ADOPTION OF INNOVATIONS AND RESOURCES OPTIMIZATION IN CROP-LIVESTOCK INTEGRATED PRODUCTION SYSTEM AMONG SMALL-SCALE COTTON FARMERS IN SOUTHERN MALI

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A Thesis Submitted to the Board of Postgraduate School in Partial Fulfilment of the Requirements of the Award of Master of Science Degree in Agricultural Economics of Egerton University

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DECLARATION AND RECOMMENDATION

Declaration

I hereby declare that this is my original work and has not been submitted in this or any other university for award of any degree.

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DEDICATION

This thesis is dedicated to my lovely wife and daughter, parents, siblings, lecturers, and colleagues.

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ABSTRACT

In Southern Mali, small-scale farmers face multiple constraints such as low soil fertility that lead to low agricultural productivity and income. Crop-Livestock Integration System (CLIS) among small-scale farmers has been promoted by extension services to tackle these challenges in order to improve farmers' livelihoods. Some small-scale farmers have embraced the integrated crop livestock production system and adopted innovations that have been promoted by extension services providers. However, little is known on the determinants of small-scale farmers' decision to uptake these innovations. In addition, the enterprise combination which gives the highest returns to small-scale farmers in crop livestock integration systems is still unknown. This study aimed to fill out that knowledge gaps. The general objective of this study was to contribute towards optimal resource use in crop livestock integration systems for improved livelihood of small-scale cotton farmers in southern Mali. Specifically, it was to determine the socioeconomic and institutional characteristics of small-scale cotton farmers in Southern Mali; to determine the socioeconomic and institutional factors influencing small-scale cotton farmers' uptake of innovation in CLIS; and to determine the enterprise combination that gives the high gross margin in CLIS. A multistage sampling procedure was used to obtain a sample size of 171 small-scale cotton farmers. Descriptive statistics, multivariate probit model, and linear programming model were used in data analysis. The key differences between small-scale cotton farmers' socioeconomic and institutional characteristics were in years in formal education, market distance, agricultural asset value, extension distance, household size, number of cattle owned, and land size. Numbers of trainings, land size, age, years in formal education, market distance, extension distance and participation in off-farm activities were the main determinants of small-scale cotton farmers' decision to adopt innovations in CLIS. Finally, small-scale cotton farmers are not efficiently used their resources. At present resource level, small-scale cotton farmers could optimally maximize their profit by 104.80%, 54.35%, 23.01%, and 19.52% increase compared to the actual total gross margin respectively. Therefore, this study recommends that there is need to reinforce the technical knowledge of lowly educated farmers through innovative agricultural training methods and techniques. Further, this study recommends that an effective advice of farmers on the efficient allocation of farm resources should be built into programs promoting increased agricultural productivity and income.

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ABBREVIATIONS AND ACRONYMS

CAADP - Comprehensive Africa Agriculture Development Programme

CIRAD - *Centre International de Recherche et d'Agriculture pour le Développement*

CLIS - Crop - Livestock Integration Systems

CMDT - *Compagnie Malienne de Développement des Textiles*

CPC - *Coopérative des Producteurs de Coton*

CPS - *Cellule de la Planification et de la Statistique*

CR - Contour Ridging

DfID - Department for International Development

FAO - Food and Agriculture Organization

FC - Fodder Crops

FCFA - *Franc de la Communauté Financière Africaine*

GDP - Gross Domestic Product

GM - Gross Margin

ICT - Information and Communication Technology

IDD - *Institut pour un Développement Durable*

IER - *Institut d'Economie Rurale*

INSTAT- *Institut National des Statistiques*

LA - Lime Application

LOA - *Loi d'Orientation Agricole*

LP - Linear Programming

MC - Marginal Cost

MCT - Manual Cotton Topping

MR - Marginal Revenue

MVN - Multivariate Normal

MVP - Multivariate Probit Model

NGO - Non Governmental Organization

PASE - *Projet d'Appui aux Systèmes d'Exploitations Agricoles*

PDA - *Politique de Développement Agricole*

RGA - *Recensement Général Agricole*

SPSS - Statistical Package for Social Scientists

SRI - System of Rice Intensification

SSA - Sub- Saharan Africa

TC - Total Cost

TLU - Tropical Livestock Unit

TR - Total Revenue

VIF - Variance Inflation Factor

CHAPTER ONE
INTRODUCTION

1.1.Background information

Rural economy in Mali is based on agriculture sector, which accounted for 35% of Gross Domestic Product (GDP) in 2008 (Staatz *et al.*, 2011). This makes the agriculture sector, the engine of economic growth because of its dominance role in the economy (Beke, 2012). Despite of its dominant role, the agricultural sector in southern Mali and other agricultural zones remains dependent on natural conditions and faces the challenge of low productivity (Droy *et al.*, 2012).

Therefore, an increase in agricultural productivity becomes a necessity in order to move from the traditional agricultural production to one based on science and technology. Agriculture based on science involves the use of modern inputs such as improved seed, fertilizers, and other improved agronomic practices. Franzluebbers, (2007) indicates that crop livestock integration system (CLIS) is one of these practices, which have been the common approach to agriculture production all over the world before modern industrialization in the 20th century. It involves a diverse range of integrated ecological, biophysical, and socio economic conditions. Compared to the mono cropping farming system, CLIS reduces farm households' dependency on chemical fertilizers in the face of changing of climate, economic and social conditions (FAO, 2009a).

In recent years, practical innovations have created synergies between crops, livestock and agro-forestry production sectors in order to ensure economic and sustainability by providing ecosystem services (FAO, 2009b). According to the International Fund for Agriculture Development (2010), CLIS reduces soil erosion, strengthen environmental sustainability, increases crop yields and improves profits, thus helping in reduction of poverty and malnutrition. Regarding the economic and production sides, CLIS increases farm households' livelihoods diversification through resource optimization and economic stresses reduction.

Food and Agriculture Organization (2010) opines that CLIS raises social, economic, and environment sustainability and improves farm households' livelihoods when efficiently managed. Thornton *et al.* (2001) argue that, over 50% of meat and 90% of milk in the world are provided by mixed crop-livestock system and is the most common form of livestock operation in developing countries. Furthermore, it is projected that CLIS is going to increase in Sub-Saharan African countries over the next thirty years as human population increases the demand of livestock products mainly meat and milk. According to Hosu and Mushunje (2013), this will give an opportunity for small-scale farmers to benefit from the growing market and raise their income thus contributing reduced poverty. In CLIS, the waste products of livestock serve as a resource for crop and vice-versa. Manure can be used to enhance crop production, while crop residues are used to feed animals and contribute to improve animal nutrition and productivity (Russelle *et al.*, 2007).

However, utilization of resources among small-scale farmers is viewed as single entity either in crop, water, or soil nutrient forms. Therefore, limited resource use in the farming system requires change in management practices in order to optimally allocate resources among small-scale farmers' enterprises or activities facing to multiple constraints. An efficient management of natural resources is a best way of increasing productivity and farmers' incomes by combining crop and livestock enterprises.

In Mali, CLIS is an integral component in rural livelihood and in particular the southern Mali area, where cotton crop has a significant impact on socio economic development through many agricultural support programs (Droy *et al.*, 2012). CLIS has been combined in various ways over time by agro-pastoral "farmer-herders" or "herder-farmers" rather than the exclusive concerns of specialised farmers or herders (Scoones *et al.*, 2000). Indeed, towards the year 1970 agricultural development policies have promoted in Mali , a production system based on crop livestock integration by leaning on chemical fertilizers, veterinary products, animal traction, and crop fodders (Dugué *et al.*, 2004). CLIS is expected to improve small-scale farmers' agricultural productivity and instead of increasing crop yields only, it has expanded the arable lands per capita through animal draught power.

The Malian Agricultural Development Policy aims to promote a modern, competitive, and sustainable agriculture through innovative agricultural techniques based on participative research (LOA, 2006). Agricultural innovations and crop-livestock integration system are in line with the Malian Agricultural Orientation Law "*Loi d'Orientation Agricole* – LOA" objectives of ensuring sustainable agriculture and innovation in CLIS is seen as one of the strategies to improve agricultural productivity and reduce poverty among small-scale farmers.

In the 1980s, the Institute of Rural Economic (IER) and a public Malian cotton company of textile development (CMDT) developed several improved technologies about seed and animal breeding. In addition, the national policy of integrated management of soil fertility (2002) emphasized the use of local resources such as manure, compost, and natural phosphate to improve soil fertility. Vall *et al.* (2012), argued that CLIS has been promoted in southern Mali as in many West African countries which has led to a massive adoption of animal traction. Furthermore, Blanchard (2010) found out that the revenue from cotton is used to buy animals, where some small-scale farmers have constituted their own herd for multiple purposes (land ploughing, milk, meat, savings, manure, prestige).

According to Bainville *et al.* (2007), crop livestock integration development in southern Mali is not only about the agricultural development policies but also innovation by farmers. Certain forms of CLIS practices were already known and practised in southern Mali through transhumance breeding which helps farmers to pen animals on their arable lands for the next rainfall season. Blanchard *et al.* (2013), state that the CLIS management must change in order to adapt and guarantee small-scale farmers' viability in the face of changing climate, economic, and institutional conditions.

1.2.Statement of the problem

Cotton growing areas in southern Mali are facing challenges of low agricultural productivity as results of low soil fertility. Therefore, crop-livestock integration system is seen as an opportunity to tackle these challenges by improving soil fertility, increase agricultural productivity and contribute to increased small-scale cotton farmers' incomes and efficient use of local inputs. Crop-livestock integration system is being promoted by extension providers. Some farmers have embraced the integrated crop livestock production system and the innovations in this crop-livestock integration system include: manual cotton topping, fodder crops, lime application, contour ridging. However, little is known on the role of socioeconomic and institutional factors in determining the uptake of these innovations. Further, the enterprise combination, which gives high returns to small-scale farmers in crop-livestock integration system, is still unknown. It is on the forgoing that this study is pitched to fill this knowledge gaps using a sample of farmers in southern Mali.

1.3. Objectives

1.3.1. General objective

The general objective of this study was to contribute towards enhanced farm resource efficiency in crop livestock integration systems for improved livelihood of small-scale cotton farmers in Southern Mali.

1.3.2. Specific objectives

(i) To determine the socio economic and institutional characteristics of small-scale cotton farmers in Southern Mali.

(ii) To determine the socioeconomic and institutional factors which influence small-scale cotton farmers' uptake of innovation in crop-livestock integrated production systems in Southern Mali.

(iii) To determine the enterprise combination that gives the high gross margin in crop livestock integrated production systems in Southern Mali.

1.4. Research questions

(i) What are the socio economic and institutional characteristics of small-scale cotton farmers in Southern Mali?

(ii) What are the socioeconomic and institutional factors influencing small-scale cotton farmers' uptake of innovation in crop livestock integrated production system in Southern Mali?

(iii) What enterprise combination gives the high gross margin in crop livestock integrated production system in Southern Mali?

1.5. Justification of the study

In Southern Mali, a recent study has noted that cotton production system has shown its limits in terms of governance and cotton and cereal yields stagnation (Droy *et al.,* 2012). In addition, Blanchard (2010) attributes the stagnating cotton and cereals yields to soil fertility depletion, non-availability of high potential land and increasing human population in rural areas. These facts combined with climate change, agricultural products price instability, increasing livestock and natural resources degradation have made it worse in small-scale farmers' production systems (Soumaré *et al.*, 2006; Coulibaly *et al.,* 2009; Ickowicz *et al.,* 2012). This generates competition for resources and faces the agricultural production system with multiple constraints that necessitate change in the interactions between different productive and limited resources. Therefore, optimal use of resources is the best way of allocating limited resources among small-scale farmers' activities (Hosu and Mushunje, 2013).

CLIS is in line with the objectives of Malian Agricultural Development Policy *"Politique de Developpement Agricole – PDA"* which aims to promote a modern, competitive, and sustainable agriculture based among small-scale farmers. CLIS is also in line with the

Comprehensive Africa Agricultural Development Programme (CAADP) objectives of encouraging sustainable agriculture and CLIS is one of the strategies to improve crop and livestock productivity and livelihood among small-scale farmers.

Inspite of the policy measures undertaken by the government and its partners, small-scale farmers in cotton area are among the poorest in the country (Balié, 2012). Currently, a project called PASE2 (Project of improving the productivity and sustainability of production systems in southern Mali) is being implemented to improve small-scale farmers' livelihood through participatory research. The innovations that are being promoted include; Manual Cotton Topping (MCT), Fodder Crops (FC), Lime Application (LA), and Contour Ridging (CR). Therefore, the study has provided empirical evidence in enhancing the uptake of innovations in CLIS among small-scale farmers in southern Mali. Findings from this study has contributed to help the policymaking process towards optimal use of resources and intensification of sustainable agriculture approaches in solving farmers' challenges leading to improved livelihood among small-scale farmers.

1.6. Scope and limitations of the study

This study was carried out in four intervention villages of the project "PASE2" particular in Ziguéna, Beguéné, Nafégué and Kokélé in order to determine the adoption of innovations and the most profitable enterprise combination in CLIS. The study was limited to cotton growing region of Sikasso. The study focused on production constraints of CLIS with respect to the gross margin. This study relied on farmers' recall as most of them do not keep records. However, thorough probing was done to assure the reliability of the data collected.

1.7. Operational Definition of Terms

Innovation: this refers to a new improved process or organizational method in practices. Rogers (1995) defines an innovation as an idea, practice, or object that is perceived new by an individual or other unit of adoption. In this study, these include Manual Cotton Topping (MCT), Fodder Crops (FC), Lime Application (LA), and Contour Ridging (CR).

Small-scale cotton farmers: refers to farmers with limited resource endowment and are those farmers owning small-based plots of land (1.5 ha for man and 0.5 ha for woman in RGA 2004). Also, their production system is based on cotton growing and their work forces for crops and livestock are exclusively relying on family labour.

Household: according to the Malian law of agricultural orientation (2006) *"Loi d'Orientation Agricole" (LOA)*, an household is formed by one or more members united by kinship or customs and jointly use production factors insight of generating resources under the direction of one of the members designate head of household whether male or female and he/she represent the household in all acts of civil life.

Resource optimization: involves designing a system or process, which favours an economic and efficient management of available resources. In other word it is the set of processes and methods to match the available resources. In this study, a farmer will optimize her/his available resources by allocating them to the activities or enterprises, which gives the most satisfactory profit (optimal profit) among all the possible alternative profit solutions.

Livelihood: this comprises the capabilities, material, social resources and activities required for small-scale farmers to develop and implement strategies to ensure their survival.

CHAPTER TWO

LITERATURE REVIEW

2.1. Cotton Growing in Mali

From the Figure 1, cotton production basin cover Koutiala North-east of Sikasso and it has progressively been expanded to the western part of the country. It covers all region of Sikasso, parts of Ségou and Koulikoro regions and more recently Kita in western part (Staatz *et al.*, 2011). This expansion of cotton area has led to a variety of agrarian changes between old and new cotton growing areas (Pegaz, 2006). Cotton growing is mainly controlled by the Malian Company of Textile Development (CMDT) created in 1974 and it is in charge of about 95% of cotton production. In 2010, the government initiated the process of privatizing CMDT by creating four cotton companies that would operate as monopsonies within designated geographic zones.

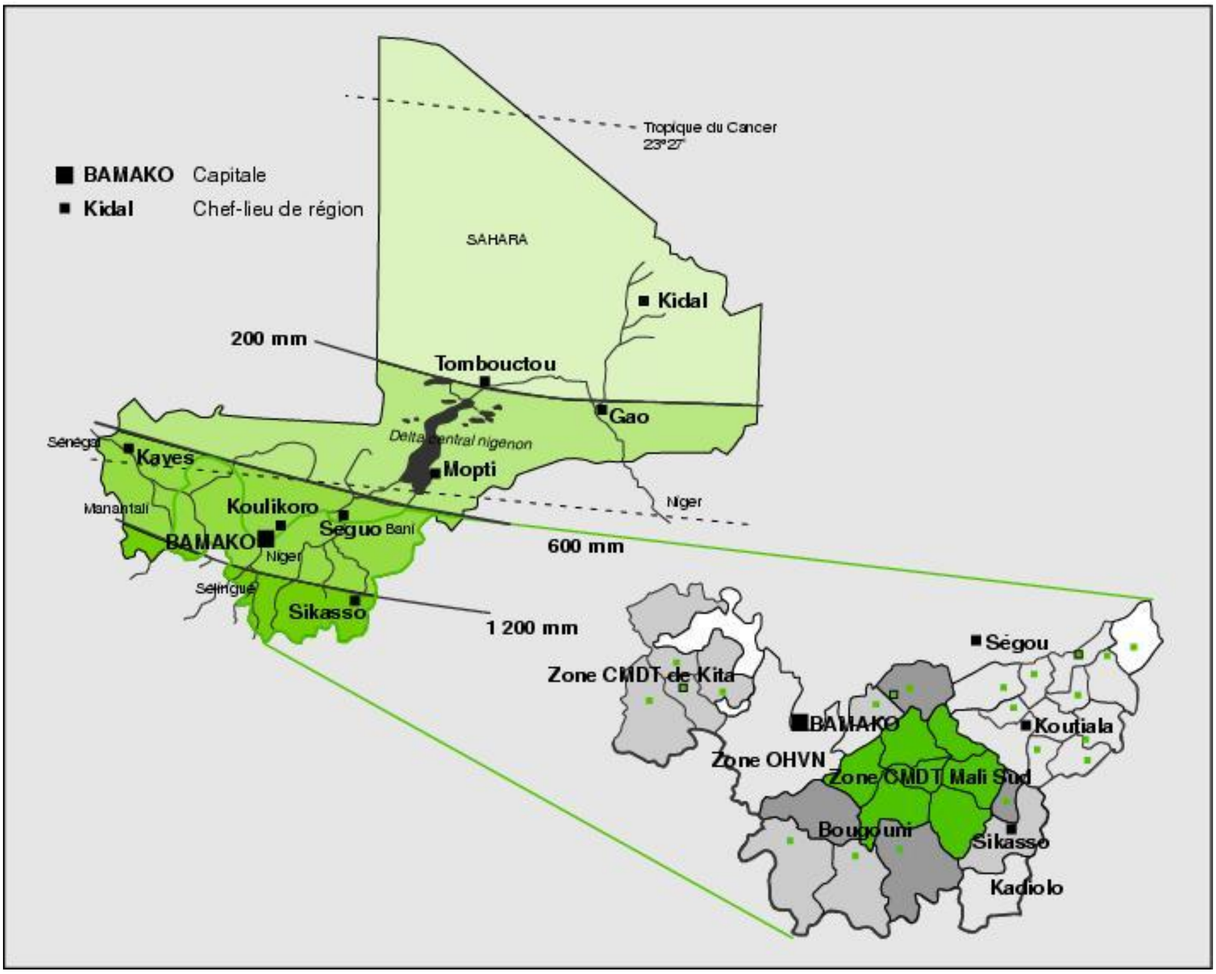

Figure 1: Cotton growing zones location in Mali

source: Djouara *et al.* (2006).

Cotton growing is also associated with other cereals crops such as maize, millet, and sorghum. Livestock system is dominated by extensive cattle breeding and sheep, goats, and poultry are fringing in this system (Blanchard, 2010). The national institute of research and the CMDT have classified family farms into four categories (A, B, C and D) in terms of level in agricultural equipment (plough and cart) and number of oxen. Class A family farms are those, which are well equipped with more than two pairs of oxen and a set of ploughing and weeding tools. Class B family farms are partially equipped with at least one pair of oxen and a plough. Class C family farms are those called under equipped with either oxen without plough, or plough without oxen and class D family farms are those without experiences with animal traction (Scoones *et al.*, 2000). This classification of the CMDT is based on agricultural equipment and number of oxen owned by the family farm.

The project of improving the productivity and sustainability of production systems in southern Mali (PASE2) is ongoing implementation to improve small-scale farmers' livelihood through participatory research. Its component Research/Development is based on five research thematic: (i) characterization and monitoring of agrarian dynamics of cotton growing zone, (ii) natural resources management, (iii) economics of small-scale farmers and innovations, (iv) water and soil fertility management and (v) cotton plant integrated protection. The population in this area is essentially rural and its economy largely depends on agricultural sector. The rural population of cotton growing zones represents 40% of the total population of Mali and the demographic growth is about 2% in average (Devèze, 2005). Therefore, the case of Sikasso region can be used for pointing up the population growth in cotton areas. The population in this region was 2 million in 2009, which has multiplied by 1.5 since the population census of 1998 (Keita, 2015).

The increasing human and livestock population has created heavy pressure on arable lands and pasture spaces, which has led to degradation of natural resources and affected small-scale farmers' production systems (Dufumier, 2005). In addition, the increased in cotton production has also raised the cultivated lands in cotton and shortens the fallow time. All these combined with the climate change and cotton price fluctuations in international market threaten the sustainability of small-scale farmers' production systems.

2.2. Cotton and Agriculture Development in Mali

Mali is one of the few countries in Africa which has invested more than 10% of its public expenditures in agriculture sector (Camara, 2015). In southern Mali, rural development policies have centred on cotton production but this study does not focus on cotton farming. But cotton in the study area is an entire entity which benefits to the whole production systems including cereals and livestock. This production system based on cotton has permitted a significant socioeconomic development in southern Mali through facilitating agricultural credit, increasing rural literacy rate, health facilities, construction of roads and rural infrastructures and organizing farmers in cooperative (Bosc *et al.*, 2015). Therefore, small-scale cotton farmers increase their land size under cotton to benefit from the inputs facilities for both cotton and cereals and hence enhance their revenues (Serra, 2012). Since 1960, cotton production has been a key driver of agricultural development and the government has focused its efforts in terms of investments.

The introduction of cotton in this area has contributed to deeper transformations in agricultural practices. It has provided a level of income that permitted farmers to purchase animal traction equipment, fertilizers, and pesticides for cotton as well as for cereal crops production such as maize, millet, and sorghum. Promotion of cotton growing led to an increase in cotton production from 100 000 tons in 1980 to 500 000 tons in 1995. In 2003, Mali became the leading producer in Sub Saharan Africa (SSA) with 600 000 tons (CIRAD, 2012). Figure 2 shows the trends of cotton production from 1985 to 2015 with different periods of crisis and production peak in cotton sector.

The first crisis in cotton sector was due to the devaluation in 1993 of the currency franc CFA used by many countries in West Africa. The second and third crises were respectively about the producers' strike in 2000 and the decline of cotton price in 2008. While, in 2004 and 2015 the production peak occurred due to an increasing in land under cotton. After the global price crisis in 2008, cotton production increased because of the incentive price of cotton and the subsidy of cotton fertilizers. As a main cash crop of export earner in Mali, cotton had an estimated sale figure of 260 billion of franc CFA in average and a revenue from taxation of 18 billion of franc CFA (Camara, 2015). It is the main source of income for majority of small-scale farmers in southern Mali and it is produced by more than 300,000 farmers (World Bank, 2011). The revenue receipts from cotton have permitted the Malian Company of Textile Development to construct roads, health centre, schools, and adult training in local language. Moreover, revenue from cotton has helped small-scale farmers to purchase their own livestock, diversify their source of income and improve their livelihood. Cotton crop has played an important role of rural development in Southern Mali by improving small-scale farmers' living conditions and supplying of foodstuffs. Some authors such as

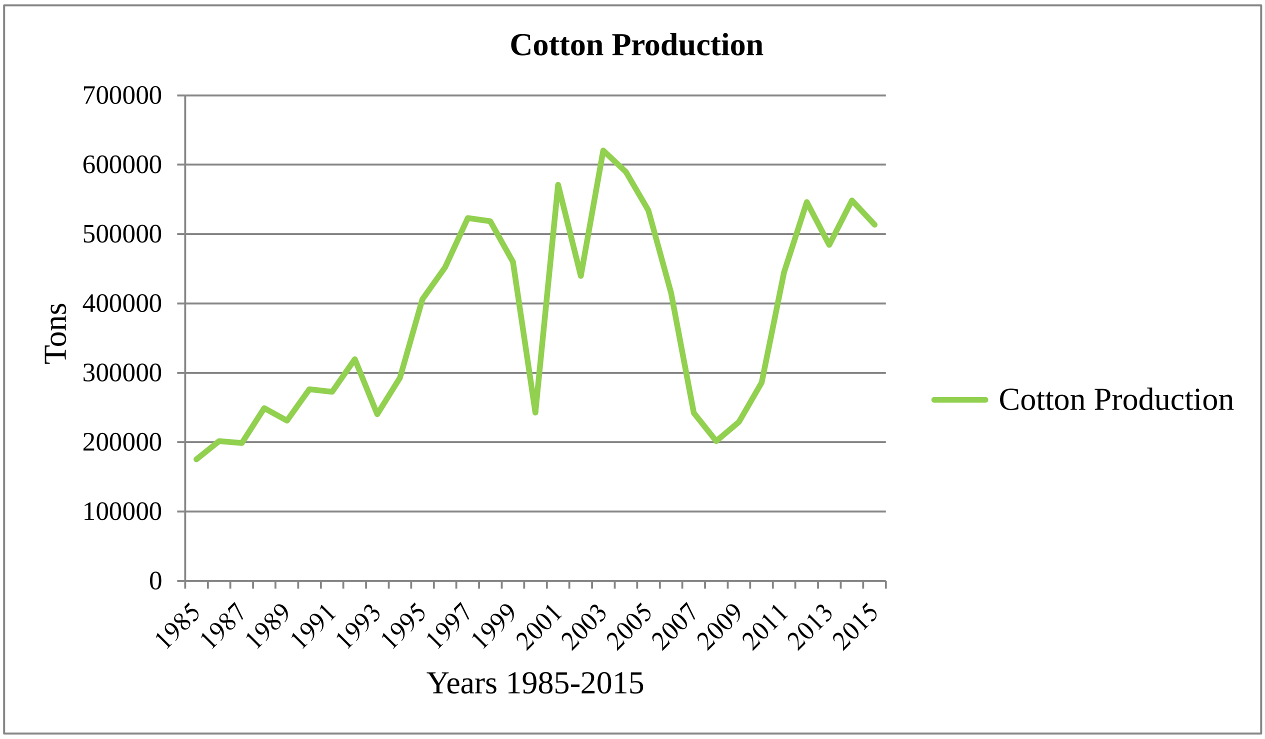

Figure 2: Trend of cotton production in Mali 1985-2015

Source: FAOStat, 2016.

Diakité *et al.* (2010) and Balié (2012) have underlined the positive effect of cotton in terms of food security. With cotton crisis due to decreasing in cotton prices in international market, the government decided in 2010 to privatize the Malian Company of Textile Development by creating four cotton companies (Staatz *et al.*, 2011). It is also forecasting to double production of cotton in five years from 440 000 tons in 2013 to 800 000 tons in 2018 through input subsidies.

2.3. Livestock Production System in Southern Mali

Livestock in Mali rural area is a structural component of the entire production system and it is kept by 80% of the rural household (RGA, 2004). It is an important source of income for rural population about 80% of the income for the pastoral system in the north of the country and 18% for agro-pastoral in the south (Alary and Dieye, 2006). According to INSTAT (2009), livestock constitutes the third export values in Mali after gold and cotton with about 41.2 billion of Fcfa. The sector is dominated by cattle in terms of number and value. Despite of its contribution to the national GDP about 8 to 9 percent, incentive policies are being missing for livestock activities.

In southern Mali, livestock has long been restricted by the presence of trypanosomiasis (Blanchard, 2010). With the development of animal traction, efforts have been made to control trypanosomiasis with fights against the vector, tsetse fly and the establishment of systematic treatment of animals in the area (Blanchard, 2010). Despite the difficulties of obtaining reliable statistics, many studies confirmed that the number of livestock in Southern Mali exceeded the main production area of Mopti region (Ramisch, 1999 and Pradère *et al.*, 2007). In 2004, a general agricultural census was conducted by the Cell of Planning and Statistics (CPS) and livestock trends in cattle, sheep, goat and donkey are presented in figure 2 for Sikasso region which is the main cotton growing area in the country.

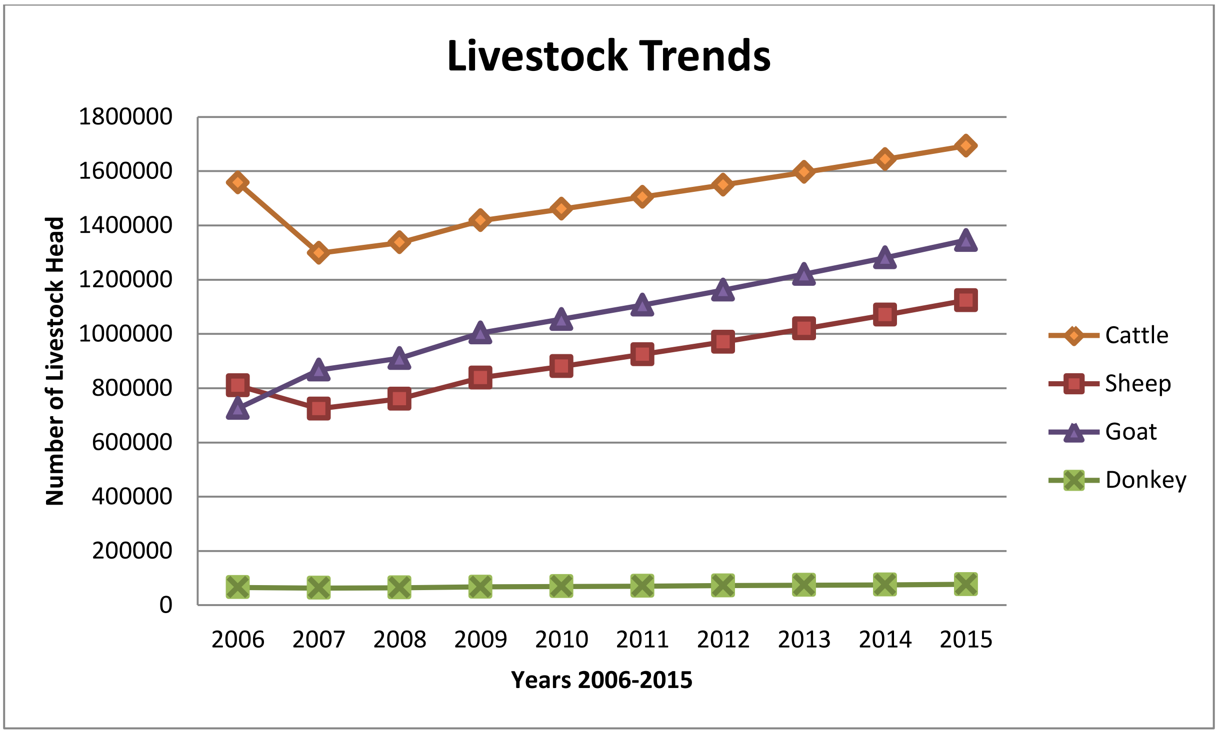

Figure 3: Trend of major livestock in Southern Mali

Source: FAOStat, 2016.

The increase in livestock numbers of cattle and small ruminants (Sheep and Goat) has been regular while the number of donkeys has stagnated from 2006 to 2015 in Sikasso region. It is instructive to mention that with the droughts of the 1970s and 1980s, the ecosystems have been further weakened in the northern part of the country leading to the move of pastoralists from the North to Southern Mali for more productive and wet pastoral area (Bertrand, 1986). In the mean time, small-scale cotton farmers have purchased draft oxen through the sale of cotton. Also, to acquire oxen some farmers placed a household child as a shepherd and in exchange he gets one or two oxen per year. Sangaré *et al.* (2006), the renewal of draft oxen varies according to farm's income. Livestock management varies by the size and structure of the farm. Small herds are led by children of the household and larger herds are led by a shepherd hired by the household.

In Southern Mali, livestock feeding mainly depends on the natural fodders and crops residues. To value crops residues, customs responsible in the villages set a date after cereals harvesting to drive animals on the ground for open grazing. Once the operation of harvesting and commercialization of cotton is complete, animals are taken to the whole village territory and beyond without restriction and sometimes without shepherds (Blanchard, 2010). During the dry season, shepherds also rely on cereals straws (maize, sorghum, and millet) stored and ligneous fodders such as *Khaya senegalensis* and *Afzelia africana* from pruning trees to feed animals (Petit, 2000). Also, the leguminous crops leaves such as groundnut and cowpea are used to feed animals. At the coming of wintering (rain season), herds are driven out from the crops areas when land preparation begins. The nutritional value and digestibility by livestock of these different crop residues are known by farmers and guide the storage practices. Supplemental feeds for animals such cotton cakes are also used by farmers to maintain the oxen and weakened cows for land preparation.

2.4. Crop Livestock Integration System in Southern Mali

Crop livestock integration has been promoted in many Sub Saharan African countries since 1960s years. It materialized with the introduction of intensive production of rice in Madagascar, cotton in Mali, and groundnut in Senegal through massive adoption of animal traction for draught animal and plough (Vall *et al.*, 2004). In West Africa, the increase in human and livestock population has led to pressure on arable lands, agricultural forest and pastoral resources, which has intensified agricultural practices and modified relationships in the crop livestock system (Vall *et al.,* 2006). In Soudano-sahelian zones, the mobility of livestock ensures the transfer of fertility from pasture areas to cultivated areas (Dugue, 1998). The use of manure in crop production establishes one of the basic elements of development models based on CLIS. In Mali, the current crop livestock research and policies have privileged cattle breeding than other livestock and cotton crop than other crops (Scoones *et al.*, 2000).

In southern Mali, the agricultural production system is based on cotton, cereals, and livestock. Cotton plays an essential role in the system and receives more manure (Zoundi *et al.*, 2006). In the past, livestock in cotton growing zones was limited to small ruminants such as sheep, goat and poultry (Dufumier, 2005). Blanchard (2010) argues that Southern Mali livestock development is confronted with the challenge of animal diseases such as trypanosomiasis. In addition to promotion of animal traction, some efforts have been made by veterinary services to fight bovine trypanosomiasis, which has led to increase livestock population.

Scoones *et al.* (2000) in their study in southern and central Mali, argue that integrated of crop and livestock production system interacts in different ways according to the agro-ecological areas. Livestock provides animal draught power to plough and weed crop land and crop residues are left in the field and grazed by animals or in some cases they are stored as fodders for dry season. Moreover, livestock provide manure to be applied back in the crop land. In southern and central Mali, livestock represents an important investment and store of wealth for small-scale farmers and procurement pair of oxen is seen as the highest priority livestock investment and ownership of cattle is considered like a sign of wealth. According to the FAO (2009a) crop livestock integrated production system improved small-scale farmers' agricultural productivity by 50% in Ethiopia and income by more than 100% in Zimbabwe. The integration of crop and livestock systems might have several benefits at farm and national levels. At farm level, the benefit includes increasing crop yields, improving farmer's income, and increasing soil fertility and organic matter. At national level, it improves food security, livelihoods, and well being of the population.

Crop-Livestock Integration System (CLIS) has a dual purpose since waste products from one (crop or livestock) serve as resource or input for the other (Rota, 2010). CLIS is a synchronized crop and livestock farming. Also, this relationship could be either competitive or complementary depending on the level of resources use such as land, labour and capital (Ngambeki, 1988). In the context of arable land saturation (acidic soils, lack of fallow land, and reduced areas for pasture) in Southern Mali, CLIS appears as an advantage of improving small-scale farmers production systems. It improves soil fertility using manure under crops land and hence increases crop yields and relatively enhances fodder production in an extensive livestock production system (Bosma *et al*., 1996).

Despite of its advantages, CLIS management in Southern Mali has lead to some disadvantages such as pressure on arable land, lack of livestock feeds, and natural resources degradation. Other important disadvantages include lack of fallow land and insufficient organic matter to maintain soil fertility because of transhumance practices by large herd farmer owners (Coulibaly *et al.*, 2009). Further, Van Keulen and Schiere (2004) highlighted disadvantages of crop-livestock mixed farming including less economies of scale, risk of disease and crop damage, causes erosion due to soil compaction and overgrazing, nutrient losses through intensive recycling, continuous labour requirement, increased rate of land use, requires capital and investment, and cause of conflict. Scoones *et al.* (2000) opines that adoption of technologies by small-scale farmers is limited by available human and animal resources to invest in changing their farming practices. However, crop and livestock are well integrated in southern Mali through manure and compost use on crop land, and fodder and crop residues for feeding animals during dry season. The promotion of this integrated farming system of crop and livestock has increased livestock population. This increase in livestock population combined with the one of human is likely to lead to more tension on land use between crop activities and pasture use (Ickowicz *et al.,* 2012).

In this area, Malian Ministry of Agriculture and its partners are implementing development project such as PASE2 through which some innovations are being promoting. The innovations are aimed at increasing significantly small-scale cotton farmers' productivity and livelihood through the implementation of project PASE2 (Project of Improving the Productivity and Sustainability of Production System in Southern Mali). The promotion of CLIS in this region comes with innovation that includes: Manual Cotton Topping (MCT), Fodder Crops (FC), Lime Application (LA), and Contour Ridging (CR). These innovations were identified through participatory research. The Manual cotton topping, showed in figure 4, is carried out manually by pinching the main stem of a cotton plant between the third and fourth leaves from the top and selecting it by pressure and torsion. It has to be carried out ten

Plate 1: Manual Cotton Topping Innovation

Source: IER, 2016.

days after the appearance of the first flower but earlier it will result in a loss of productivity and later it reduces the expected phytosanitary benefits. This innovation is practised to improve cotton yield and reduce pest incidence such as bollworm infestations, which are responsible for the majority of cotton yield losses (Renou *et al.*, 2011). It is also an ecological intensification practice in the cotton crop as it reduces the use of insecticides and cotton production cost.

In Figure 5, the second innovation is fodder crop such as *Mucuna Pruriens* and it is an important cover crop in many parts of the world. It benefits both livestock and crops by providing animal feeds to improve the quality and quantity of milk and prevent the build up of weeds under crops. This innovation is used for biomass production to feed cows and small

Plate 2: Fodder Crops Innovation

Source : IER, 2016.

ruminants (Coulibaly *et al.*, 2012). In the study area, it is used by intercropping it with maize and increases the biomass production to about 22% compared to pure maize cropping and contributes to improved soil fertility by the symbiotic fixation of nitrogen from the air. It also contributes to improved soil fertility by the symbiotic fixation of nitrogen from the air. The third and fourth innovations are shown in Figures 6 and 7. The former one is lime application, which is applying in a soil to reduce the acidity. It has a positive incidence on crops yields and then contributes to improved small-scale farmers' agricultural productivity. The later one is contour ridging, which is an effective way of using water, draining excess water, and

Plate 3: Lime Application Innovation

Source: IER, 2016.

limiting soil degradation (Gigou *et al.*, 1997). It can contribute to reduced soil erosion to about 20-50 percent, increase the use of fertilizer, manure, and increase crop yields to about 30% (IER, 2012).

Plate 4: Contour Ridging Innovation

Source: IER, 2016.

2.5. Factors Influencing Uptake of Innovation

Several studies have defined innovation in different ways. Innovation is defined depending on the field of thought to different concepts such as ideas, practices, products, services, processes, technologies, and so on that the adopting unit perceives as new (Monge *et al.*, 2008). Thus, there is a large literature on the adoption of agricultural innovation and Rogers (1995) defines an innovation as an idea, practice, or object that is perceived new by an individual or other unit of adoption. In this study, Rogers' definition of innovation is used. Several factors influencing farmers' uptake of innovation have been identified by researchers. These factors can be socioeconomic and institutional and are important in farmers' uptake decisions depending on the innovation itself or the area of study.

Gender variable is an important attribute for policy implications when implementing innovations. Doss *et al.* (2001) argue that gender difference has an influence on agricultural technology adoption when living in female headed households or male headed households. They found that the adoption rate of modern variety of maize for female farmers living in male headed households is significantly higher than the rate for female farmers living in female headed households. Buabeng-Andoh (2012) also confirm this gender difference by saying that males' scores were higher than females' scores by using ICT in their teaching and learning processes.

Sezgin *et al.* (2011) states that farmer age and education level positively influence the decision to adopt an innovation. These variables were found to be statistically significant regarding the uptake of artificial insemination. Farmers with high education level and younger farmers had a tendency to uptake an AI innovation. Further, Murage *et al.* (2013) argue that elderly farmers and farmers with some level of education are likely to have the ability for early uptake of innovation. Kersting and Wollni (2012) argue that highly educated farmers find it easy in understanding and implementing food standards. Higher education achievement is also empowers farmers in management of new technologies, including their risks and benefits that accompany the technology (Tey *et al*., 2014).

Farm labour force is based on family population and the size of active members, thus family size is an important component of the labour supply for small-scale farmers (Nmadu *et al.*, 2015). Therefore, large family size will lead to pressure on land and the effect is large family size may not readily take up an innovation that requires large scale farming. While large farm size farmers are more likely to adopt an innovation compare with those with small farm size farmers since they can afford to allocate part of their land to try out the improved technology. Also farmer with freehold land tenure is more likely to adopt agricultural innovation compare to those with leasehold land tenure (Langat *et al.*, 2013). Farm size was found to positively influence the adoption of agricultural innovations (Lavison *et al.*, 2013). Caveness and Kurtz (1993) cited by Mignouna *et al.* (2011) argued that having a large land size contributes to perceive security and increase willingness to invest in new technology. Handschuch *et al*.

(2013) found that there is a positive relationship between global good agricultural practices certification and land size. Households holding smaller land had lower chances to participate in high value market because of being uneconomical.

Off-farm income has been shown to positively impact on technology adoption because it helps farmers to overcome the credit constraints they are facing. Diiro (2013) noted that off-farm income provides to farmers enough cash to purchase inputs for enhancing their productivity. As regards to economic theory, Karki *et al.* (2004) opine that production cost and profit of an innovation are very important factors for adoption decision. Agricultural technology cost has been shown to be a constraint for adopting technology. Muzari *et al.* (2012) argued that the suppression of subsidies on price of seed and fertilizers since the 1990s with the structural adjustment programs sponsored by the World Bank in sub-Saharan Africa has broadened this constraint of agricultural technology cost.

Most studies concur that farmer' who receive assistance from extension services are more likely to take up an innovation (Peter *et al.*, 2012). These variables in the context of agricultural innovations are strongly influencing farmer's decision of uptake innovation. Farmers who receive visits from extension and participate in agricultural training are likely to adopt artificial insemination because they accessed to information than those who have not received assistance (Sezgin *et al.*, 2011). Mwangi and Karuiki (2015) found out that advice from extension services is a key factor in innovation adoption. The awareness of farmers about the existence as well as the effective use and benefit of an innovation through extension agents influence the adoption decision. Extension agent plays the role of link between the innovators (Researchers) of the technology and users (farmers) of that technology. Abebe *et al.* (2013) stated that the technical assistance from NGOs is positively correlated to innovation adoption as some NGOs have been involved in promoting agricultural innovations. However, Egwu (2015) found that poor extension services hinder the uptake of agricultural innovations.

Dandedjrohoun *et al.* (2012) argued that membership of farmer group is positively associated with knowledge of the improved technology. Since the NGOs in charge of the dissemination of technology are focused on farmer group to extend the adoption of technology. Adegbola and Adekambi (2008) have shown that membership of farmer's group or association favour the access to information through other members of the same group or association. Market and credit access have been reported to stimulate uptake of innovation among small-scale-farmers. These variables are important in farmer' adoption decision because they determine the amount of land to be used. Abebe *et al.* (2013) shown that market-related attributes and access to credit have a significant positive relationship with the presence of potato improved varieties. However, Muzari *et al.* (2012) argued that access to credit is gender biased in some developing countries where male-headed households are mostly the one to benefit agricultural loans by credit institutions than female-headed households.

Social capital has been found to have major impact on the income and welfare of the poor by improving the outcome of activities that affect them (Yusuf, 2008). It improves the efficiency of rural development programs by increasing agricultural productivity, facilitating households' access to credit and education in rural and urban areas. Grootaert (1999) said that social capital is hypothesized to have several long-term benefits, such as better access to credit and a resulting better ability to smoothen out income fluctuations by borrowing and accumulating assets. Sezgin *et al.* (2011) argued that farmers who participate in agricultural training are more likely to adopt artificial insemination because they accessed to more information than those who have not participated in training. Ayuya *et al.* (2015) found that higher number of agricultural trainings was an important variable in increasing the likelihood of household participation in certified organic vegetable production. Agricultural training was found to be helpful for household members to understand the importance of manure application to soil fertility (Nigussie *et al.*, 2017).

Nevertheless, Odame *et al.* (2011) express that adoption of agricultural technology in most studies have so far focused on factors related to farm resources, farmer characteristics, farm systems, market related, extension services and membership in cooperatives. All these factors influencing farmers' uptake of innovation are decisive and can positively or negatively influence the decision to uptake or not an innovation. Therefore, these factors are classified into: socioeconomic factors (age, education, gender, family size, farming experience, farm size, cost of innovation, level of expected benefits, livestock ownership, family income, and agricultural equipment) and institutional factors (credit access, information, extension services, member in farmers' groups, land tenure, and social networks),

2.6. Linear Programming Application

Generally, linear programming is the mathematic programming, which simplified and qualified the representation of a real phenomenon (Pacaud and Cournut, 2007). It consists to optimize in a way to maximize or minimize an objective function subject to a set of constraints (Boussard, 1987 cited by Ouédraogo, 2005). The word "programming" is synonymous of planning (Hillier and Lieberman, 1967 cited by Valazquez, 2004). Linear Programming (LP) is a particular case of mathematic programming where the objective function and the technical various constraints are specified in a linear way in relation to the decision variables (Gohin and Chantreuil, 1999). In other words, the objective function and the constraints are the combination of linear variables (IDD, 2003). The adjective “linear” indicates that all the mathematic functions of the model are necessarily linear in nature. Therefore, the LP is the planning of several activities in order to attain an optimal solution that is to say a solution which permits to reach the most satisfactory a specific goal among all the possible alternative solutions. In other words, LP searches the extreme value of a combination of linear activities subject to constraints which limit the dimension and the nature of the possible combinations.

The LP appears as a veritable tool of decision making which is able to compare the reference situation results to various scenarios (Boussard, 1987). The decisions are always made in comparison of what the decision maker loose or gain in making such decision rather than the others (Brossier, 1980). Therefore, since its formulation by George Dantsig in 1947, the LP has been widely applied in agriculture. In fact, the objective was to determine the optimal production plan for farmer regarding the application of the new economic measures taken in Brussels (Velazquez, 2004). It had permitted to measure the effect of the agricultural policy on the agricultural production and the revenue of farmers. The LP rely on an hypothesis that a farmer searches to maximize his profit or minimize his cost by conducting his agricultural activities while satisfying a series of constraints regarding to inputs such as land, labour, and the available capital of the farm. It explores the rationality of technical changes as the choice of activities or substitutions among inputs. In other words, the LP model maximizes the objective function of the farmer by optimally allocating the available resources or production factors to the most productive activities (Ouédraogo, 2005).

Several studies have shown the interest of linear programming on small-scale farmers' production system' sustainability, intensification, innovation and the impact of agricultural policy. Despite its usefulness of optimizing small-scale farmers' objective function, the LP model still has some limitations because it does not take into account the variability observed among farmers which may lead to bias in the obtained results (Ouédraogo, 2005). The LP model is static which means that it does not consider the changes and the evolution of variables as time goes by. Another limitation arises in the formulation process which should be taken into account, values must be known with certainty. According to Hazell and Norton

(1986), the ideal would be to model the objective function of each farmer in order to avoid such bias. In practice, this would be very difficult in terms of time and financial regarding the high number of farmers. However, it is possible to minimize the bias in identifying the criterions to classify farmers. Therefore, this study will optimize small-scale cotton farmers' resources in CLIS based on the typology of the Malian Company of Textile Development (CMDT).

2.7. Theoretical Framework

This study was based on profit optimization theory because small-scale farmers focus on how to get the highest profit with the available resources regardless of the consequences and risk involved. The decision of small-scale farmer to combine crop and livestock enterprises can be regarded as a binary choice. This is because of the dichotomous nature of the dependent variable, that is, when the enterprise is combined and when it is not. Therefore, the binary choice model is true if the following conditions hold true:

i. Small-scale farmers are facing two alternative choices either to combine or not crop and livestock enterprises.
ii. The choice of small-scale farmers' enterprise combinations in crop and livestock integration systems depends on socio-economic and institutional characteristics.

According to KayRonald (1981) quoted in Bamiro *et al.* (2015), many firms diversify or produce more than one product to avoid having their income totally dependent on the production and price of one product. Therefore, if profit from an enterprise is poor, the one from the second enterprise may prevent the total profit to fall below unacceptable level. Bamiro *et al.* (2009), note that in agricultural production, diversification or enterprise combination may reduce income variability if all prices and yields are not low or high at the same time. In this study, resource use optimization is based on small-scale farmers profit optimization and the combination of crop and livestock enterprises, which will offer farmers the most profitable combination is a decision they often take by integrating or not crop and livestock enterprises and it is estimated using the following equations (1) and (2) by Debertin (2012);

$$\pi_i = TR_i - TC_i \tag{1}$$

$$\begin{gathered} \partial\pi_i = MR - MC = 0 \\ for Max \pi \Rightarrow MR = MC \end{gathered} \tag{2}$$

Where, π_i is the expected profit of small-scale farm i from combining enterprise in crop and livestock systems. TR is total revenue which simply means the total amount of money that the small-scale cotton farmer i, receives from selling its products. TC is total cost of all factors of production that the small-scale cotton farmer i spends to produce its products. MR and MC are marginal revenue and marginal cost.

2.8. Conceptual Framework

The conceptual framework of this study is presented in figure 3. The interactions between crop and livestock revolve around the supply of nutrients to the field for crop and the energy needs to feed animals. Livestock provides manure for soil amendment and animal draught power to plough and weed land. Compost is made with manure and dead leaf or crop residues and this mixture is used on land. Crop residues are left in the field and grazed by animals or in some cases they are stored as fodders for feeding animals in dry season. Fodder crops also such as *dolichos lablab* and *stylosanthes hamata* are used to feed animals.

The combination of crop and livestock activities might have several benefits at farm level. It improves small-scale farmers' agricultural productivity and then increases the gross margin. The performance of that enterprise combination depends not only on the levels of inputs used, but also on the integrated management practices. The level of input used will also depend on their market prices and the output price. The input and the integrated management practices put together determine the performance of output produced in terms of gross margin. The uptake of these innovations including manual cotton topping, fodder crops, lime application, and contour ridging depends on small-scale farmers' socioeconomic and institutional characteristics. In this study the enterprise combination of crop and livestock is a function of several factors.

The decision making to uptake innovations in CLIS is one of the small-scale cotton farmer's characteristic that will determine the profitability of crop livestock enterprise combination. Furthermore intervening variables such as government policy, amount of rainfall, drought and temperature play an important role in determining the optimization of resource use and increased small-scale cotton farmers' uptake of innovations in CLIS. Other environmental concern together with all the factors cited above will influence decision making process at the farm level on whether to integrate or not which in turn will influence will influence the returns levels of output for improved family farming incomes.

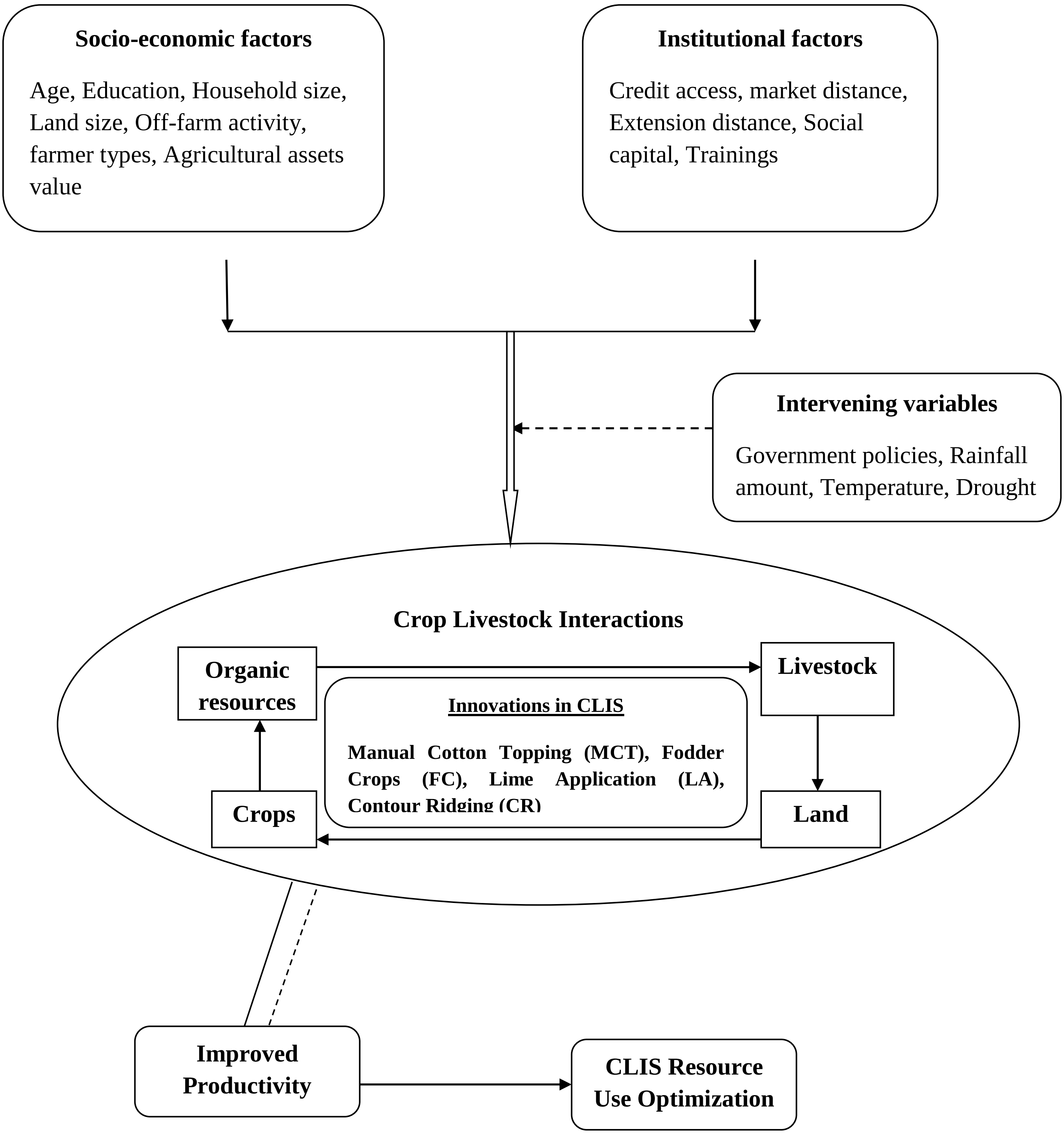

Figure 4: Conceptual framework of interaction in CLIS

CHAPTER THREE

METHODOLOGY

3.1. Study Area

The study was carried out in cotton growing zone which is located in southern part of Mali lies in latitudes 13°S and drained by the rivers Niger and Bani with its tributaries such as Baoulé, Bagoé and Banifing (Dufumier, 2005). This area of cotton growing is about 181 000 Km² shared out on 6,345 villages and it has been chosen because it is the main agricultural region in Mali where crop-livestock integrated production system has been promoted to solve the problem of declining soil fertility. In this area, cotton is grown with other cereals crops such as maize, millet, and sorghum and livestock system which is dominated by extensive cattle breeding. The estimated human population in this area is about 4.5 million with an average annual growth rate between 3.2 to 4.3 percent (Camara, 2015). Small-scale farmers in this area are affected by low soil fertility, low productivity, fluctuation of cotton prices and climate change.

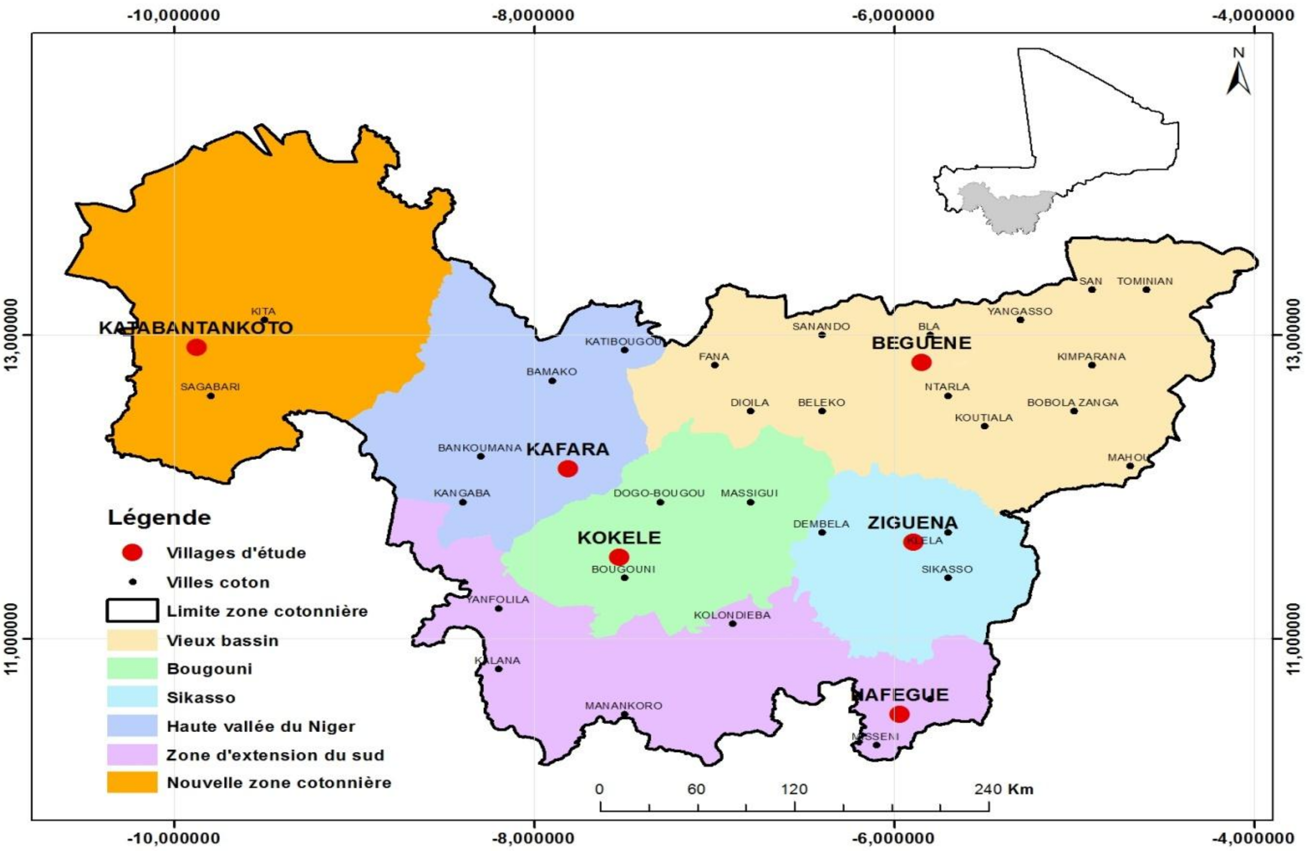

Figure 5: Location of villages in the study area

Source: IER (2014)

The climate varies from the Sudano-Sahelian type in the north to Sudano-Guinean in the south with one rainy season recording yearly fluctuation. These climatic types distinguish three areas which are semi-arid, transitory and sub-humid areas with a mean rainfall 550 to 800 mm/year; 800 to 1000 mm/year and 1000 to 1200 mm/year respectively. In these areas, the types of soil are clay, clay-loam, sandy-loam and gravelly (Soumaré *et al.*, 2006).

The study was carried out in the project PASE2 intervention zones. This project is based on five research thematic: (i) characterization and monitoring of agrarian dynamics of cotton growing zones, (ii) natural resources management, (iii) economics of small-scale farmers and innovations, (iv) water and soil fertility management and (v) cotton plant integrated protection. Therefore, four villages (figure 4) were chosen among the six villages of the aforesaid project to conduct this study according to their accessibility, agricultural practical diversity and crop livestock integration.

3.2. Sampling Technique

The study used a multistage sampling technique to get the required sample size where the family farm is the sampling unit. The target population was all farmers involving in crop and livestock mixed enterprises. The first stage was the purpose selection of southern Mali where most of the small-scale farmers are practicing mixed farming of crop and livestock and CLIS is being promoted in this area by extension staff. Four villages; Ziguéna, Nafégué, Kokélé and Beguéné were then chosen according to the diversity of agricultural production system in the study area and also the intensity of crop livestock integration. Lastly, linear systematics sampling method was used to select the respondents in each village proportionate to size from the available list of farmers.

3.3. Sample Size Determination

The sampling was based on the 4 types of family farms established by the Malian Company of Textile Development (CMDT) and the Institute of Rural Economic (IER) according to their labour, cultivated land under cotton and cereals, agricultural equipment and livestock owned. In each village, there are four types of farmers, which are types A, B, C, and D. Type A farmers are those, who are well equipped with more than two pairs of oxen and a set of ploughing and weeding tools. Type B farmers are partially equipped with at least one pair of oxen and a plough. Type C farmers are those called under equipped with either oxen without plough, or plough without oxen and type D farmers are those without experiences with animal traction (Scoones *et al.*, 2000). In table 1, the total number of household practicing crops and livestock activities in the four villages chosen is 300 (CPC, 2017) and the sample size is determined using the following formula by Yamane (1967) as the population is known:

$$n = \frac{N}{1 + N(e)^2} \quad (3)$$

Where n = sample size

N = total number of household farmers of the four villages = 300

e = level of error term allowable (0.05)

1 = constant value

Hence replacing the value into the formula gives

$$n = \frac{300}{1 + 300(0.05)^2} = 171.4285$$

n= 171 Family farms

Table 1: Number of family farming by types and by sample size in each village.

Villages		Type A	Type B	Type C	Type D	Total
Ziguéna	Number FF	26	15	17	4	62
	Sample Size	**15**	**9**	**10**	**2**	**36**
Nafégué	Number FF	40	23	6	0	69
	Sample Size	**23**	**13**	**3**	**0**	**39**
Kokélé	Number FF	4	53	37	15	108
	Sample Size	**2**	**30**	**21**	**9**	**62**
Beguéné	Number FF	31	22	7	1	61
	Sample Size	**18**	**12**	**4**	**0**	**34**
Total		**58**	**64**	**38**	**11**	**171**

Type A: well equipped with more than two pairs of oxen and a set of ploughing and weeding tools ; **Type B**: partially equipped with at least one pair of oxen and a plough ; **Type C**: under equipped with either oxen without plough, or plough without oxen ; **Type D**: no experiences with animals traction.

3.4. Data collection and analysis

Both primary and secondary data were used in this study. The study used cross sectional data on the inputs and outputs of crop and livestock production and farm characteristics. Primary data were collected through interview using semi-structured questionnaire administered by trained enumerators. The questionnaire was pretested to ensure its validity in one of the non-selected villages (Kafara) of Southern Mali. Data collected includes information on farm and farmer characteristics, institutional, production and purchase prices. This information included all factors of production (land, labour, fertilizers, pesticides, herbicides, seeds, equipment, and livestock) used in crop livestock integration system and their respective costs. Also they included output of crop and livestock such as yields, quantity of output sold, and sale prices. Data on farm and farmer characteristic variables were gathered the farmer's sex and age, level of education, marital status, occupation, access to credit, participation in off-activity, distance of farm to market, experience in crop and livestock production systems, family size, distance to agricultural extension services, use of fertilizers on crops production, livestock feeding among others. The data were collected for the period 2015/2016 production season. Secondary data were obtained from government services such as Cell of Statistics Planning, CMDT, national research institution (IER), journals, and other written literature. Secondary data included cotton production trends, total livestock units and input prices. Data were imputed in SPSS version 20.0 software. The descriptive statistics and econometric models were analyzed using STATA version 13.0 and Microsoft Excel Solver was used through Linear Programming to determine the optimal solution of resource use in CLIS.

3.5. Analytical framework

3.5.1. Objective One

To determine small-scale cotton farmers' socio-economic and institutional characteristics in crop-livestock integration systems in Southern Mali. Both descriptive and inferential statistics were used such as means, frequencies and standard deviation. Inferential statistics used includes f-test and chi-square tests.

3.5.2. Objective Two

To determine the socio-economic and institutional factors which influence small-scale cotton farmers' uptake of innovation in crop-livestock integration systems in Southern Mali, multivariate probit model was used. The decision to uptake a technology is dichotomous, where the farmer can decide to use or not the technology. Therefore, the decision to uptake is considered like qualitative dependant variable in a regression model with a value of 0 or 1 which also depends on farmer's socio-economic and institutional characteristics. From the literature review on technology adoption, there are some types of models commonly used to analyse the decision to uptake or not an agricultural technology: linear probability model, logit, and probit. Etoundi *et al.* (2008), noted that the linear probability model often has a disadvantage to define the forecast probability beyond the [0.1] interval.

As for probit and logit models, they are often used in most adoption studies. Morimune *et al.* (1980) quoted in Etoundi (2008), highlighted that it is hard to make the difference between the two models when estimating the parameters and their precisions obtained by the probit and logit models. That proximity can be explained by the logistic and normal law. Farmers will uptake CLIS innovations to counteract the constraints of production they are facing and this implies that the farmer decision to uptake is discrete in nature. Since the estimation was based on several innovations, uptake of one or more innovations was more likely due to variation in farmers' expectations. Therefore, this study used multivariate probit model as a tool to analyse objective two. The variables used in this model are described in table 2. In this model, we focused on the use of the four innovations including Manual Cotton Topping (MCT), Fodder Crops (FC), Lime Application (LA) and Contour Ridging (CR). In principle, a multivariate probit is characterized by a set of binary dependent variables (Y_{hpj}) then the resulting equation system would be:

$$Y^{*}_{hpj} = X^{'}_{hpj}\beta_j + u_{hpj}, \text{ j=1,...m} \quad (4)$$

and

$$Y_{hpj} = \begin{cases} 1 \text{ } if \text{ } Y^{*}_{hpj} > 1 \\ 0 \text{ } otherwise \end{cases}, \quad (5)$$

Where

j=1,...m denotes the innovations choices available (CLIS in our case), Y^{*}_{hpj} is a latent variable which captures the unobserved preferences, $X^{'}_{hpj}$ is a linear combination of observed characteristics X_{hpj} of farm households, β_j is the vector of parameters to be estimated, u_{hpj} is the stochastic error term of unobserved characteristics which follow jointly a multivariate normal *MVN* distribution with zero conditional mean and variance normalized to unity, where

$u_{hpj} \sim MVN(0,\Sigma)$ and the covariance matrix, Y_{hpj} Denotes uptake of the j^{th} CLIS on a p^{th} plot by an i^{th} farm household.

The equation was decomposed to form m simultaneous equations;

$$Y_1^* = X_1\beta_1 + u_1, Y_1 = 1 \; if \; Y_1^* > 0 \;\; Y_1 = 0 \;\; otherwise \tag{6}$$

$$Y_2^* = X_2\beta_2 + u_2, \;\; Y_2 = 1 \; if \; Y_2^* > 0 \;\; Y_2 = 0 \;\; otherwise \tag{7}$$

$$Y_3^* = X_3\beta_3 + u_3, \;\; Y_3 = 1 \; if \; Y_3^* > 0 \;\; Y_3 = 0 \;\; otherwise \tag{8}$$

$$Y_4^* = X_4\beta_4 + u_4, \;\; Y_4 = 1 \; if \; Y_4^* > 0 \;\; Y_4 = 0 \;\; otherwise \tag{9}$$

The implicit functional form of empirical model is specified as follows:

$$Y_j^* = f_x(\beta_0 + \beta_1 Age + \beta_2 Education + \beta_3 OffarmAct + \beta_4 Hsize + \beta_5 Landsiz + \beta_6 AssetValue + \beta_7 mktdist + \beta_8 CreditAc + \beta_9 Extensdist + \beta_{10} DecisionMkg + \beta_{11} TrustLevel + \beta_{12} Indexmeet + \beta_{13} IndexGroupHet + \beta_{14} NbTraining + \beta_{15} TypeB + \beta_{16} TypeC + \beta_{17} TypeD) + \varepsilon$$

Table 2 presents the description of the variables used in multivariate probit model and their corresponding hypothesized signs.

Table 2: Description of variables used in Multivariate Probit Model

Variables	Description	Measurement	Expected sign
Dependent variable			
CLIS_innov (Y)	If a farmer uptake an innovation (MCT, FC, LA, and CR) of CLIS	1=Yes, 0= No	+
Independent variables			
Age	Age in year of the head of family	Year	+
Education	Years of schooling of the decision maker	Year spend in school	+/-
Hsize	Total number of members of the family	number	+

Landsize	Total of land size owned by the family farm in hectares	hectares	+
Off-farm activity	Dummy=1 if the household head participates in off-farm activity, 0 otherwise	1=Yes; 0=No	+
Market distance	Distance to the nearest market (km)	Kilometers	+
Extension Distance	Distance to the nearest extension service	Kilometers	+
Asset_value	Value of agricultural assets (plough, cart, sower…)	Currency (FCFA)	+
Credit_access	Dummy=1 if the household access to agricultural credit	1 = Yes 0 = No	+
Training number	Number of agricultural training received	number	+
Socaptl	The level of social capital based on 4 indicators (Decision making, trust, meeting attendance index, and group heterogeneity index)	Score/index	+/-
Type A	Dummy =1 if the household is type A farmer (reference category)	1 = Yes 0 = No	+
Type B	Dummy =1 if the household is type B farmer	1 = Yes 0 = No	+
Type C	Dummy =1 if the household is type C farmer	1 = Yes 0 = No	+
Type D	Dummy=1 if the household is type D farmer	1 = Yes 0 = No	+

3.5.3. Objective Three

To determine the enterprise combination that gives the high gross margin in crop livestock integration systems in Southern Mali, the study used Linear Programming (LP) model. Small-scale farmer enterprise mix profit was computed using Gross Margin (GM) and the linear programming model was followed. The idea behind LP is to maximize objective function which is in our case either "Profit" or "Gross Margin" subject to some constraints, which are restrictions that show what we are allowed to do. In this study, small-scale farmer's objective is to maximize their profit facing to some challenges such as low agricultural productivity and soil fertility. To overcome these challenges, small-scale farmers choose crop and livestock enterprise combinations. This LP model or simplex algorithm was formulated by George Dantzig (1947) and has been a veritable tool for decision making and has also been widely applied in agriculture area. In this study the model will be adapted as applied by Hosu and Mushunje (2013).

The LP model is a mathematical programming, which refers to a simplified and qualified representation of a real phenomenon (Pacaud *et al.*, 2007). From Boussard (1987), quoted in Ouédraogo (2005), it is a problem of maximizing or minimizing a linear function (objective function) subject to various constraints. The linear programming is a particular case of the mathematical programming, where the objective function and constraints are specified in linear combination of variables

The problem to solve is which enterprise combination in crop livestock integrated production system will obtain the higher gross margin given the limited resources available production factors. Equation (11) presented below requires that the quantity of resources used ($bX + bY$) should not exceed the available resources (G) and equation (12) shows the non-negativity of the unit of livestock and the amount of crop. The LP model will maximize an objective function (10) which is gross margin in our case by allocating optimally resources or factors of production to the most productive crop-livestock enterprise combination. Therefore, the objective function of small-scale farmer would be as follows:

$$Max.Z = \sum a_j X_j + \sum C_k Y_k \tag{10}$$

Subject to:

$$\sum b_{ij} X_j + \sum b_{ik} Y_k \leq G_i, \tag{11}$$

$$X_j, Y_k \geq 0 \tag{12}$$

Where

$Z =$ Gross Margin to maximize, $a_j =$ Gross margin from the j^{th} livestock enterprise,

$X_j =$ Livestock unit of the j^{th} livestock enterprise, $C_k =$ Gross margin of the k^{th} crop enterprise, $Y_k =$ Amount (ha) of the k^{th} crop enterprise, $b_{ij} =$ i^{th} Resource of the j^{th} livestock enterprise, $b_{ik} =$ i^{th} Resource of the j^{th} crop enterprise, $G_i =$ maximum level of the i^{th} resource available of production factors.

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter is divided into three major sections. The first section describes small-scale cotton farmers' socioeconomic and institutional characteristics. The second section discusses empirical results of Multivariate Probit Model. In the third section, Linear Programming Model of small-scale cotton farmers' profit maximization results are presented and discussed.

4.1. Descriptive statistics

This section presents descriptive statistics of variables used in the regression model by type of farmers. Table 3 presents farm and farmer characteristics for continuous variables. The results revealed that years of schooling of the key decision maker of the household were significantly different at 10% across the four types. It shows that farmers in Southern Mali were lowly educated with an overall mean of 0.51 year of schooling. Types A and C farmers' household decision maker had relatively higher education level than types B and D farmers who had none formal education level. Namara *et al.* (2013) found that level of education was an important variable in predicting system of rice intensification adoption in Sri Lanka. Higher education achievement is also empowers farmers in management of new technologies, including their risks and benefits that accompany the technology (Tey *et al*., 2014).

Concerning the current value of agricultural assets, type A farmers had the highest asset value of 2,205,586 Fcfa compared to 602,073 Fcfa for type B, 476,571 Fcfa for type C and 415,333 Fcfa for type D. Agricultural asset value was significantly different at 1% across the four types of farmers. Agricultural asset value is a proxy of family wealth and higher agricultural asset value enhances the likelihood of risk absorption by farmers. Wealthier farmers are better placed in absorbing production and marketing risks as well as raising farm liquidity important in adoption food production standards (Kersting and Wollni, 2012).

Distance to the market is an important variable in commercializing because of access to farm inputs, information, and also affects the transportation cost (Fort and Ruben, 2009). Distance to the nearest market was significantly different at 10% level across the four types of farmers. The result also indicates that the highest distance to the nearest market was 34 kilometers for

Table 3: Mean of farm and farmer characteristics for continuous variables.

Variables	Overall		Type A		Type B		Type C		Type D		F-test
	Mean	**Sd**	**Mean**	**Sd**	**Mean**	**Sd**	**Mean**	**Sd**	**Mean**	**Sd**	
Age	46.017	13.388	48.974	11.472	49.135	14.216	47.743	15.416	55.833	16.774	0.602
Education	0.508	1.610	0.390	1.339	0.356	1.423	1.114	2.336	0.000	0.000	0.088*
Asset_Val	1, 268,499	2, 537,640	2, 205,586	3, 629,387	602,073	366,373	476,571	356,431	415,333	70,799	0.000***
marketdist	24.186	14.024	25.364	13.765	24.034	13.979	20.057	13.311	34.667	17.282	0.073*
extensiondist	6.028	4.707	5.636	4.368	5.169	4.825	8.514	4.598	5.000	4.517	0.005***
Training_nber	1.785	1.648	1.909	1.648	1.966	1.712	1.343	1.533	1.000	1.263	0.170
Hh_size	17.932	11.069	24.000	12.404	14.237	7.233	12.257	6.908	9.500	1.871	0.000***
Landsize	11.674	8.623	15.987	10.643	9.538	4.024	7.003	4.721	4.583	1.715	0.000***
Decision_Mkg	4.181	3.781	4.130	3.084	4.254	4.652	3.943	3.710	5.500	3.391	0.827
Trust_Level	5.695	4.214	5.597	3.087	5.983	4.528	4.714	3.885	9.833	10.553	0.045**
index_meeting	0.634	0.450	0.637	0.424	0.690	0.464	0.525	0.490	0.694	0.400	0.383
indexGroupHeterogeneity	0.478	0.241	0.487	0.222	0.496	0.209	0.414	0.310	0.562	0.304	0.308

Notes: ***, **, *, indicates significance level at 1%, 5% and 10% respectively type D farmers while types A, B, and C had a nearest market distant of 20 to 25 kilometers. Market may be associated with provision of agricultural inputs as well as information which is important in adoption of innovation among farmers. Muzari *et al.* (2012), argued that farmers in developing countries live and farm in areas where institutions such as market tend to be poorly developed.

Regarding the distance to extension services, type C farmers had longer distance (8 kilometers) to the nearest extension services compared to other types with significant difference observed across the four types of farmers. Lowly educated farmers may require frequent advice and poor infrastructure may limit farmers' decision of adoption due to inadequate access to agricultural or technology information. Kariyasa and Dewi (2011), found out that distance to extension services providers influenced negatively adoption of integrated crop management farmers field school because the greater distance had an impact on the decline in the level of adoption probability.

Concerning the number of trainings, types A and B farmers had 2 trainings compared to 1 training for types C and D farmers. The higher number of trainings among types A and B farmers may be due to their relatively higher land size, cattle owned, household size and agricultural asset value which may enhance adoption of innovations introduced. Trainings may also be important to farmers with low education level and where innovations introduced are relatively knowledge intensive.

Household size determines labour availability for farm production and is an important determinant when implementing innovations. This is on the backdrop that Manual Cotton Topping (MCT) is a labour intensive innovation (Renou *et al.*, 2011). Household size was significantly different at 1% for the four types of farmers. The results indicate that type A farmers had the highest family members with 24 compared to 14, 12, and 9 for types B, C, and D farmers respectively. It is likely that larger households have the capacity to relax the labor constraints required to implement certain innovations. Di Falcao *et al*. (2011) noted that household size had a significant and positive effect among the determinants of adoption and continued use of stone terraces for soil and water conservation in an Ethiopian highland watershed. Teklewold *et al.* (2013) argued that household size increases the adoption of cropping system diversification, improved variety and conservation tillage because of demand of labor-saving technologies.

Land size was statistically different for the four types of farmers at 1% significant level. Results indicate that type A farmers had larger land size of 16 hectares compared to 9.52 hectares, 7 hectares, and 4.58 hectares for type B, C and D farmers respectively. It could be that farmers with relatively larger land size may have higher farm output and thus higher income which, may be used to meet the labor and other input costs related to the innovations. Manda *et al.* (2016), argued that farmers with larger land size have a high probability to adopt many sustainable agricultural practices. Langat *et al.* (2013) showed that land size had significant influence on adoption of tissue culture banana production in Western Kenya because of increasing household members food security will continue to be an issue among farmers in this area.

Social capital is important in transforming structures and processes in the sustainable livelihood framework as developed by DfID (1999). The study adapted the social capital dimensions as described by Grootaert (1999) and Yusuf (2008), which included variable such as level of decision making, trust level, meeting attendance index, and group heterogeneity index (Table 3). The decision making was included as it shows the activeness of participation in group activities. Further, it might influence member's participation in emerging agricultural product supply chains not forgetting that it is through group decision making that members develop their own decision making skills. The decision making index was measured in a ranked scale from 0 to 10 for each household. Active participation in decision making is higher for type D farmers with 5.5 compared to 4 for types A, B, and C farmers respectively.

Trust among group members makes it easier for members to trust each other and facilitates information sharing. It was measured in a ranked scale from 0 to 10 for each household. Trust level was significantly different between the four types of farmers at 5%. Type D farmers had the highest level of trust with 9.83 compared to 5.6 for type A, 6 for type B, and 4.71 for type C. Intuitively, farmers from the same neighborhood, same kinship and same occupation may have a shared perception of a common good and reach the decision to adopt innovations.

Active participation of a member in group settings was measured by the member meeting attendance and also it is through attending meeting that a member gains from the exchanges of information, experience and knowledge (Yusuf, 2008). The meeting attendance index was computed from a ratio of scheduled meetings in 6 months and the actual meetings the members attended. It was observed that types B and D farmers attended on average 69% of all the scheduled meetings compared to 64% for type A and 52% for type C.

Group heterogeneity index was computed from household responses on diversity of group composition. In each group, questions were asked if members were from the same neighborhood, occupation, kinship, economic status, religion, gender, education level and age group. Farmer's membership in homogeneous groups could have similar information on the innovations and so members gain less from information exchange. However, group heterogeneity plays an important role during the exchange of information, experiences and knowledge among the group members and hence having members with different background is an important element in group members' performance (Yusuf, 2008).

Farm and farmers characteristics for categorical variables are presented in Table 4. Household that access to alternative source of income may enhance adoption of sustainable agricultural practices since it raises household financial capacity to invest (Kassie *et al.*, 2013). The higher participation in off-farm activities was 77% among type C farmers while types A, B, and D farmers had 73%, 66%, and 67% respectively of participation in off-farm activities. Off-farm income is important in agricultural production as it improves farm liquidity through supplementary income for purchase of farm inputs. It could also be an indicator of access to information due to exposure by the household head enhancing the adoption of innovations. However, Wollni *et al*. (2010) argues that participation in off-farm activities constraints the time available for adoption of labour intensive conservation agriculture technologies.

The result indicates that type D farmers had the highest percentage (83%) of access to credit while types A, B, and C farmers had access to credit with 78%, 80%, and 60% respectively. Lower access to credit for type C farmers could be due to their higher participation in off-farm activities which enhance the financial capacity of type C farmers to purchase farm inputs. Small scale farmers require access to sufficient financial capital to undertake productive investments in agricultural technology (Mohamed *et al.*, 2008).

Table 4: Farm and farmer characteristics for categorical variables.

Variables	**Categories**	**Overall**	**Type A**	**Type B**	**Type C**	**Type D**	
		Per.	**Per.**	**Per.**	**Per.**	**Per.**	**Chi2-test**
Off_Farm_Act	Yes	71.19	72.73	66.10	77.14	66.67	0.683
	No	28.81	27.27	33.90	22.86	33.33	
Credit_Acces	Yes	75.14	77.92	79.66	60.00	83.33	0.309
	No	24.29	20.78	20.34	40.00	16.67	

4.2. Determinants of small-scale cotton farmers uptake of innovations

4.2.1. Preliminary diagnostics of the variables used in the regression model

The preliminary diagnostics of pair-wise correlation and variance inflation factor (VIF) were used to detect the problem of multicollinearity to the socio-economic and institutional variables employed in the study. According to Graham (2003), multicollinearity is defined as lack of independence or the presence of interdependence signified by high inter-correlations within a set of variables. Therefore, it constitutes a threat or a serious problem both to the proper specification and to the effective estimation of the type of structural relationships commonly sought through the use of regression techniques.

Multi-collinearity, a state of very high inter-correlations or inter-associations among the independent variables proposed, was tested using pair-wise correlation for categorical variables and variance inflation factor (VIF) for continuous variables. VIF measures the presence of multi-collinearity among the independent variables in a regression model on the precision of estimation. It expresses the degree to which multi-collinearity amongst the predictors degrades the precision of an estimate (Stine, 1995). It is a statistic used to measure possible multi-collinearity amongst predictors or explanatory variables.

The Variance inflation factors result is presented in Table 5. By the rule of thumb, Akinwande *et al*. (2015) said that a value of VIF between 5 and 10 indicates high correlation amongst the

Table 5: Variance inflation factor test for continuous variables in MVP regression equation

Variables	VIF	1/VIF
Group heterogeneity index	4.18	0.239108
Trust	3.68	0.276519
Decision	3.30	0.303140
Land size	2.81	0.356080
Meeting index	2.42	0.413572
Household size	2.25	0.443540
Training	1.56	0.639171
Market distance	1.54	0.650183
Extension distance	1.30	0.767955
Age_Hh	1.12	0.892122
Education	1.08	0.926994
Mean VIF	2.29	

explanatory variables in a regression model. If the VIF value goes above 10, it can be assumed that the regression coefficients are poorly estimated due to multi-collinearity. The VIF result showed that there was no strong relationship amongst all the continuous explanatory variables since its values were less than 5. Also, appendix 2 presents the pair-wise correlation results for categorical variables, which confirmed that there was no serious linear relationship amongst the categorical explanatory variables tested. Therefore, all the proposed potential explanatory variables were used in regression analysis.

4.2.2. Factors influencing small-scale cotton farmers' uptake of innovations

The pair-wise correlation was used to check the relationship between the innovations and results in Table 6 showed that there was no serious relationship between the innovations. Multivariate probit model was used to determine the determinants of household's adoption decision of innovations in CLIS. The model fits the data reasonably well with the Wald test $\left[\chi^2(68)=126.12, \quad p=0.00\right]$ and the likelihood ratio test $\left[\chi^2(6)=49.395, \quad p=0.00\right]$ of the independence of uptake of various innovations was strongly rejected.

Table 6: Correlation coefficients for MVP regression equation

	MCT	FC	LA	CR
Manual Cotton Topping (MCT)	1.000			
Fodder_Crop (FC)	0.164***	1.000		
Lime Application (LA)	0.420***	0.230***	1.000	
Contour Ridging (CR)	0.438***	0.137***	0.512***	1.000

Notes: *** indicates significance level at 1%

As indicated in Table 7 there are four dependent variables, which are the decision to adopt innovation (MCT, FC, LA and CR). The MVP model results revealed that the age of household head had positive effect on the uptake of FC. Elderly household heads are more likely to uptake LA compared to the younger households head. This an indication that elderly farmers have gained knowledge and accumulated more experience over years, which makes them better able to assess innovation information than younger farmers. This result was inconsistent with those of Howley *et al.*, (2012) and Langat *et al.*, (2013), who argued before that elderly farmers are less receptive towards artificial insemination use and tissue culture bananas adoption than younger farmers because of the shorter time horizon of older farmers to receive returns from the adoption of innovations compared to younger farmers.

Table 7: Multivariate probit model results adoption of innovations in CLIS

	Manual Cotton Topping		Fodder Crops		Lime Application		Contour Ridging	
Variables	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Age	0.006	0.009	0.010	0.009	0.022**	0.010	0.006	0.010
Education	-0.101	0.091	0.018	0.069	0.142**	0.072	0.020	0.076
Off_Farm_Act	0.105	0.283	0.213	0.270	0.468	0.305	0.580*	0.307
Asset_Value	-0.002*	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000
Credit_Acces	0.951**	0.446	0.096	0.139	0.091	0.111	-0.169	0.407
marketdist	-0.002	0.011	-0.021*	0.011	-0.025**	0.012	0.000	0.011
extensiondist	-0.048	0.029	-0.041	0.025	-0.066**	0.028	-0.065**	0.031
Training	0.349***	0.098	0.462***	0.105	0.201**	0.086	0.122	0.087
Hh_size	-0.014	0.018	-0.002	0.015	-0.013	0.016	-0.002	0.016
Landsize	0.100***	0.030	0.021	0.024	0.045*	0.025	0.069***	0.025
Decision_Making	-0.032	0.039	-0.018	0.041	-0.006	0.042	-0.030	0.041
Trust_Level	-0.020	0.032	0.029	0.038	-0.048	0.044	-0.001	0.037
index_meeting	0.041	0.301	0.119	0.286	0.141	0.290	0.153	0.292
index_Group_Heterogeneity	0.208	0.594	-1.134**	0.545	0.943*	0.520	0.580	0.544
TypeB	-0.393	0.298	-0.470**	0.279	-0.105	0.297	-0.317	0.288
TypeC	-0.325	0.370	-0.156	0.327	-0.042	0.373	-0.317	0.378
TypeD	0.331	0.711	-0.623	0.792	-0.176	0.868	-0.075	0.850
_cons	-1.633**	0.785	-0.489	0.679	-2.407***	0.807	-2.161***	0.815

Notes: ***, **, *, indicates significance level at 1%, 5% and 10% respectively

Education had a significant effect at 5% on LA uptake decision. An increase in education by one year enhances LA out adoption by proportion of about 14%. Almost 50% of the household head has undergone adult education through rural literacy on how to read and write. This could be due to the impact of the alphabetization program implemented in cotton zones by the Malian cotton company (CMDT), whereby many farmers in that area have benefited. This implies that higher education influences farmers' attitudes and making them more open to analyze the benefits and comprehend the dynamics that come with innovations. These findings is in line with Namara *et al.*, (2013), who found that education level is an important variable in predicting system of rice intensification technology adoption in Sri Lanka because of the understanding of risks and benefits that accompany the technology.

Participation in off-farm activity was positively significant on CR at 10% level. Farmers who have access to alternative sources of income are able to solve liquidity problem such as hiring labor in making ridges. Further, participation in off-farm activity could also be a source of information on the innovation through household head interaction with others from diverse background, which could inform the adoption decision. This result is consistent with Kassie *et al.* (2013), who found that households that accessed alternative source of income were more likely to adopt sustainable agricultural practices since it enhances the capacity to finance investments. However, Lapple *et al.* (2015), where participation in off-farm job is a barrier to innovation adoption attributed to limited time for agricultural information gathering and implementation of the innovations.

The value of household's agricultural asset was significant and had a negative effect on MCT innovation at 10% level. Possibly this could be due to the nature of the MCT innovation, which is conducted manually and intensive regarding labor. Higher value of agricultural asset decreases the likelihood to uptake MCT innovation suggesting that farmers with higher asset value prefer more capital intensive technologies. This result is in contrast with Ayuya *et al.* (2015), who found that higher agricultural asset value increased the probability of participation in certified organic vegetable production and safeguards farmers against any risks and assure them liquidity during the production of organic products.

Distance to the market had a negative significant effect on adoption of FC at 10% and LA at 5%. By implication, longer distance means higher transaction costs involved in getting the inputs such as fodder seeds and lime. Further, longer distance is made worse with the relative poor road infrastructure particularly during the rainy season. Vorster *et al.* (2007) opined that distant markets made it harder to access technologies due to higher transportation cost. Muzari (2012) stated that farmers in Sub-Sahara Africa live and farm in areas where institutions such as irrigation, credit, market and extension tend to be poorly developed. Hence, there is need for efforts on infrastructures and institutions development in these areas.

Credit access was only significant for MCT innovation. Findings indicate that farmers who had access to credit had 95% likelihood of adopting MCT. This is a clear indication that the main challenge to MCT uptake is the labor cost, which can be solved through credit. Mohamed *et al.* (2008) argued that agricultural technology adoption is regarded as a key element for increasing productivity. Therefore, small-scale farmers require access to sufficient financial capital to undertake productive investments in agricultural technology. Abebe *et al.* (2013) found that access to credit among potato farmers in Ethiopia positively influenced adoption of improved potato varieties since it provides farmers liquidity to purchase agricultural inputs for enhancing their productivity.

Distance to extension services providers negatively influenced farmers' uptake decision of LA and CR innovations. Farmers who are far away to the extension service had 5% likelihood to adopt LA and CR innovations. During lime application and contour ridges construction, farmers may require frequent advice based on the technical requirements of the innovations. Inadequate access to the information about technology due to longer distances with defective road may limit the adoption of the innovation. Genius *et al.* (2010) found that extension services and social learning are strong determinants of technology adoption and diffusion and the presence of one enhanced the effectiveness of the other one. Kariyasa and Dewi (2011), in Indonesia, found that distance to agricultural technology information sources is significantly affected by the level of improvement opportunities of adoption because greater distance had an impact on the decline in the level of adoption probability.

Number of trainings was significant and had a positive effect on MCT, FC, and LA adoption. This is due to the training sessions organized through the project PASE2 towards sensitizing farmers on the benefits of the innovations. This implies that farmers who have received more training were more likely to uptake these innovations. Low educated farmers need to be trained several times to increase the uptake of innovations because of the technical knowledge required to implement these innovations. Namara *et al.* (2013), found that among other factors, determinants of adoption in the System of Rice Intensification (SRI) in Sri Lanka were years of schooling and access to training programs. Farmer's participation in agricultural training programs significantly increases the probability of a farmer being an SRI adopter. Suri (2011) stated that one of the major determinants affecting maize technology adoption in Kenya is farmers' training.

Land size significantly influenced MCT, LA and CR uptake decision with about 4, 7 and 10 per cent respectively. This variable had a positive effect on the three innovations adoption decision. This is due to the characteristics of the innovations such as MCT and CR, which require more labor to be implemented and thus farmers with larger land size are able to benefit from economies of scale. Larger land size also allows farmers to try out innovations, particularly CR. Further, farmers with relatively larger land size may have higher farm output and thus higher income. The income generated may be used to meet the labor and other input costs related to adoption of innovations. Previous studies on adoption (Uaiene *et al.,* 2009; Mignouna *et al.,* 2011; Langat *et al*., 2013; Lavison *et al.,* 2013) found positive relationship between farm size (land size) and adoption of agricultural innovations attributed to household food security needs.

Farmers' social capital was measured as described by Grootaert (1999), which included variable such as decision making, trust level, meeting attendance index, and group heterogeneity index. Group heterogeneity index negatively influenced adoption of FC at 5% significant level and positively adoption of LA at 10%. Group heterogeneity index was measured from household responses on diversity of group composition and questions were asked if members were from the same neighborhood, occupation, kinship, economic status, religion, gender, education level and age group. This could be due to the interest of group members on the nature of the two innovations. The former one regards farmers who only owned cattle then the higher the group heterogeneity, the lower the information related to FC innovation. Whereas, the later one is a common issue in this region, where all farmers are confronted and the higher the group heterogeneity, the higher the information share on LA innovation. This is consistent by Grootaert (1999), who found that internal heterogeneity of association influenced positively household welfare. However, group heterogeneity plays an important role during the exchange of information, experiences and knowledge among the group members and hence having members with different background is an important element in group formation (Yusuf, 2008).

Being a type B farmers negatively influenced adoption of FC innovation at 5% significant level. They were less likely to uptake FC innovation compared to type A farmers. This could be due to the number of cattle owned by the farm, whereby type B farmers have small number of cattle of about 4.8 TLU compared to type A farmers, which has 33.6 TLU. This implies that the higher the number of cattle, the higher the demand for fodder crops as livestock feed. Therefore, households with more livestock such as type A farmers are more likely to invest in fodder crops than those with less livestock such as type B farmers. This is also consistent with types C and D farmers with respectively 2.4 and 1.6 TLU where they are less likely to adopt FC innovation as compared to type A farmers. Furthermore, type B farmers have less land resources compared to type A farmers and the larger the land size, the larger the available land resources for fodder crops production.

4.3. Gross margin in crops and livestock enterprise combinations

Small-scale farmers have been classified into four categories which are types A, B, C and D by the national institute of research (IER) and the Malian Company of Textile Development (CMDT). This classification was based on the level of agricultural equipment (plough and cart) and number of oxen (Scoones *et al.*, 2000). Class A farms were well equipped with more than two pairs of oxen and a set of ploughing and weeding tools. Class B farms were partially equipped with at least one pair of oxen and a plough. Class C farms were under equipped with either oxen without plough, or plough without oxen and class D farms were those without experiences with animal traction. This classification provides the foundation of the results interpretation in the optimization model (Linear Programming) then the analyses were focused on the four types of farms.

The major enterprises of crop and livestock and their gross margin by type of farmers are shown in Table 8. Each one of these enterprises has its average gross margin per unit different by type of farms and by enterprise itself. The results indicated that gross margins from cotton and maize were significantly different at 1% are across the four types of farmers with the highest gross margin of cotton for type A farmers and the highest gross margin of maize for type C. This is due to the differences among farmers' land size whose type A farmers had the largest land size followed by types B, C, and D farmers. This implies that farmers with larger land size have higher farm output and higher gross margin. While for livestock, the results revealed that gross margins from oxen and donkey were also significantly different at 1% across the four types of farmers. The possible explanations of those differences are due to

Table 8: Gross Margin of major and livestock enterprises identified in the study area

Variable	Enterprises	Average gross margin (in Fcfa)/Unit/Enterprise				F-test
		Type A	Type B	Type C	Type D	
X1	Cotton	166,026.20	145,992.30	137,033.60	137,970.70	0.000***
X2	Millet	67,267.13	64,873.38	61,582.92	12,526.67	0.220
X3	Sorghum	45,094.58	37,832.58	40,410.46	45,389.33	0.212
X4	Maize	79,762.52	58,483.99	99,710.64	83,826.86	0.000***
X5	Rice	345,269.00	243,243.00	118,663.80	62,684.00	0.452
X6	Groundnut	220,173.00	183,215.20	77,644.70	-	0.058*
X7	Oxen	92,517.18	137,845.00	103,293.00	103,336.67	0.001***
X8	Other cattle	124,690.00	95,405.60	102,100.00	77,783.70	0.443
X9	Sheep	25,242.50	38,815.00	37,300.00	32,755.00	0.162
X10	Goat	15,489.00	20,004.00	14,950.50	11,814.98	0.205
X11	Donkey	43,520.00	27,450.00	31,460.00	10,660.00	0.000***

Notes: ***, *, indicates significance level at 1% and 10%

livestock inputs expenses incurred by each type of farmers. Also, the price of selling an ox or a donkey might explain those differences.

The expenses in terms of labor and other inputs such as fertilizers, seeds and veterinary services incurred by enterprise and by type of farms to produce were different. These expenses are incurred in one year for crops and several years for livestock depending on the reformed ages of the type of livestock. Only sheep and goat enterprises have a maturity age of less than two years (one and half year). Crops enterprises such as rice, cotton and groundnut have the high average gross margin followed by oxen and other cattle enterprises. These gross margins for crops and livestock enterprises were determined so as farmers could maximize their profit functions with limited resources.

Summary of the Linear Programming (LP) results that maximize profit function subject to the available resources for an integrated crop-livestock system by type of farms is shown in Table 9. The linear programming (LP) results showed that in Southern Mali small-scale cotton farmers could be more efficient working in small sized land because of input efficiency than

Table 9: Summary result for the LP model optimal solution by type of farmers

Variable	Enterprises	Variable amount in the final solution			
		Type A	**Type B**	**Type C**	**Type D**
X1	Cotton	2.44 Ha	1.12 Ha	0.57 Ha	0.82 Ha
X2	Millet	0	0	0.36 Ha	0
X4	Maize	3.26 Ha	1.74 Ha	0.41 Ha	1.06 Ha
X5	Rice	1.34 Ha	1.16 Ha	1.05 Ha	0
X7	Oxen	1.6 TLU	0.8 TLU	0.8 TLU	0.8 TLU
X8	Other cattle	0	0.7 TLU	0.7 TLU	0
X9	Sheep	0	0	0.1 TLU	0.1 TLU
X11	Donkey	0	0	0	0.5 TLU
Solution Maximized (Fcfa) =		1,263,180.72	700,003.16	376,212.10	362,677.69

working in large sized lands. It also shows the importance of crops-livestock enterprise mixes in small-scale farmers' diversification strategies to maximize their profit and enhance food security because livestock enterprises system in Southern Mali are based on free grazing which incur fewer expenses compared to crop-based enterprises. The conversion factors of Tropical Livestock Unit (TLU) was used for the number of each type of livestock owned by farmers in the final solution and 1 ox = 0.8 TLU, 1 other cattle = 0.7 TLU, 1 sheep = 0.10 TLU, 1 goat = 0.08 TLU, 1 donkey = 0.50 TLU (Storck, *et al*., 1991).

The production activities that maximized profit are 2.44 ha of cotton (X1), 3.26 ha of maize (X4), 1.34 ha of rice (X5) and 1.6 TLU of ox (X7) for type A farmers. These mixed enterprises of crop and livestock (cotton/maize/rice/ox) give a value of 1,263,180.72 Fcfa for the maximized total gross margin of type A farmers. This means that to maximize their profit with limited resources, types A farmers should opt for cotton/maize/rice/oxen enterprises mix. It does not mean that type A farmers have no interest of growing other crops and type of livestock. This maximized profit of major crops and livestock is higher than the real total average gross margin of 616,783.91 Fcfa of type A. the results showed that type A farmers at the present level of resources can optimize their productivity to yield a 104.80% increase in their present profit margin if they efficiently used their resources.

The production activity for type B farmers that maximized their profit are mixed enterprises cotton/maize/rice/ox/other cattle. Type B has a maximized total gross margin of 700,003.16 Fcfa with the available resources. These mixed enterprises of crop and livestock for type B farmers were also more efficient with small sized lands of 1.12 ha for cotton (X1), 1.74 ha for maize (X4), 1.16 ha for rice (X5), 0.8 TLU for ox (X7) and 0.7 TLU for other cattle (X8). The maximized total gross margin is greater compared to the real total average gross margin of 453,526.63 Fcfa. Therefore, type B farmers can optimize their profit to yield a 54.35% increase at the present level of available resources if they can efficiently used the available resources. This means that type B farmers should choose cotton/maize/rice/ox/other cattle enterprises mixed to maximized their profit with a total land of 4.02 ha for crops (cotton, maize, and rice) and a total number of 1.5 TLU (ox and other cattle) for livestock.

Crops and livestock enterprises mixed that maximize type C farmers profit were cotton/millet/maize/rice/ox/other cattle/sheep with a maximized total gross margin of 376,212.10 Fcfa for the optimal solution. The production activities that maximized type C farmers profit function were 0.57 ha of cotton (X1), 0.36 ha of millet (X2), 0.41 ha of maize (X4), 1.05 ha of rice (X5), 0.8 TLU of ox (X7), 0.7 TLU of other cattle (X8) and 0.1 TLU of sheep (X9). This maximized profit is greater than the real total average gross margin of 305,831.07 Fcfa and type C farmers can maximized their profit to yield a 23.01% increase with the present level of resources by efficiently used their available resources. Therefore, to maximize their profit type C farms should opt for crops-livestock enterprises mixed of cotton/millet/maize/rice/ox/other cattle/sheep.

The production activities that maximized type D farmers profit are 0.82 ha of cotton (X1), 1.06 ha of maize (X4), 0.8 TLU of ox (X7), 0.1 TLU of sheep (X9) and 0.5 TLU of donkey (X11). The value of the maximized profit function for type D farms plan was 362,677.69 Fcfa with the highest contribution of 137,970.7 Fcfa from the production of cotton (X1) activity. Type D farmers' real total average gross margin of 303,431.97 Fcfa is smaller than the maximized profit of 362,677.69 Fcfa. Therefore, type D farmers can optimized their profit to yield a 19.52% increase at the present level of resources by using efficiently the available resources. They should choose cotton/maize/rice/ox/sheep/donkey enterprises mixed for maximizing their profit subject to the available resources. Further, results showed that type D farmers had experiences with animal traction such as oxen to plough their land.

Resources status by type of farmers is shown in Table 10. The constraining resources are similar for all the four types of farmers. The common constraints are labor for crops and livestock, fertilizers such as urea. These resources are called active resources because any unit change of them will affect the optimal solution of maximized profit. For instance, any additional unit of labor (man/day) for harvesting operation will increase the profit for types A, B, C, and D farmers by 3,983.96 Fcfa, 3,614.22 Fcfa, 914.39 Fcfa, and 3,143.67 Fcfa respectively. All the details on types A, B, C, and D farmers' resources status are shown in appendices 3, 4, 5, and 6 respectively. The constraining resource, which gives the highest increase in farmers profit plan, is land of rice for types A, B, and C with 204,466.80 Fcfa,124,740.88 Fcfa, and 32,073.49 Fcfa respectively. This means that the profit will increase by those respective amounts as result of an extra unit of land (1 ha) for growing rice. As regards to type D farmers, they will have the highest increase of 18,851.32 Fcfa in their profit as result of one additional unit of sheep. Others resources, which are not constraining farmers' profit maximization profit plan, are called inactive resources. This is to say that any unit change in those resources will have no effect on the optimal solution and do not change the maximized profit.

When maximizing the profit, type C farmers are facing more constraints compared to other types. This might explain the importance of mixing seven enterprises of crops and livestock by type C farmers in their diversification strategies and risk management for increasing their profit. The maximized solution of gross margins was increased about 104.80, 54.35, 23.01, 19.52 percent for respectively types A, B, C, and D farmers under the existing available resources for the major crops and livestock enterprises. This implies that the available resources are not efficiently used by all the four types of farmers. The results underscored that crop and livestock are well integrated in the study area and all the types of farmers are practicing both activities of crops and livestock. It also revealed that farmers in southern Mali are labor constrained for both crops and livestock activities as shown by the resource status. These results are similar to past studies, which found that farmers' resources were not efficiently used in the existing plan compared to optimum plan. Hosu and Mushunje (2013), using LP to model crop and livestock enterprises mixed that will maximize profit in South Africa, found that farmers will yield a 122% increase in their present profit margin if they can

Table 10: Summary result for the LP model on resources status by type of farmers

Resource variable	**Type A**		**Type B**		**Type C**		**Type D**	
	Shadow price (Fcfa)	**Resource status**	**Shadow price (Fcfa)**	**Resource status**	**Shadow price (Fcfa)**	**Resource status**	**Shadow price (Fcfa)**	**Resource status**
Harvesting labor	3,983.96	Active	3,983.96	Active	914.39	Active	3,143.67	Active
Urea Quantity	133.35	Active	133.35	Active	573.30	Active	244.48	Active
Insecticide Quantity	0.00	Inactive	0.00	Inactive	17,948.28	Active	0.00	Inactive
Average_Land_Rice	204,446.80	Active	204,446.80	Active	32,073.49	Active	0.00	Inactive
Labour Livestock	0.00	Inactive	0.00	Inactive	289.47	Active	463.38	Active
Crops_Residus_Labor	8,410.65	Active	8,410.65	Active	0.00	Inactive	-	-
Dewormers	0.00	Inactive	0.00	Inactive	6,781.58	Active	0.00	Inactive
Antibiotic	0.00	Inactive	0.00	Inactive	0.00	Inactive	5,562.78	Active
Straw _Labor	0.00	Inactive	0.00	Inactive	3,476.61	Active	0.00	Inactive
Average Sheep	0.00	Inactive	0.00	Inactive	0.00	Inactive	18,851.32	Active

optimized the available resources use. Igwe and Onyenweaku (2013), in their study of applying LP to food crops and livestock enterprises in Nigeria, found that optimizing and reallocating available resources can bring significant increasing in farmers' existing gross margin up to about 61.35%.

Resources such as land and livestock were not limited factors to optimize small-scale farmers' gross margins in Southern Mali and only land available for rice was limited. However, there were not used efficiently by farmers and there is a scope for increasing farm gross margin by opting for small sized land and keeping small unit of livestock. This corroborates with Igwe *et al.* (2013), using LP to combination of crop, monogastric farm animal, and fish enterprises in Abia state, Nigeria, concluded that farm resources were not optimally allocated and optimization of crop and livestock enterprises combination can improved the gross returns about 72.90% to the farmers with the present resources used. It is also supported by Sanni *et al*. (2003) who found that resources were unused or inefficiently used among smallholder farmers in integrated crop livestock farming systems in Katsina State, Nigeria.

At optimal, small-scale farmers in Southern Mali should devote their present resources for small land size of 7.04 ha, 4.02 ha, 2.39 ha, and 1.88 ha for respectively types A, B, C, and D farmers with a small unit of livestock of 1.4 to 1.6 TLU. The implication of cultivating less than the real average land available is that farmers in Southern Mali pursue to ensure their households' food security rather than optimizing profit. Hosu and Mushunje (2013), found that a majority of farmers do aimed for food security rather than profit maximization plan and smallholder farmers in Eastern Cape Province of South Africa are more efficient with small sized land because of input efficiency than working on a large sized land.

Kumari *et al.* (2014), when optimizing allocation of agricultural land to the vegetable crops in India, said that allocation of land to various crops with limited resources has become major challenge to fetch higher profits and therefore there is need of proper land utilization and proper cropping pattern at farm level. It is also noted that in the optimal solution some crops such as millet, sorghum and groundnut do not appear. This implied that farmers in southern Mali do not apply inputs such as fertilizers and herbicides into sorghum or millet plots and then incur less cost compared to cotton, maize and rice.

Therefore, when optimizing the resources use these crops do not appear in farming rotation because the required quantity in terms of inputs is high than what is available (or applied). Also, the average gross margin of cotton, rice and maize are greater than the one of millet, sorghum and groundnut. It is instructive to note that a limitation of LP is that the prices of output and input were assumed to remain constants. Therefore, if they change so that would bring about different combinations of crops and livestock enterprises in farmers' optimal solution.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

- This study concluded that the key differences between the socioeconomic and institutional characteristics of small-scale cotton farmers were in years in formal education, market distance, agriculture asset value, extension distance, household size, number of cattle owned, and land size.
- The main socioeconomic and institutional factors that influenced small-scale cotton farmers' uptake decision of various innovations in CLIS were number of trainings, land size, age, years in formal education, market distance, extension distance, and participation in off-farm activities.
- Finally, the study concluded that small-scale cotton farmers are not efficiently utilizing their resources since they held some resources in excess, which is an indication of inefficiency. Therefore, at optimal resource use in crop-livestock integration system, small-scale cotton farmers could be more efficient when working in small sized land with small unit of livestock from 7.04 ha to 1.88 ha for crops and 1.4 to 1.6 TLU for livestock.

5.2. Recommendations

- This study recommends that there is need to reinforce the technical knowledge of lowly educated small-scale farmers through innovative agricultural training methods and techniques such as mobile training unit. These innovative training methods should be short with video and supplemented by hands-on training in fields so that it will reach a large number of farmers.
- This study also recommends the encouragement of investment on the importance of small-scale farmers' income diversification through creation of sustainable off-farm activities. As farmers, who have access to alternative sources of income are able to solve liquidity problem such as hiring labor in conducting certain innovations. Further, participation in off-farm activity could also be a source of information on the innovation through household head interaction with others from diverse background, which could inform the adoption decision.
- Although this study found that resources in small-scale farmers' crop-livestock integrated production system were not efficiently used. Based on this findings arising

from the study, this study further recommends an effective advice of farmers on the efficient allocation of farm resources, which should be built into programs promoting increased agricultural productivity and income among small-scale farmers cotton-based system.

5.3. Suggestions for further research

While this research only covered resource optimization of small-scale farmers' major enterprises of crops and livestock in four villages in Southern part of Mali, further research can be conducted to establish optimal combination enterprises prototype for all cotton zones. The study used cross sectional data to determine the drivers of farmers' decision to uptake multiple innovations, future research should use panel data to understand the long term impact of innovations adoption on small-scale farmers' productivity and income.

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APPENDICES

Appendix 1: Questionnaire

Adoption of Innovations and Resources Optimization in Crop-Livestock Integrated Production System among Small-Scale Cotton Farmers in Southern Mali.

Dear sir / madam
My name is Abdoulaye Nientao, a postgraduate student at Egerton University (Kenya) and a junior scientist research assistant. I am conducting a research entitled: "**Adoption of Innovations and Resources Optimization in Crop Livestock Integrated Production System among Small-Scale Cotton Farmers in Southern Mali".** I kindly request your assistance by providing information to fill the questionnaire below. Please note that your participation is voluntary and that any information given will be treated with utmost confidentiality and will only be used for the purpose of this study.

Partie A

SECTION I: Household Farm Information

1.Date : …./…… /……   Code enumerator I____I   ***N° Household Farm I___I___I___I___I***

Code Village I_____I (code villages= 01 ; 02 ; 03 ; 04)

2.Name of the household head (HH):………………………………………………………

3.Type of farm:………….. (1=Type A ;2=Type B ;3=Type C ;4=Type D)

SECTION II: SOCIO ECONOMIC CHARACTERISTICS

A. **Household Farm Characteristics** (the information in this table regards the household member who make decision on crops and livestock activities)

QUESTIONS	CODES	RESPONSE
1.Are you the head of the household?	*0=No;1=Yes*	
2.If the answer of Q2 is No, relationship with the HH?	*1=Spouse;2=Son/Daugther;3:Nephew/Niece; 4=Brother/Sister; 5=other precise……….*	
3.Gender of the respondent?	*1=Male; 2=Female*	
4. Age in years of the respondent if not the HH	Actual number of years	
5. Marital status	*1=never married; 2=monogamously married; 3=polygamously married; 4=Divorced;5=Widowed;6=other (specify)*	
6.Level of education of the HH	*1= None;2=Primary School;3=Secondary School;4= High School;5=University*	
7. Number of years in school	Actual number of years	
8. How many people are currently living with you at home?	*Females* *Males*	I_____I I_____I
9.What is your current occupation?	*1=farming; 2= off-farm business; 3=salaried 4=others (specify)*	
10.Participation in off-farm activities	*0=No;1=Yes*	

B. Farm Assets

Assets.sav

Items		Actual Number	*Actual unitary value*	*Actual total value*	Items		Actual Number	*Actual unitary value*	*Actual total value*
Items		**cnum**	**untval**	**totval**	**Items**		**cnum**	**untval**	**totval**
Shed	**1**				Truck	**18**			
Plough	**2**				Threshing Machine	**19**			
Farm store	**3**				Milling machine	**20**			
Sower	**4**				Weighing machine	**21**			
Disc harrow	**5**				Générating set	**22**			
Wheelbarrow	**6**				motorbike	**23**			
Manual pulverizer	**7**				Mobile phone	**24**			
Engine pulverizer	**8**				Boreholes	**25**			
Battery pulverizer	**9**				Other1 (Specify)	**26**			
Cart Donkey/Cattle/Horse	**10**				Other2 (Specify)	**27**			
bicycle	**11**				Other3 (Specify)	**28**			
Television	**12**					**29**			
Radio	**13**					**30**			
Energy solars	**14**					**31**			
Vehicule	**15**					**32**			
Lorry	**16**					**33**			
tractor(s)	**17**					**34**			

SECTION III: CROP LIVESTOCK INTEGRATED SYSTEM AND INNOVATIONS

1. Are you aware of any innovations of CLIS? I_____I (0=No; 1=Yes) INVCLIS

2. If yes, which innovations have you practiced in the last 2 years? I__________________I (Multiple responses) INVPRAT

   0=None ;1= Manual Cotton Topping ;2= Fodder Crops ;3= Lime Application ;4= Contour Ridging ;5= Other specify…………..
3. Sources of innovations? I________I (Multiple responses) INVSOCE

   Code information source: *1=Neighbour/Family/Friend;2=Radio;3=TV;4=Extension worker;5=Agro-dealer;6=University/Research Institution;7=NGOs/Projects;8=CBOs/Producer association;9=Other precise……………………*

4. **4.** Are you aware of any practices of CLIS? I_____I (0=Non ; 1= Yes) INVCLIS
5. **5.** If yes, which CLIS practices have you used in the last 2 years: I_________________I (Multiple responses)

Practices Codes: *1=Mulching to feed livestock;2=Green Manure Use;3=Livestock Manure Use;4= Composting Land;5=Crop Residues for feeding livestock;6=Fodder crops for feeding livestock;7=Other precise………..*

6. **6.** Source of CLIS practices? I__________I (Multiple réponses) INVSOCE

Code information source:*1=Neigbhour/Family/Friend;2=Radio;3=TV;4=Extension worker;5=Agro-dealer;6=University/Research Institution;7=NGOs/Projects;8=CBOs/Producer association;9=Other precise……………………*

SECTION IV: INSTITUTIONAL FACTORS

1. Access to Rural Financial Services

Did any Family Farm member try to get any agricultural cash credit during the season 2015-2016 cropping year? I____I 0=No; 1= Yes **AGRICREDT**

2. Accès aux facilités

Facilities /Services		Distance (Km) to the facility
Nearest and and permanent market centre	**markdist**	
Nearest extension services	**extendist**	
Nearest veterinary services providers	**vetdist**	

3. Extension services

a. Did you receive any extension advice? I______I (0=No;1=Yes) recextadv

b. If no, why? ....

..………………………………………………………………………………………

c. If yes, which extension service provider did you get information from? I____I extprov

Codes extension provider: 1=Government agent ;**2**=Non-Governmental Organization (NGOs);**3**=Farmers organization;**4**=Community based organizations (CBOs);**5**=Faith Based Organization (FBOs);**6**=Input dealer; **7**=Processing and marketing enterprise ;**8**=Research organizations**; 9**=private individual/firm; 10=other farmer(s);11=local leaders; 12= radio; 13=other specify…………..

4. Membership to farmers group and characteristics of group members (Give information on the 2 main groups)

a. Is anyone in this household a member of farmer or community organizations? 0=No; 1=Yes

b. If yes, indicate the details in the table below

Type of group	Activity of the group	Number of meeting scheduled in the last 6 months	Number of meeting attended in the last 6 months	Ranking from 0-10 How will you classify your participation in the group decision making?	Ranking from 0-10 How will you classify the trust level among group members?	Please, describe the group members' characteristics. Enumerator: **Ask if the group members are the same**							
grptyp	**actvty**	**smeting**	**mtnatd**	**decisions**	**trust**	**Neibor**	**ocuptn**	**Kin**	**Ecstat**	**religion**	**gender**	**age**	**heduc**
						Neighbourhood	Profession	Kinship	Economic Status	Religion	Sex	Age	Education level

(1)Type of group : 1= crops production ;2= livestock production ;3=forest protection ;4= commercialization of agricultural products ;5= seed production ; 6= village group; 7=selfhelp groups ; 8= well being group ; 9=other (specify)…………**(2) Activity of the group:**1=training;2=marketing for agricultural products ; 3= inputs acquisition ;4=financial services ;5=bio- agriculture ; 6=other (specify)………………

5. Training

a. Did you attend any training on CLIS in the past one year? I______I (0=No; 1=Yes) attdtrn

b. If yes, indicate the number of times you had attend training in the past one year? I____I trainattd

Partie B

Section I : Livestock Activities (Ask for the 4 major type of livestock)

What type of livestock are you keeping? (*see codes*)	2016-2017	
	Number owned	Average value per animal (Fcfa)

Livestcode: 1= Oxen; 2= other cattle; 3=sheep; 4= goat; 5=pigs; 6=chicken indigenous; 7=chicken improved; 8=guinea fowl; 9= donkey; 10=other specify………

- **Livestock Inputs - Oxen**

Inputs	Oxen (2016-2017)					
	Unit	Requirement	Available	Real	Unitary Price	Total cost
Labour	10					

Input unit: 1= Liters; 2=Kg ; 3= number ; 4=cart ; 5= wheelbarrow; 6=trays ; 7=lot ;8=bundle; 9=bag ;10=Man/day ; 11= other specify **LivestInput codes:** 1= veterinary services ;2=vaccines; 3= crab ; 4= salt bags ; 5= lick block stone ; 6= Cotton cake ; 7= Bran from cereals ; 8= crop residues ; 9= fodder crops ; 10= dewormers; 11= antibiotics ; 12= ligneous leaves; 13=other animal feed (specify)

- **Livestock Inputs – Other cattle**

Inputs	Other cattle (2016-2017)					
	Unit	Requirement	Available	Real	Unitary Price	Total cost
Labour	10					

Input units: 1= Liters; 2=Kg ; 3= number ; 4=cart ; 5= wheelbarrow; 6=trays ; 7=lot ;8=bundle; 9=bag ;10=Man/day ; 11= other specify **LivestInput codes:** 1= veterinary services ;2=vaccines; 3= crab ; 4= salt bags ; 5= lick block stone ; 6= Cotton cake ; 7= Bran from cereals ; 8= crop residues ; 9= fodder crops ; 10= dewormers; 11= antibiotics ; 12= ligneous leaves; 13=other animal feed (specify)

- **Livestock Inputs - Sheep**

Intrants	Sheep (2016-2017)					
	Unit	Requirement	Available	Real	Unitary Price	Total cost
Labour	10					

Input units: 1= Liters; 2=Kg ; 3= number ; 4=cart ; 5= wheelbarrow; 6=trays ; 7=lot ;8=bundle; 9=bag ;10=Man/day ; 11= other specify **LivestInput codes:** 1= veterinary services ;2=vaccines; 3= crab ; 4= salt bags ; 5= lick block stone ; 6= Cotton cake ; 7= Bran from cereals ; 8= crop residues ; 9= fodder crops ; 10= dewormers; 11= antibiotics ; 12= ligneous leaves; 13=other animal feed (specify)

- **Livestock Inputs - Goat**

Inputs	Goat (2016-2017)					
	Unit	Requirement	Available	Real	Unitary Price	Total cost
Labour	10					

Input units: 1= Liters; 2=Kg ; 3= number ; 4=cart ; 5= wheelbarrow; 6=trays ; 7=lot ;8=bundle; 9=bag ;10=Man/day ; 11= other specify **LivestInput codes:** 1= veterinary services ;2=vaccines; 3= crab ; 4= salt bags ; 5= lick block stone ; 6= Cotton cake ; 7= Bran from cereals ; 8= crop residues ; 9= fodder crops ; 10= dewormers; 11= antibiotics ; 12= ligneous leaves; 13=other animal feed (specify)

- **Livestock Inputs - Pigs**

Inputs	Pigs (2016-2017)					
	Unit	Requirement	Available	Real	Unitary Price	Total cost
Labour	10					

Input units: 1= Liters; 2=Kg ; 3= number ; 4=cart ; 5= wheelbarrow; 6=trays ; 7=lot ;8=bundle; 9=bag ;10=Man/day ; 11= other specify **LivestInput codes:** 1= veterinary services ;2=vaccines; 3= crab ; 4= salt bags ; 5= lick block stone ; 6= Cotton cake ; 7= Bran from cereals ; 8= crop residues ; 9= fodder crops ; 10= dewormers; 11= antibiotics ; 12= ligneous leaves; 13=other animal feed specify…….

- **Livestock Inputs – Indegenous Chicken**

Inputs	Indigenous (2016-2017)					
	Unit	Requirement	Available	Real	Unitary Price	Total cost

Input units: 1= Liters; 2=Kg ; 3= number ; 4=cart ; 5= wheelbarrow; 6=trays ; 7=lot ;8=bundle; 9=bag ;10=Man/day ; 11= other specify **LivestInput codes:** 1= veterinary services ;2=vaccines; 3= crab ; 4= salt bags ; 5= lick block stone ; 6= Cotton cake ; 7= Bran from cereals ; 8= crop residues ; 9= fodder crops ; 10= dewormers; 11= antibiotics ; 12= ligneous leaves; 13=other animal feed (specify)

- **Livestock Inputs - Broilers Chicken**

Inputs	Broilers (2016-2017)					
	Unit	Requirement	Available	Real	Unitary Price	Total cost
Labour	10					

Input units: 1= Liters; 2=Kg ; 3= number ; 4=cart ; 5= wheelbarrow; 6=trays ; 7=lot ;8=bundle; 9=bag ;10=Man/day ; 11= other specify **LivestInput codes:** 1= veterinary services ;2=vaccines; 3= crab ; 4= salt bags ; 5= lick block stone ; 6= Cotton cake ; 7= Bran from cereals ; 8= crop residues ; 9= fodder crops ; 10= dewormers; 11= antibiotics ; 12= ligneous leaves; 13=other animal feed (specify)

- **Livestock Inputs - Guinea-fowl**

Inputs	Guinea-fowl (2016-2017)					
	Unit	Requirement	Available	Real	Unitary Price	Total cost

Inputs units: 1= Liters; 2=Kg ; 3= number ; 4=cart ; 5= wheelbarrow; 6=trays ; 7=lot ;8=bundle; 9=bag ;10=Man/day ; 11= other specify **LivestInput codes:** 1= veterinary services ;2=vaccines; 3= crab ; 4= salt bags ; 5= lick block stone ; 6= Cotton cake ; 7= Bran from cereals ; 8= crop residues ; 9= fodder crops ; 10= dewormers; 11= antibiotics ; 12= ligneous leaves; 13=other animal feed (specify)

- **Livestock Input – Other**

Inputs	Pintade (2016-2017)					
	Unit	Requirement	Available	Real	Unitary Price	Total cost

Inputs units: 1= Liters; 2=Kg ; 3= number ; 4=cart ; 5= wheelbarrow; 6=trays ; 7=lot ;8=bundle; 9=bag ;10=Man/day ; 11= other specify **LivestInput codes:** 1= veterinary services ;2=vaccines; 3= crab ; 4= salt bags ; 5= lick block stone ; 6= Cotton cake ; 7= Bran from cereals ; 8= crop residues ; 9= fodder crops ; 10= dewormers; 11= antibiotics ; 12= ligneous leaves; 13=other animal feed (specify)

- **Livestock Products**

Products	Production (2016-2017)			
	Number of month	Average Quantity	Unit	Unitary Price

Livestprod: 1= cow milk ; 2 =Eggs ; 3=Hides and skin ; 4=Manure (only if sold) 5=meat ; 6=Other specify **Product units:** 1= Liters; 2=Kg ; 3= number ; 4=cart ; 5= wheelbarrow; 6=trays ; 7= other specify

- **Hiring/Renting of oxen and tractor (2016-2017)**

Oxen/Tractor				
1=Hire ; 2=Renting	1=Oxen ; 2=Tracteur	Number of day/ha	Price of a day/ ha	Hiring/Renting Cost

- **Livestock Selling (2016-2017)**

Livestock Type	Sale	
	Number sold	Average Price of selling

Livestcode: 1= Oxen ; 2= other cattle ; 3=sheep ; 4= goat ; 5=pigs ; 6=chicken indigenous ; 7=chicken improved ; 8=guinea fowl ; 9= donkey ; 10=other specify

Section II : Crops Activities (Give information for the 4 major crops of rainy season)

Which crop are you producing?				
What is the total land (ha) available per season for this crop?				
What is the area of land (ha) used to produce that crop?				
What is the land (ha) requirement for that crop?				
Total expected yield (Kg) for that crop?				
Actual yield (Kg) produced?				
Total expected yield (Kg) for that crop?				
Requirement labour for ploughing per ha for that crop?				
Expected available labour for ploughing for that crop?				
Actual labour for ploughing for that crop?				
Average price of labour ploughing per day for that crop?				
Requirement labour for sowing per ha for that crop?				
Expected available labour for sowing for that crop?				
Actual labour for sowing for that crop?				
Average price of labour sowing per day for that crop?				
Requirement labour for weeding per ha for that crop?				
Expected available labour for weeding for that crop?				
Actual labour for weeding for that crop?				
Average price of labour weeding per day for that crop?				
Requirement labour for earthing up per ha for that crop?				
Expected available labour for earthing upfor that crop?				
Actual labour for earthing up for that crop?				
Average price of labour earthing up per day for that crop?				
Requirement labour for harvesting per ha for that crop?				
Expected available labour for harvesting for that crop?				
Actual labour for harvesting that crop?				
Average price of labour harvesting per day for that crop?				
Total cost of threshing for that crop?				
Total cost for other1 operation for that that crop?				
Total cost for other2 operation for that that crop?				
Total cost for other3 operation for that that crop?				
Input1 code NPK				
Unit NPK				
Expected available quantity of NPK for that crop ?				
Real quantity NPK used per ha for that crop?				
Average price per unit of NPK ?				
Input2 code Urea				

Unit Urea				
Expected available quantity of Urea for that crop ?				
Real quantity Urea used per ha for that crop?				
Average price per unit of Urea ?				
Input3 code Herbicide				
Unit Herbicide				
Expected available quantity of Herbicide ?				
Real quantity Herbicide used per ha for that crop?				
Average price per unit of herbicide?				
Input1 code Seed				
Unit Seed				
Expected available quantity of seed?				
Real quantity of seed used per ha for that crop?				
Average price per unit of seed?				
Input1 code Insecticide				
Unit Insecticide				
Expected available quantity of Insecticide?				
Real quantity of Insecticide used per ha for that crop?				
Average price per unit of Insecticide?				
Code other input6 specify				
Unit input6				
Expected available quantity of Intrant6?				
Real quantity of Intrant6 used for that crop?				
Average price per unit of input6?				
Code other input7 specify				
Unit input7				
Expected available quantity of Intrant7?				
Real quantity of Intrant7 used for that crop?				
Average price per unit of input7?				
Code other input8 specify				
Unit input8				
Expected available quantity of Intrant8?				
Real quantity of Intrant8 used for that crop?				
Average price per unit of input8?				

Crop codes :01 : cotton, 02 : Millet, 03 : Sorghum, 04 : Maize, 05: lowland rice ; 06:Fonio ; 07:groundnut , 08: Cowpea (niebe), 09 : Potatoes; 10 : Sweet potatoes ; 11 : fodder crop ; 12 : Tomato ; 13 :yam; 14: soyabeans ; 15: sesame; 16: chilli pepper ; 17= Cassava; 18: other (specify)……… **Input Units:** 1=kg ; 2= liter ; 3=bag ; 4= box ; 5= sachet ; 6= cart ; 7=other (specify)………. **Input codes:** 1=NPK ; 2=DAP ; 3=Urea ; 4=seed ; 5=Pesticide ; 6= Herbicide ; 7=Insecticide; 8=Fungicide ; 9=Manure ; 10= compost ; 11= other input (specify).

THANK YOU

Appendix 2 : Pair-wise correlation coefficients for categorical variables used in MVP

	OfFarmAct	MCT	FC	LA	CR	CreditAc	TypeA	TypeB	TypeC	TypeD
OfFarmAct	1.000									
MCT	0.013	1.000								
FC	0.113	0.164	1.000							
LA	0.097	0.420	0.230	1.000						
CR	0.075	0.438	0.137	0.512	1.000					
CreditAc	-0.064	0.285	0.029	0.073	0.084	1.000				
TypeA	0.019	0.249	0.123	0.096	0.249	0.113	1.000			
TypeB	-0.079	-0.040	-0.065	0.010	-0.095	-0.014	-0.611	1.000		
TypeC	0.065	-0.233	-0.059	-0.104	-0.166	-0.121	-0.417	-0.351	1.000	
TypeD	-0.019	-0.007	-0.090	-0.015	-0.027	0.004	-0.168	-0.132	-0.093	1.000

Appendix 3: Result of the LP model on resources status for type A farms.

Resource variable	Shadow Price (Fcfa)	Resource status	Slack
Land	0.00	inactive	8.84
Ploughing labor	0.00	inactive	7.04
Sowing labor	0.00	inactive	12.53
Weeding labor	0.00	inactive	12.78
Earthing labor	0.00	inactive	9.88
Harvesting labor	3,983.96	active	0.00
NPK Quantity	0.00	inactive	862.81
Urea Quantity	133.35	active	0.00
Herbicide Quantity	0.00	inactive	11.60
Insecticide Quantity	0.00	inactive	5.12
Average_Land_cotton	0.00	inactive	5.75
Average_Land_Millet	0.00	inactive	3.55
Average_Land_Sorghum	0.00	inactive	2.43
Average_Land_Maize	0.0	inactive	2.01
Average_Land_Rice	204,446.80	active	0.00
Average_Land_Groundnut	0.00	inactive	1.30
Labour Livestock	0.00	inactive	285.79
Vet-services	0.00	inactive	35.58
Vaccins	0.00	inactive	39.19
Crab	0.00	inactive	295.35
Salt	0.00	inactive	165.88
CottonCake	0.00	inactive	454.29
Bran from Cereals	0.00	inactive	325.19
Crops_Residus_Labor	8,410.65	active	0.00
Dewormers	0.00	inactive	53.61
Antibiotic	0.00	inactive	53.78
Ligneous Leaves Labor	0.00	inactive	7.33
Straw _Labor	0.00	inactive	60.58
Average ox	0.00	inactive	4.54
Average other cattle	0.00	inactive	35.00
Average Sheep	0.00	inactive	12.00
Average Goat	0.00	inactive	10.00
Average_Donkey	0.00	inactive	1.00

Appendix 4: Result of the LP model on resources status for type B farms.

Resource variable	Shadow price (Fcfa)	Resource status	Slack
Land	0.00	inactive	5.48
Ploughing labor	0.00	inactive	7.32
Sowing labor	0.00	inactive	12.44
Weeding labor	0.00	inactive	10.71
Earthing labor	0.00	inactive	6.05
Harvesting labor	3,614.22	active	0.00
NPK Quantity	0.00	inactive	490.51
Urea Quantity	28.47	active	0.00
Herbicide Quantity	0.00	inactive	6.13
Insecticide Quantity	0.00	inactive	3.44
Average_Land_cotton	0.00	inactive	2.76
Average_Land_Millet	0.00	inactive	2.93
Average_Land_Sorghum	0.00	inactive	1.90
Average_Land_Maize	0.00	inactive	1.17
Average_Land_Rice	124,740.88	active	0.00
Average_Land_Groundnut	0.00	inactive	1.13
Labour Livestock	0.00	inactive	83.18
Vet-services	0.00	inactive	7.95
Vaccins	0.00	inactive	14.66
Crab	0.00	inactive	20.80
Salt	0.00	inactive	41.47
CottonCake	0.00	inactive	28.43
Bran from Cereals	0.00	inactive	112.30
Crops_Residus_Labor	6,354.05	active	0.00
Dewormers	0.00	inactive	1.61
Antibiotic	0.00	inactive	13.51
Ligneous Leaves Labor	8,487.88	active	0.00
Straw _Labor	0.00	inactive	3.92
Average ox	0.00	inactive	2.56
Average other cattle	0.00	inactive	3.04
Average Sheep	0.00	inactive	4.00
Average Goat	0.00	inactive	5.00
Average_Donkey	0.00	inactive	2.00

Appendix 5: Result of the LP model on resources status for type C farms.

Resource variable	Shadow Price (Fcfa)	Resource status	Slack
Land	0.00	inactive	4.33
Ploughing labor	0.00	inactive	7.59
Sowing labor	0.00	inactive	14.24
Weeding labor	0.00	inactive	21.71
Earthing labor	0.00	inactive	5.41
Harvesting labor	914.39	active	0.00
NPK Quantity	0.00	inactive	204.96
Urea Quantity	573.30	active	0.00
Herbicide Quantity	0.00	inactive	4.07
Insecticide Quantity	17,948.28	active	0.00
Average_Land_cotton	0.00	inactive	2.89
Average_Land_Millet	0.00	active	2.63
Average_Land_Sorghum	0.00	inactive	2.35
Average_Land_Maize	0.00	inactive	2.04
Average_Land_Rice	32,073.49	active	1.05
Average_Land_Groundnut	0.00	inactive	1.04
Labour Livestock	289.47	active	0.00
Vet-services	0.00	inactive	5.76
Vaccins	0.00	inactive	0.16
Crab	0.00	inactive	16.68
Salt	0.00	inactive	32.22
CottonCake	0.00	inactive	13.65
Bran from Cereals	0.00	inactive	72.42
Crops_Residus_Labor	0.00	inactive	1.66
Dewormers	6,781.58	active	0.00
Antibiotic	0.00	inactive	3.76
Ligneous Leaves Labor	0.00	inactive	8.69
Straw _Labor	3,476.61	active	0.00
Average ox	0.00	inactive	2.60
Average other cattle	0.00	inactive	1.39
Average Sheep	0.00	inactive	3.83
Average Goat	0.00	inactive	2.00
Average_Donkey	0.00	inactive	1.00

Appendix 6: Result of the LP model on resources status for type D farms.

Resource variable	Shadow Price (Fcfa)	Resource status	Slack
Land	0.00	inactive	2.82
Ploughing labor	0.00	inactive	3.37
Sowing labor	0.00	inactive	5.58
Weeding labor	0.00	Inactive	0.79
Earthing labor	0.00	inactive	2.81
Harvesting labor	3,143.67	active	0.00
NPK Quantity	0.00	inactive	166.33
Urea Quantity	244.48	active	0.00
Herbicide Quantity	0.00	inactive	4.03
Insecticide Quantity	0.00	inactive	0.43
Average_Land_cotton	0.00	inactive	0.88
Average_Land_Millet	0.00	inactive	0.60
Average_Land_Sorghum	0.00	inactive	0.50
Average_Land_Maize	0.00	inactive	0.64
Average_Land_Rice	0.00	inactive	0.10
Labour Livestock	463.38	active	0.00
Vet-services	0.00	inactive	14.00
Vaccins	0.00	inactive	7.00
Crab	0.00	inactive	35.75
Salt	0.00	inactive	14.75
CottonCake	0.00	inactive	23.25
Bran from Cereals	0.00	inactive	32.35
Crops_Residues_Labor	0.00	inactive	1.38
Dewormers	0.00	inactive	7.25
Antibiotic	5,562.78	active	0.00
Ligneous Leaves Labor	0.00	inactive	0.79
Straw _Labor	0.00	inactive	2.00
Average ox	0.00	inactive	0.79
Average other cattle	0.00	inactive	2.00
Average Sheep	18,851.32	active	0.00
Average Goat	0.00	inactive	2.00
Average_Donkey	0.00	inactive	0.71