Gram protein, MD = Man days, No. = Number, Kshs = Kenya Shillings.

### Category I. (0.2HA ≤ I < 1.2HA)

In this category a household number 125 with a farm of 0.8 hectares was selected for modelling being close to the mean farm size category of 0.72 hectares. Plan A represents the farmers plan in terms of enterprise mix and household food consumption mix before optimization.

**Plan A:** Farmers plan before optimization involved:

**Enterprises**— Maize and Beans (MB), Sorghum and Green Grams (SGG), Local Cattle (CA)

**Foodstuffs**—Sorghum (S),Maize (M), Beans(B), Groundnuts (GN), Cassava (CS), Sugar (SU), Avocado (AV), Rice (R), Chicken (CHK), Sweet Potatoes (SP).

**Plan B:** Involved optimization of plan A. Rice was dropped from the household food consumption mix. The Farmer's income increased from a loss of Kshs -29999 to Kshs 5601 representing an increase of 635.6%.

**Plan C:** Involved optimization of plan B in Category I. Groundnut was dropped in this plan and Finger millet was brought into the production plan. The Farmer's income was increased further by 175.6% from Kshs 5601 to Kshs 15440.

**Plan D:** involved optimization of plan C in Category I. Sweet Potatoes (SP) and Green grams (GG) were dropped in this plan. The Farmer's income was increased by 59.5% from Kshs 15440 to Kshs 24620.

The change in net farm income from Plan A to Plan C increases by over 100% hence a more than 100% return to capital employed. Plan D provides the optimal plan having the highest increase in return from plan A, the farmers plan. The plan also provides adequate dietary requirement for the household. This suggests that Plan C is the optimal plan for the farmers in this category to adopt. The plan provides an enterprise combination that is diverse, nutritious as well as profitable and affordable to the farmers.

### **Category II ( $1.2 \text{ HA} \leq I < 5 \text{ HA}$ )**

In this category a household number 53 with a farm of 4 acres was selected for modelling being close to the mean farm size of category (II) of 3.770 acres. Plan A represents the farmers plan in terms of enterprise mix and household food consumption mix before optimization.

**Plan A:** Farmers plan before optimization involved:-

**Enterprises** - Cattle (CA) Maize (M) and Beans (B), Chicken (CHK), Goats (GT), Cattle (CA)

**Foodstuffs** –Maize (M), Beans (B), Sorghum (S)and Green ,Grams (SGG), Goats(GT), Onion (N), Kales (KL), Sugar (Su), Pawpaw (PP), Rice (R), Chicken (CHK), Tomatoes (TM), Mangoes (MG), Meat (MT), Fish (FS), S/Potatoes (SP).

Plan A gives the farmer an income of ksh123260 per annum however the plan provides inadequate dietary energy (Table 11).

**Plan B: Involved Optimization of Plan A:**

The farmer's income was reduced by 45.3% from Kshs 123260 to Kshs 67548 per annum to accommodate household food security in terms of providing household dietary energy requirement per annum. Cattle and Goats are assumed to graze out of the farm hence allocated no grazing land in the plan.

**Plan C: Involved optimization of Plan B:**

In this plan sweet potatoes are produced instead of being bought for household food security requirements. Cattle are assumed to graze out of the farm hence allocated no grazing land. The farmer's income was increased by 29.5% from Kshs 67548 to Kshs 87442 per annum.

**Plan D: Involved optimization of Plan C:**

In this plan Cattle and Goats were allocated grazing land on the farmer's field. The cattle and goats constitute 5.8 TLU in Plan C which would require 3.5HA of grazing land (given existing natural unimproved grazing pastures). Jaetzold and Schmidt (1982), recommends a stocking rate of 0.6 HA/TLU. The optimization results taking into account grazing land for cattle is given in Table 11. The farmer's net farm income is reduced by Kshs 56,434 to Kshs 31008 per annum. The land being limited among the small holder farmers in Bondo district, and low productivity of local Cattle, the inclusion of grazing land in the farm plan reduces the net farm income drastically.

Plan C in category II becomes optimal plan for farmers to adopt that is profitable as well nutritious. However this plan is feasible where farmers are grazing outside their farms in common grazing field which is a common practice in Bondo district. However as common grazing grounds shrink the farmers would need to improve the productivity of the pasture on their farms and keep quality cattle which will reduce the necessity of keeping many cattle. A policy targeting integrated crop-livestock diversity as a strategy to increase food security and

income for smallholder farmers will have to facilitate farmers to improve the quality of their pasture and livestock.

### **Category III ( $\geq 2$ HA)**

In this category a household number 147 with a farm of 2.8 hectares was purposively selected for modelling being close to the mean farm size of category (III) of 3.96 hectares. Plan A represents the farmers plan in terms of enterprise mix and household food consumption mix before optimization.

**Plan A:** Farmers plan before optimization involved:-

**Enterprise** - Maize and Beans (MB) , Sorghum (S), Finger millet (FM), Sesame (SS), Cattle (CA), Sheep (SHP)

**Food Stuffs** – Maize (M), Beans (B), Sorghum (S), Finger millet (FM), Kales (KL), ,Sweet Potatoes (SP), Sugar (Su), Onion (N), Chicken (CHK), Meat (MT), Fish (FS), Milk (MLK), Tomatoes (TM), Cowpeas (CP), Sweet potatoes (SP) and Cassava (CS).

This plan yields negative net farm income of Kshs -81400 per annum, though it provides adequate dietary energy and protein to the household. The plan provides 113.7 million kilocalories against the household requirements of 76.1 million kilocalories and 4.3 million gram protein against a household requirement 1.2 million gram protein.

**Plan B:** Involved optimization of Farmers plan:-

This plan yields negative net farm income of Kshs -74540 per annum. A marginal increment from the farmer's initial plan though it provides adequate dietary energy and protein to the household. The plan provides 102.2 million kilocalories against the household requirements of 76.1 million kilocalories.

**Plan C:** Involved optimization of plan B in category III:

In this plan Maize, Beans, Sorghum, and Finger Millet are produced using modern inputs (seeds, manure, fertilizers and pesticides) leading to high yields and gross margins (G.O.K, 2009a). The farmer produced the food security crops namely cassava, sweet potatoes and cowpeas instead of purchasing from the market. The household budget spent on fish was reduced by half, as the household dietary protein consumption in plan B already exceeded the per capita requirement. These interventions made the net farm income to increase from Kshs -74540 to Ksh38784. The Cattle and Goats were not allocated grazing land. They were assumed to graze on off the farm in uncultivated farms and farm residues of maize, sorghum and beans. Off the farm livestock feeding is a common practice in smallholder farming system (Connelly et al., 1987).

**Plan D:** involved optimization of plan C:

In category (III) farm plan D, Maize, Beans, Sorghum, and Finger Millet, Groundnuts were produced using improved inputs (seeds, manure, fertilizers and pesticides) as in plan C in category (III) leading to high yields and Gross margins. The cattle were dropped since the pasture requirement exceeded the land constraint of five (2) hectares (Jaetzold and Schmidt, 1982). Goats (0.99TLU) were retained in the plan and allocated 1.5 acres of grazing land on the farm in accordance with their natural pasture requirement. This allocation of land to livestock reduced net farm income above household food security requirement by 38.5% to Kshs.29985 per annum. Similar results were obtained by Nyaribo et al., (1989) in the study of economic implications of forage innovations on smallholder farms in western Kenya.

**Plan C** in category III was the optimal plan for the farmers to adopt since it provides the highest net farm income but the farmers will need to improve the quality of their pasture and livestock for the plan to continue being feasible in the future.

## CHAPTER FIVE CONCLUSIONS AND POLICY IMPLICATIONS

### 5.1. Conclusions

The purpose of this study was to determine the impact Agrobiodiversity (ABD) interventions on Smallholder farmers' food security and income using comparison groups. The study was conducted in Bondo district which is predominantly Smallholder mixed farming system. In this area FAO-Netherlands Partnership Programme(FNPP) Agrobiodiversity project was implemented using Farmer Field Schools with an aim of enhancing agrobiodiversity. The study sought to find out whether there was significant increase in crop and livestock diversity among ABD-FFS farmers compared to NABD-FFS farmers. The study further sought to find out whether the change in agrobiodiversity had any associated impact on food security and farmers income. Similarly the study sought to determine the optimum enterprise combination for the smallholder farmers in Bondo district that would enable them attain the objective of food security and income.

The study indicated that there was a significant difference in agrobiodiversity between the ABD-FFS and NABD - FFS farmers. The ABD- FFS farmers had higher level of crop diversity compared to NABD-FFS farmers implying the project interventions had a positive impact on agrobiodiversity. Agrobiodiversity study also showed that crop and livestock diversity had a significant positive impact on farm income. Further, the study showed that an increase in agrobiodiversity increases the probability of a household being food secure. These findings imply that smallholder farmers in Bondo district need to enhance agrobiodiversity on their farms to ensure food security and income. However, household size had a strong negative effect on the probability of the household being food secure. This study showed that the mean household size in Bondo district was six (6) people with a mode five (5) and a maximum of fourteen (14). This outcome compares favourably with the district household mean of five (5) people per household (G.O.K, 2009a).

Increase in enterprises diversity especially if enterprises have low gross margin though it assures the farmer food security, it reduces the net farm income. Farmers under low resource endowment can attain a profitable, diverse and nutritious plan by bringing in enterprises with low production costs and positive gross margins. Further farmers need to adopt improved

technology to increase productivity of their farm enterprises. Farmers will need to improve the productivity of their pasture and livestock to keep less livestock which will release land for crop production. A farm plan with few but productive livestock in the mixed farming system provides a better balance in income and food security.

## 5.2. Policy Implications

This study showed that diverse crop and livestock production system would be appropriate to reduce smallholder farmers' vulnerability to food insecurity as it is likely to enhance household food security as well as promote sustainable management of agrobiodiversity. However it's imperative that farmers will need to embrace technological advancement to reduce pressure on production resource requirement especially land. This in line with Government policy aspirations as articulated in Vision 2030 under the Agriculture Sector plan 2008 – 2012 (G.O.K, 2009b).

It was observed from this study that use of modern technology enhances small holder farmers' food security and income. The farmers would need to raise capital from internal and external sources in order to employ modern technology on their farms. The smallholder farmers can seldom raise capital internally as often their net farm income is negative hence they will need financial support from external sources. Most financial institutions cannot provide them with credit as they are deemed not creditworthy. The factors that constrain small holder farmers access to credit should be addressed to enable them acquire capital for improvement of productivity of their farms.

Household size had a significant negative impact on food security and income. Policies and strategies aimed at increasing food security among the smallholder farmers such as Bondo district should consider encouraging them to maintain small households. This is because large households require increased food and non-food expenditure which reduces resources meant for improvement of farm productivity. National food security policy will need to integrate strategies that will bring about small household size among the smallholder farmers.

## REFERENCES

- Alemayehu G., Niek J., Mwangi S. K., and Germano, M. (2005). "Determinants of Poverty in Kenya: A Household Level Analysis", University of Nairobi and Yale University, Working Paper 2005-44, January 2005, RePEc, <http://repec.org/>.
- Amelie, C., and Zimmermann, K.F. 2004. Occupational Choice across Generations. Discussion Paper No. 395. German Institute for Economic Research, Berlin, Germany.
- Antle, J.M. (1995). "Methodological issues in assessing potential impacts of climate change on Agriculture" *Journal of Agricultural and Forest Meteorology* 80:67-85.
- Argwings-Kodhek, G., T. Jayne, G. Nyambane, T. Owuor, and T. Yamano. (1999). "How Can Micro-Level Household Information Make a Difference for Agricultural Policy Making?" Tegemeo Institute for Agricultural Policy and Development, Kenya Agricultural Institute Research Institute, and Michigan State University, Mimeo.
- Benin, S., Smale, M., Pender, J., Gebremendhin, B., Ehui, S. (2004) "The Economic Determinants of Cereal Crop diversity on the farms in the Ethiopian highlands". *Journal of Agricultural Economics* 31: 197-208.
- Binswanger, H.P., and Townsend R.F.(2000)" The growth performance of agriculture in sub-Saharan Africa" *American Journal of Agricultural Economics* 82(5):1075-1086.
- Calkins, P.H. (1981). "The Nutritional adaptation of Linear Programming for planning rural development". *American Journal of Agricultural Economics* 63(2): 247-284.
- Connelly, W. T., Mukhebi, A. W., Oyugi, L. and Knipscheer H .C. (1987). *Household labour allocation in an intensive crop/livestock farming system in western Kenya*. Selected Paper, Farming Systems Research Symposium, held at the University of Arkansas,

Fayetteville, Arkansas, USA, and 18-21 October 1987. 19 pp. [Copies available from SR-CRSP, PO Box 58137, Nairobi, Kenya, or PO Box 252, Maseno, Kenya].

Dixon, J., Aidan G., Gibbon D.(2001). “*Farming system and poverty: Improving farmers livelihood in the cHanging world*”. FAO and World Bank, Rome and Washington D.C.

Ehui S., and Pender J. (2003)”Resource degradation, low agricultural productivity, and poverty in sub-SaHaran Africa: pathways out of the spiral” Proceedings of the International Conference of Agricultural Economists held in Durban, South Africa, August.

Erbaugh, J.M., Donnermeyer J., Kibwika P., Kyamanywa S. (2002) “Assessment of the integrated pest management collaborative research support project’s (IPM CRSP) activities in Uganda: Impact on farmers’ awareness and knowledge of IPM skills”. *African crop science Journal*, 10 (3):271-280.

FAO (1996b). Rome Declaration on world Food security and world food plan of action,[www.fao.org/docrep/003/w3613e/w3613e00.htm](http://www.fao.org/docrep/003/w3613e/w3613e00.htm).

FAO (1999a). Agricultural Biodiversity, malfunctioning character of agriculture. Land conference background paper 1, Maastricht, September 1999.

FAO. (1999b). Women users, preservers and managers of Agrobiodiversity. [www.fao.org/FOCUS/E/Women/Biodiv-e.htm](http://www.fao.org/FOCUS/E/Women/Biodiv-e.htm).

FAO (2005). *Building on Gender, Agrobiodiversity and Local Knowledge*. Gender development service. Sustainable development department, Rome.

FNPP. (2005). FNPP Report of the national workshop for the development of the Kenya Agrobiodiversity programme, Nairobi, 4-6 July, 2005.

- Frank, W. (2001). "Biological diversity of livestock and crops: useful classifications and appropriate Agri-environmental indicators". A paper presented to OECD Expert meeting on Agrobiodiversity indicators.5-8 November, 2001,Zurich, Switzerland.
- Gujarat, D.N., and Porter, D.N. (2009). *Basic Econometrics*, Fifth Edition, McGraw-Hill/Irwin, New York, NY 10020.
- G.O.K (2007a). Bondo District Agrobiodiversity Farmer Field Schools Report. Ministry Livestock Development.
- G.O.K (2007b). Bondo District Development Plan, Ministry of Planning.
- G.O.K (2009a). Bondo District Farm Management Guidelines, Ministry of Agriculture.
- G.O.K (2009b). Sector Plan for Agriculture 2008-2012. Ministry of Agriculture.
- Hazell, P.BR.,Norton,R.D.(1986).*Mathematical programming for economic analysis in agriculture*. Macmillan publishing company New York.
- Holden, S.T., and Binswanger, H.P. (1998). "Small-Farmer decision making, market imperfections, and natural resource management in developing countries," in E. Lutz, ed., "Agriculture and the environment: perspectives on sustainable development". A World Bank symposium (the World Bank Washington: Washington, D.C.
- Jaetzold R and Schmidt H. (1982). *Farm management HAndbook of Kenya, Volume II. Natural conditions and farm management information, Part A, West Kenya, Nyanza and Western Province*. Kenya Ministry of Agriculture and the German Agricultural Team (OAT) of the German Agency for Technical Cooperation (GTZ), Nairobi, Kenya. 397 pp.
- Jaswant, K.S. (1993). *National Food Composition and the Planning of Satisfaction Diets in Kenya*. Government Printer.

- Khan, M.A. (2007). "Factors affecting employment choices in rural north western Pakistan", Conference on International Agricultural Research for Development ,Tropentag University of Kassel-Witzenhausen and University of Göttingen, October 9-11, 2007 .
- Kooten, G.C., Bulte, E.H., Sinclair, A.E.R. (Eds.). (2000). *Conserving Nature's Diversity*. Ashgate, Aldershot, UK.
- Kothari, C.K. (2004). *Research Methodology: methods and techniques*, Second edition. New Age International Publishers.
- Lifeng, W., Diemuth P. and Hermann W. (2007). The role of Farmer Training in the Diffusion of Biotechnology in Cotton in China: A Multi-period analysis .Conference on International Agricultural Research for Development. University of Kassel-Witzenhausen and University of Göttingen, October 9-11.
- Miyuki, I. (2006). Land use change, impacts and dynamics (LUCID) Project Working Paper No. 51. Nairobi, Kenya: International Livestock Research Institute.
- Morris, M.L., R. Tripp, and A.A. Dankyi. (1999) "Adoption and Impacts of Improved Maize Production Technology: A Case Study of the GHANA Grains Development Project". *Economics Program Paper 99-01*. Mexico, D.F.: CIMMYT.
- Mungai, N.W, Nakhone L.W, Lagat J. K, Opiyo A.M and Mumera L. M. (2008) "The Role of Traditional Leafy Vegetables and Associated Cropping Systems: A Case Study of Bondo District, Kenya": Project Report of Egerton University, faculty of agriculture in collaboration with FAO Netherlands Partnership Programme.
- Nijkamp, P., Gabriella V., Nunes P. A.L.D. (2008) "Economic valuation of biodiversity: A comparative study". *Journal of Ecological Economics* 67: 217-231.
- Nunes, P.A.L.D., van den Bergh, J.C.J.M., Nijkamp P. (2004) *The Economics of Biodiversity*. Edward Elgar, Cheltenham, UK.

- Nyaribo, F.B., Onim, J. F. M. and Young, D. L. (1989). "Economic implications of forage innovations on smallholder farms in western Kenya".  
[www.ilri.org/InfoServ/Webpub/Fulldocs/X5519b/x5519b1c.htm](http://www.ilri.org/InfoServ/Webpub/Fulldocs/X5519b/x5519b1c.htm) -14:58hrs
- Oakley, E. and Momsen J. H. (2004)." Gender and Agrobiodiversity: A case study from Banglad–sh" *Geographical Journal* 171 (3): 195 - 208
- Odulaja, A., Kiros,F.G.(1996) "Modelling agricultural production of small-scale farmers in sub-SaHArans Africa: A case study in western Kenya". *Journal of Agricultural economics* 14:85-91.
- Place, F., Barret, B.C., Freeman, A.H., Rarnisch, J.J., Lauwe.,V.B.(2003) "Prospects for integrated soil fertility management using organic and inorganic inputs: evidence from smallholder African agricultural systems". *Food policy*, 28:365-378.
- Pretty, J.N., Morison, J.I.L., Hine, R.E. (2003)."Reducing food poverty by increasing agricultural sustainability in developing countries". *Journal of Agriculture, Ecosystems and Environment* 95:217-234.
- Raphael, O. B., Martin, Q. (2010). Impact of off-farm income on food security and nutrition in Nigeria. *Food Policy journal*. Homepage: [www.elsevier.com/locate/foodpol](http://www.elsevier.com/locate/foodpol).
- Rosegrant, M., Painsier, M., Mijer S., Witcover, J., (2001). "Global food projections to 2020; emerging trends and alternative futures". IFPRI (International Food Policy Research Institute) Washington, D.C., U.S.A. pp 207.
- Roth, D. S., Perfecto I. and Rathcke B. (1994). "The effects of management systems on ground-foraging Ant diversity in Costa Rica". *Ecological Applications* 4(3):423-436.
- Thrupp, L.A. (1997). Linking biodiversity and agriculture: Challenges and opportunities for sustainable food security. World Resources Institute, U.S.A.

Waithaka, M.M., Salasya, B.D., Thorton, P.K., Shepherd,K.D., Staal, S.J., Ndiwa, N.N. (2003). Factors influencing soil fertility management in Vihiga, Western Kenya. Best poster finalist at the 25<sup>th</sup> international conference of IAAE, Durban, August 16-22.

World Health Organization. (1985).”Energy and Protein requirements”. A Report of A Joint FAO/WHO/UNU Expert Consultation, Geneva, WHO Technical report serial, No.724.

Thi Mai, H.P., Mavans M., Brigitte,K., and Anne V.(2007). Production and Marketing of Indigenous Pig Breeds in Uplands of Vietnam. Conference on international Agricultural Research for Development. University of Kassel-Witzenhausen and University of Göttingen, October 9-11.

Sharon S. (2006). A “Triangulated data” Approach to assessing academic English language learners” A paper presented at the Pan Pacific Association of applied linguistics. Kangwon University, Chuncheon, South Korea. July, 2006.

## APPENDICES

### Appendix 1: Questionnaire

This is a study of the impact of FAO-Netherlands Partnership Programme (FNPP) agrobiodiversity interventions in Bondo District. The information you provide will assist to improve project activities and will be used only for the purpose of this study. The information required is for the period January- December, 2008

#### Questionnaire Identification

Name of enumerator \_\_\_\_\_

Division \_\_\_\_\_ Location \_\_\_\_\_ Sub- location  
\_\_\_\_\_ village \_\_\_\_\_

Farm household number \_\_\_ Date \_\_\_\_\_ Starting time \_\_\_\_\_ Ending time \_\_\_\_\_

**ABD-FFS Household** [  ] **Non-ABD-FFS Household** [  ]

#### 1.0. Background information

Farmers name (Head of Household) \_\_\_\_\_ sex (male/female)

Education level (Years of schooling) \_\_\_\_\_

Respondents name \_\_\_\_\_ relation to farmer \_\_\_\_\_

Name of household member who attends FFS \_\_\_\_\_ Sex (M/F)

Household size (living and eating together) \_\_\_\_\_

Name of nearest market centre \_\_\_\_\_ distance to market center \_\_\_\_\_

Total farm area (acres) [  ]

Land tenure: freehold [  ] leasehold [  ] communal [  ]

Total rented out farm area (acres) [  ] Rental income per year [  ]

Total hired farm area (acres) [  ] hiring cost per year [  ]

Other land ownership specify

N/B- Tick as applicable HHH = Household head

## 2.0. Farming objectives

What are your main objectives of farming? List and rank them (1-most important, 2-next important, etc)

objective	Rank
Food supply	
Basic income/profit	
Others (specify)	

## 3.0. Composition of household

HH Memb. No.	First name	Relation to HH Head	Marital status	Sex M= 1 F = 0	Age in years	Highest Education level reached (years of schooling)	Labour profile			Non-Farm Occupations	Day/ months involved	Est. income /day/ month (Kshs)
							Months Worked On farm	Days per month	Hours per day			

**Non-Farm Occupation** - 1=Petty Business, 2= Business, 3=Fishing, 4=Hired Out Labour, 5=Salaried Employment, 6= Student, 7=Others Specify.

### Relation to head codes

7=Head, 8=Parent, 9=Child, 10=Sibling, 11=Wife, 12=Husband, 13= Grand Child, 14=Cousin, 15=Aunt/Uncle, 16= Niece/-Nephew, 17= Brother /Sister- In -Law, 18=Others Specify

### Marital Status Codes

19=Married, 20=Single, 21=Widow(Er), 22=Divorced, 23= Others Specify

#### 4.0. Crop enterprise information (2008)

Long rains season				Short rain season			
crop	variety	Cropped area(acres)	Yield(kgs)	crop	variety	Cropped area(acres)	Yield(kgs)

#### Crop type:

1- Maize, 2-Sorghum, 3- F/Millet, 4-Beans, 5-Maize +Beans, 6=Maize+Green /Grams, 7.Avocado,8=Maize+Green/ grams, 9=Cassava, 12=Groundnuts, 13= Cotton, 14=Kales, 15=Tomato, 16=Onions, 17=Cowpeas 18=, Green/Grams, 19=Sugarcane, 20=Pawpaw, 21=Mangoes, 22=Oranges, 23=Watermelon, 24= Sweet potatoes,25. Butter nut, 26=others Specify

#### 4.1.0. Crop Labour input (January-December/2008)

Long rains season						Short rains season						
Activity	month	crop	Labour type family= 1 Hired= 2	Quantity		Cost (kshs)	Activity	crop	Labour type Family= 1 hired= 2	Quantity		Cost (kshs)
				Hours	Days					Hours	Days	

Activity-1= clearing, 2=ploughing, 3= planting, 4=transplanting,5= weeding, 6=spraying,7= pruning, 8=thinning, 9=Harvesting, 10=threshing,11= shelling,12= bagging, 13=others specify

#### 4.2.0. Crop input expenditure (Non-labour input)

Input	month	Crop	Type (local/ exotic)	unit	Total amount	Unit cost	Total cost(kshs)

#### Inputs

1= seeds, 2=pesticides, 3=fertilizer, 4=manure, 5=storage containers, 6=seedlings, 7=cuttings, 18=nes, 19=others (specify)

**Crop type:**

1- Maize, 2-Sorghum, 3- F/Millet, 4=Beans, 5=Maize +Beans, 6=Maize+Green /Grams, 7=Maize+Green/ grams, 8=Cassava, 9=Groundnuts, 10= Cotton, 11=Kales, 12=Tomato, 13=Onions, 15=Cowpeas 16 = Green/Grams, 17=Sugarcane, 18=Pawpaw, 19=Mangoes, 20=Oranges, 21=Watermelon, 22= Sweet potatoes,23=others Specify

**5.0. Livestock enterprises information (2008)**

Livestock Type	Breed	Number	Live Weight (Kgs)	Yield Type Milk, Eggs, Meat, Cash, Others(Specify) <b>Jan-December/2008</b>	Units Litres, Nos., Kgs, Kshs

Livestock enterprises- 1=cattle, 2=goats, 3=sheep, 4=chicken,5= ducks,6= gees, 7=rabbits, 8=pigs, 9=donkeys, 10=others specify

**Breeds:**

1=Friesian, 2=Aryshire, 3 = Jersey, 4=Guernsey, 5=Crossbreed, 6= Local, 7=Sahiwal, 8=Toggenberg, 9=Germany Alpine, 10=Chinchilla, 11=California White, 13=others specify

### 5.1.0. Livestock Labour input

January-December						
Activity	month	Livestock type	Labour type family= 1 Hired= 2	Quantity		Cost (kshs)
				Hours	Days	

#### Livestock activity

1=herding, 2= feeding, 3= watering, 4=spraying, 5= dipping, 6=maintaining the house or shed,  
7= others specify

#### Livestock type-

1=cattle, 2=sheep, 3=goats,4= pigs, 5=donkeys, 6=local chicken,7= poultry-layers, 8=poultry-  
broilers, 9=ducks, 10= others specify

### 5.2.0. Livestock input expenditure

Livestock Input			Livestock Input in specified units											
Input type	Lives tock type	unit	J a n	Feb.	mar	Apr.	May	June	July.	Aug.	Sept.	Oct.	Nov.	Dec
drugs	cattle	lts												
	price	Kshs												

#### Input type

1=feeds, 2=drugs, 3=treatment, 4=watering, 5=input transportation cost, 6= others specify

### 6.0. Household expenditure:

#### 6.1. Household Food consumption (Total)

Food type	unit	Quantity consumed in specified units												
		Jan	Feb.	mar	Apr.	May	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	

#### Food types

1=maize, 2=sorghum,3= F/Millet,4= cassava,5= rice ,6= sweet potatoes, 7=arrow roots,8= bean, 9=green grams, 10= bananas, 11=mangoes, 12=oranges, 13=pawpaw, 14=avocadoes, 15=meat,

16=fish, 17=chicken, 19=eggs, 20=milk, 21=sugar, 22=bread, 23= tomatoes, 24=onions, 25=cabbages, 26=kales, 27=Irish potatoes, 28=others specify

### 6.2. Household Food consumption (Purchases only)

Food type	unit	Quantity purchAsed in specified units											
		Jan	Feb	mar	Apr.	May	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
food													
price													
food													
price													/
food													
price													
food													
price													

#### Food types:

1=maize, 2=sorghum,3= F/Millet,4= cassava,5= rice ,6= sweet potatoes, 7=arrow roots,8= bean, 9=green grams, 10= bananas, 11=mangoes, 12=oranges, 13=pawpaw, 14=avocadoes, 15=meat, 16=fish, 17=chicken, 18=eggs, 19=milk, 20=sugar, 21=bread, 22= tomatoes, 23=onions, 24=cabbages, 25=kales, 26=Irish potatoes, 27=others specify



16=Onions, 17=Cowpeas 18=, Green/Grams, 19=Sugarcane, 20=Pawpaw, 21=Mangoes,  
22=Oranges, 23=Watermelon, 24= others Specify

## 7.2. Livestock output information

### 7.2.1. Livestock output information (Sales (Kshs))

enterprise type			unit	Quantity sold in specified units												
				Jan	Feb	mar	Apr.	May	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	
livestock	type	produce														/
price																
livestock																
price																
livestock																
price																

**Livestock outputs-** 1=milk, 2=eggs, 3=meat, 4=hides and skins, 5=manure, 6=live animal sold

## 8.0. Non-farm household sources of income/capital

Source	Amount(kshs)	No. of days/year	No of months/year
	Day, Month, Year		
Remittance			
Rent			
Sale of cHArcoal			
Sale of HAnd cratfs			
Sale of firewood			
Sale of fish			
Hire out oxen/Donkey cart			
Credit/loan			
Gifts			
Sale of land			
Sale of capital asset			
Others specify			

## 9.0. Extension Services and enterprise diversity

### 9.0. Extension service

a. Did you have an extension contact last year? Yes [ ] No [ ]

b. If yes, what is the frequency?

Once a week [ ] twice a month [ ] once a month [ ] once in three months [ ] others specify [ ]

c. Did you receive extension service as: group [ ] individual [ ]

### 10.0. Agrobiodiversity

Are you growing more or less or same crops and crop varieties today (2008) as compared to 2005?

Crops: More [ ] same [ ] less [ ]

Crop varieties: More [ ] same [ ] less [ ]

Are keeping more or less or same livestock and livestock breeds today (2008) as compared to 2005?

Livestock: More [ ] same [ ] less [ ]

Livestock: More [ ] same [ ] less [ ]

Is your food security situation better, worse, same today (2008) as compared to 2005?

Food security: More [ ] same [ ] less [ ]

Is your farm income higher, same, less, today (2008) as compared to 2005?

Farm income: Higher [ ] same [ ] less [ ]

### **Crop and Livestock Estimates**

Strip crop area to be estimated by length and width

Local banana stools (isolated) area to be estimated by number of stool and average cross-sectional area of stool.

Local mangoes area (isolated) to be estimated by number and average cross-sectional area of canopy cover

Mature East African Zebu average live weight- 300kgs (TLU=250kg, A Bull is equivalent to 1.29 TLU, Cow 1 TLU, Calf 0.7 TLU)

Mature Goat, Sheep average live weight = 27 Kgs (Sheep and Goat= 0.11TLU )

Mature scavenger Pig average live weight = 60 Kgs (Piglet-25%, middle age -50%)

Mature Donkey average live weight = 0.7 TLU (young-25%, middle aged-50%)

Mature Chicken, Duck average live weight = 1.5kgs

## Appendix 2: World Health Organization Nutritional Requirements

Category	Age	Energy	Energy	Protein Grams
		Kilojoules	Kilocalories	
Children	<b>1</b>	<b>3230</b>	<b>820</b>	<b>13.5</b>
	1 -2	4800	1150	13.5
	2 -3	5700	1350	15.5
	3 -5	6500	1550	17.5
Boys	<b>5 -7</b>	<b>7700</b>	<b>1850</b>	<b>21</b>
	7 -10	8800	2100	27
	10 -11	9200	2200	34
	12 -14	10000	2400	43
	14 -16	11100	2650	52
	16 -18	11900	2850	56
Girls	<b>5 -7</b>	<b>7300</b>	<b>1750</b>	<b>21</b>
	7 -10	7500	1800	27
	10 -11	8200	1950	36
	12 -14	8800	2100	44
	14-16	9000	2150	46
	16-18	9000	2150	42
Adult males	<b>18-30</b>	<b>14800</b>	<b>3550</b>	<b>49</b>
	30-60	10500	3400	49
	>60	12000	2850	49
Adult females	<b>18-30</b>	<b>9800</b>	<b>2350</b>	<b>41</b>
	30-60	10100	2400	41
	>60	9000	2150	41

### Appendix 3: Nutritional Values of Food Commodities

Commodity	Energy KJ/Kg	Kilocalories /Kg	Protein g/Kg
Avocado	6860	1640	20
Bananas	3260	760	9
Beans	11510	2710	222
Beef	11070	2660	240
Bread(brown)	9480	2230	
Bread(white)	9910	2800	109
Cabbage	660	150	
Cassava Dried	14140	3288	15
Cassava Fresh	14560	3386	9
Chicken	9540	2300	308
Coconut	24920	6040	19
Cooking oil	36960	8990	0
Cowpease	14430	2658	222
Eggs(shelled 50g/egg)	6120	147	110
Fish	8340	1990	220
Green Grams	14430	3356	222
Groundnuts	23640	5700	256
Kales	1130	263	25
Maize	14930	3500	95
mangoes		540	4
Mangoes (6fruits local)	1670	388	4
Milk	2720	660	250
Millet	14210	3305	97
Onion	990	230	0
Oranges(200g/fruit)	1500	350	11
Pawpaw		800	12

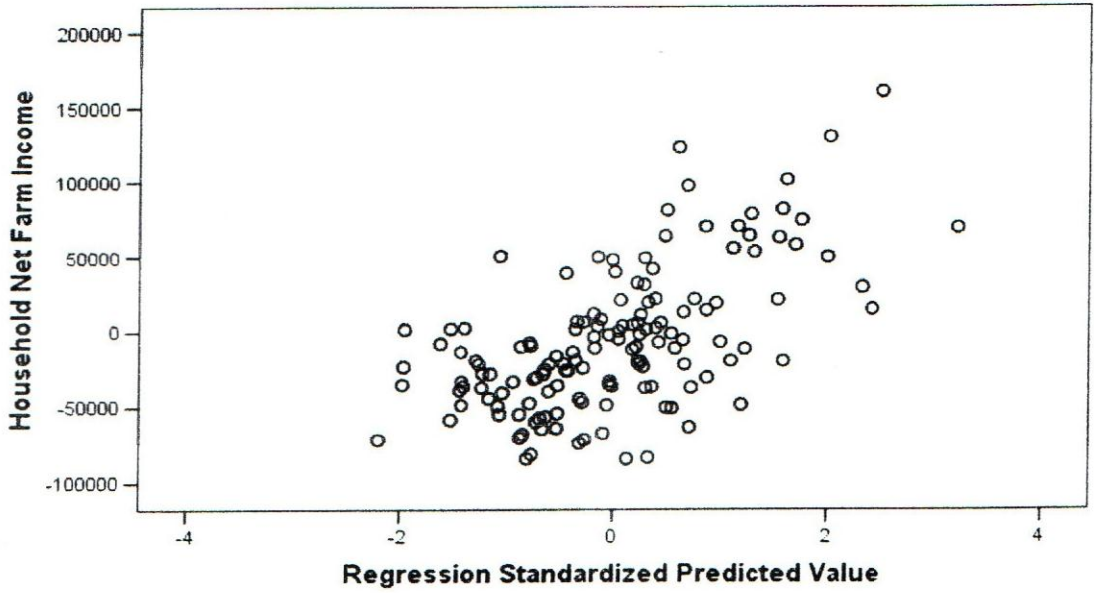
Potatoes	3390	790	17
pumpkin	600	100	10
Refined Sugar	16800	3940	0
Rice	15360	3610	27
Sorghum	14430	2658	101
Tomatoes(16fruits)	600	140	11
Wheat flour		3390	140

Source: Jaswant, 1993

Appendix 4: Scatter Plot for Income Regression Model

Scatterplot

Dependent Variable: Household Net Farm Income



BERGTON UNIVERSITY LIBRARY

**Appendix 5: Gross Margins for Main Enterprises (Gm/Unit/Year)**

<b>CROP</b>	<b>Unit</b>	<b>Gross Output</b>	<b>Labour (MD)</b>	<b>Working Capital</b>	<b>Gross Margin</b>
1. Maize	HA	24000	103	25437	3472
2. Maize + Beans	HA	24000	92	26087	4988
3. Sorghum	HA	18000	76	8496	8824
4. Beans	HA	30000	65	15,550	24800
5. Finger millet	HA	16000	86	8910	6377
4. Cassava	HA	75000	105	18475	20155
6. Sweet Potatoes	HA	40000	105	18475	20155
7. Groundnuts	HA	48000	120	15850	25882
8. Simsim	HA	18000	100	11520	5558
10. Kales	HA	180000		72570	78375
11. Tomatoes	HA	275000	430	107350	159060
12. Onions	HA	22500	262	53950	
13. Mangoes	HA	81927	200	40162	120,878
14. Bananas	HA	235519	223	36355	152169
15. Indigenous poultry	0.026 TLU	7650		850	6800
16. Indigenous cattle	3.99 TLU	5,900		6200	19700

**Source: G.O.K, 2009a**