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Farm Resource Allocation Decisions in Smallholder Farming Systems in the Mt. Elgon Region, Uganda

Dissertation
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Preface

This study focuses on farm resource allocation decisions that smallholder farm households have to make in order to achieve increased farm production. These decisions are usually made under constrained farm resources. Therefore, farm households often have to decide how and where to allocate their resources depending on their objective of production. This study assessed farm households' labor input in crop production activities, as well as the diversity that exists in the farming systems in relation to production resources. In addition, optimal cropping patterns in the smallholder farming systems were identified.

Analysis of the farming systems diversity in the research area revealed differences in resource endowments amongst farm households, which ultimately influences their labour allocation decisions. Results from the mathematical programming model, suggested optimal cropping patterns inclined towards crop mixtures. Eventually, the study then offers recommendations that can increase farm productivity through optimal crop selection, land and labour allocation.

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List of Abbreviations

AEU	Adult Equivalent Unit
ANOVA	Analysis of Variance
CA	Cluster Analysis
CP	Compromise Programming
DM	Decision Maker
EUT	Expected Utility Theory
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
GDP	Gross Domestic Product
GP	Goal Programming
LGP	Lexicographic Goal Programming
LP	Linear Programming
MAR	Mean Adequacy Ratio
MAUA	Multiple Attribute Utility Analysis
MAUT	Multi-Attribute Utility Theory
MCDM	Multiple Criteria Decision Making
MOP	Multi-Objective Programing
NAR	Nutrient Adequacy Ratio
PC	Principal Component
PCA	Principal Component Analysis
RNI	Recommended Nutrient Intake
ROC	Rank order centroid
TLU	Tropical Livestock Unit
UBOS	Uganda Bureau of Statistics
VOCP	Vector Optimizing Compromise Program
WGP	Weighted Goal Programming
WHO	World Health Organization

CHAPTER 1

1 INTRODUCTION

1.1 Background information

Usually, farmers' behavior in allocating resources, deploying farm practices and making payments made to the resources, is explained by a combination of microeconomic theories of rational choice, profit maximization and utility maximization (Donnellan and Hennessy, 2012). Farmers are believed to be rational in decision-making, and the decisions, they take, have social and economic implications; yet on the farm output and productivity. However, the "rational behavior" hypothesis is based on the knowledge and skills they have, the resources available to them and the input and output as well as market conditions. In this regard, socio-economic factors present (dis)incentives for farmers to select from the probable production activities (Altieri and Nicholls, 2004; Kruseman et al., 2006; Donnellan and Hennessy, 2012). Household resources such as land, capital and labour are allocated to various household activities in order to produce farm outputs which may either be for consumption or investment (Weltin et al., 2017).

Farmers' rational behavior specifically is also influenced by external conditions, including the agro-ecological factors and exposure to interventions. In particular, the agro-ecological environment offers a range of production possibilities or choices that the farm household can undertake (Kruseman et al., 2006). Farm households are seen as units where decisions regarding the allocation of scarce resources in order to achieve household objectives are undertaken. The farmer's goal to maximize "utility" is based, in this context, on decisions like which crops to grow and in what quantities, how to allocate resources to the different crop enterprises and the methods of production. The choice of crop and the management of these crops are fundamental in sustaining the stability between economic and ecological benefits of cropping systems.

Smallholder farming systems are multifaceted systems that interact with various internal and external factors. This makes the farm production system complex, with farmers' having incomplete knowledge of the whole system, and therefore, the so-called rationality in decision making may actually not be economically rational par se. This then calls for empirical modelling that relates the various farm constraints both internal and external to the farmers' objectives.

One major, resource smallholder farmers in developing countries, largely depend on is labour. Farm labour is a critical resource for most of the smallholder farmers in developing countries and therefore limited availability of labour is a major constraint to agricultural productivity (White et al., 2005; Ruben et al., 2006; Rosalien et al., 2017). Human labour, according to Pimentel and Pimentel (2008), expended in the production of food represents the main energy expenditure in developing countries. This labour is provided by the farmers themselves, who directly work on the farm with their household members and/or use hired labour from other households. On the output side, one major objective of smallholder farmers is producing food for their households in adequate amounts and throughout the year. At the same time, they aim at attaining consistent returns to household labour (White et al., 2005).

Additionally, higher population densities in developing countries also increase labour requirements necessary for the reinstatement and enhancement of soil fertility in smallholder farms (Binswanger-Mkhize and Savastano, 2017). They, however, face a challenge of appropriately valuing the labour they deploy in relation to the types of farm enterprises to operate, given the agro-ecological environment and market conditions. Like in many other farming cases, labour has been either undervalued making the enterprise seemingly profitable, or overvalued making the enterprise seemingly unprofitable (White et al., 2005). The farm household decision making therefore, offers an opportunity to assess labour value and the implications of various measures for crop choice, production technologies and resource use and allocation.

1.2 Problem statement

In many smallholder farming systems, farm household decision making on production is shaped by numerous factors including both internal and external. These external factors including the agro-ecological environment, market factors, and exposure to agricultural innovations together with other internal factors such as household resources make the production system very complex and this leaves the farmers with inadequate knowledge of the whole system (Rola-Rubzen and Hardaker, 1999). External influences from other actors on one hand, manifested through incentives, policies, extension services etc, have an effect on decisions made by the farm household. Price incentives on the other hand in the agricultural sector have also been found to provide positive signals for decisions in the production of agricultural commodities and resource allocation (Kamara, 2004; Tittonell et al., 2007).

In certain situations where there are missing markets or where market failures exist, as evident in developing countries, production and consumption decisions of the household have been known to be inseparable because both consumption and production decisions are affected by the same factors. De Janvry et al., (1991), for instance, noted that market failures occur for particular households and does not occur for commodities. The authors argued that, when such happens for certain peasant households, they are definitely forced to adjust on their household food consumption as well as the resources needed for the production of the food especially labour.

Circumstances of market failures such as the inelastic supply of labour during peak seasons have been found to constrain farmers' capacity to meet short-term labour demands and this, consequently affects farm profits (White et al., 2005). Additionally, such concerns like market failures, land tenure insecurity, lack of knowledge and information and unsupportive policies still inhibit the implementation of supposedly productive farming practices by smallholder farmers (Altieri and Nicholls, 2012). On the other hand, Smallholder farmers, especially in Africa, have been exposed to technologies geared towards conventional agriculture and this as well affects their decisions regarding resource use and allocation. It also presents a shortfall to transform to practices that conserve the natural resource base and enhance farm productivity (Mapfumo et al., 2014).

Farmers' production decisions such as which crops to grow, using which practices in order to meet their household food needs, given the available resources in combination with other external factors present a farm management trade-off. The trade-off arises because some farm resources such as labour are limited. For instance, there is competition for labour at peak periods especially between cash crops and food crops. Innovative technologies as well imply new labour demands and yet farm labour resources are limited. This makes such seemingly productive innovations to be financially less attractive. Even if such technologies might increase agricultural production and productivity, it can only yield larger benefits if it lessens farm labour requirements (White et al., 2005).

Therefore, the farm households' rationality in decision making may possibly not be economically oriented in terms of farmers' efforts, given the farm trade-offs. Household resource allocation is usually done in order to meet household food and nutrition needs; however, less attention is given to input factors such as labour which is a real constraint on production especially during critical tasks (White et al., 2005). Consequently, labour constraint results in some crop management practices not to be taken up by farmers because they demand much labour (Altieri et al., 2012; Lemken et al., 2017). Therefore relating various farm constraints to household production objectives requires a focus in on empirical modelling.

Therefore valuing labour based on the market wage rate is likely to misrepresent farmers' opinion of the value of labour. According to Marx's theory, labour in its self is just an activity and has no value, and that the labour-power exercised in labouring is the one that has value (Hollander, 2008). Accordingly, farm households apply their power to perform cropping activities. Consequently, this study values farm labour by taking into account the labour-power expended in crop production.

The study aims at improving an understanding of the farm household's rationality of crop choices, management practices based on labour availability in order to maximize farm household objectives in the Mount Elgon region in Eastern Uganda.

1.3 Research questions

The following research questions helped in guiding the study and fostered the achievement of the research objectives.

1. Which crops and crop combinations do farm households grow and what is the reason for choosing the particular crops?
2. How do farm households arrive at the decisions regarding which crops to grow and what drives those decisions?
3. How is farm labor allocated to the different kinds of crops grown in terms of subsistence and commercial crops?
4. Does farm labour input by farm households differ among the subsistence and commercial crops?
5. Does diversity exist among the farm households in relation to their production decisions?
6. Do household objectives have an impact on the allocation of farm resources?

1.4 Objectives of the study

The overall objective of the study is to assess farm households' decisions in resource allocation to production activities in the Mt. Elgon region in Eastern Uganda.

Specific objectives

1. To determine the rationality of labour allocation to the chosen crops by the farm households
    a) To identify the crop and crop combination choices of the farm households
    b) To identify labour allocation patterns and variability regarding food and income goals of farm households
2. To classify smallholder farms with regards to their crop production resources
3. To build linear programming and compromise programming models to estimate the optimal cropping pattern and resources needed to meet farm household objectives

1.5 Hypothesis

1. Crop usage and function as food or as a cash source within the household determines a farm households' decisions on resource use
2. Farms differ in their resource allocation and production orientation
3. Farm households consider several objectives during the decision-making process

1.6 Conceptual framework of the study

Attaining overall farm productivity must entail an understanding of how farm households behave and react towards ever-changing farming conditions. The behavior of farm households on the other hand has implications on farm productivity. Policy interventions targeted at improving the welfare of farm households should therefore focus on these changes that persuade farm household responding to these circumstances. Additionally, farm household behavior results from a decision making process which households strive to make. From literature, decision-making is based on the assumption that the goal of a particular decision is known though there are other possibilities, which are also fixed. Furthermore, the outcomes and risks of these possibilities are also presumed to be known (Ohlmer et al., 1998). Farm households operate under limited production alternatives from which they can choose probable possibilities.

Farm households are assumed to make decisions on crop production activities, such as the allocation of labour and land management practices in order to maximize their welfare. These decisions are made based on the human, physical, financial and natural capital available to the household every year. As such, (1) the decisions on which crops are grown, (2) how labour is allocated and (3) which land management practices to use, will vary since decisions are made at the start of each year (Nkonya et al., 2008). Sakai and Umetsu (2014) view farm households as embedded within a social-ecological system with both internal and external factors influencing farm production at the household and community level. These factors are important drivers in household decisions regarding cropping activities. This study focuses on the influence of these factors as illustrated in Figure 1.1. It looks at how the different components link within the system and how strongly they influence each other.

Figure 1.1 demonstrates the major factors that influence farm household decisions in the Mt. Elgon region regarding the allocation of resources, with a major focus on the labour resource. The interaction of the different components for example, the agro-ecological environment and the household characteristics influence farm labour allocation. The agro-ecological conditions explain the location of the household on the mountain landscape whereas the farm household characteristics include the household composition, asset ownership, among others. Determining farm productivity in relation to labour allocation is of great significance as it explains the total labour effort required in producing various crops. It also explains the "importance" attached to the individual crops by the farm households.

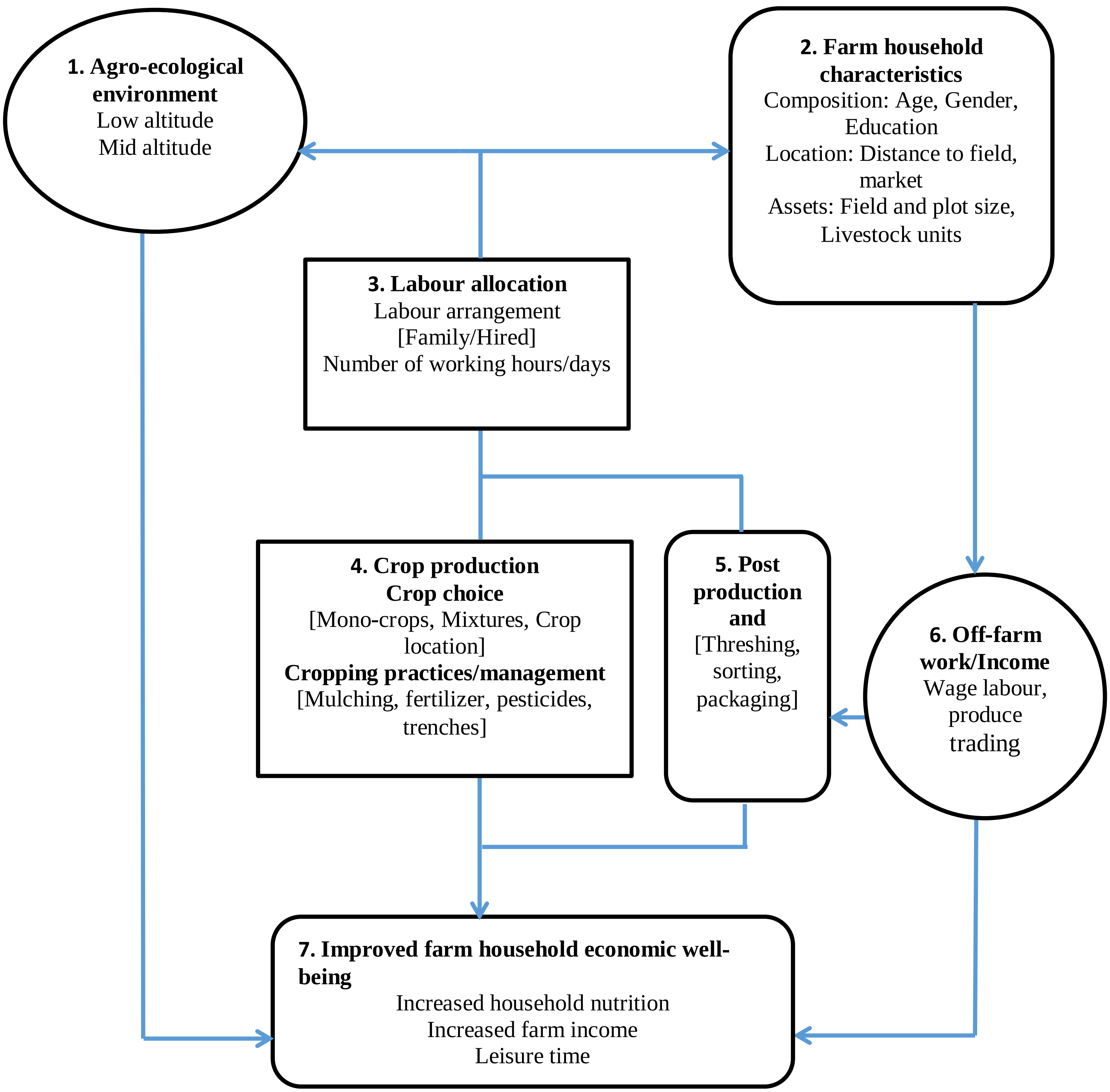


Figure 1. 1: Conceptual framework of the study

Source: Author's own conceptualization

1.7 Organization of the Thesis

This study is organized into eight chapters. The first part of the study (Chapter 1) introduces the study. This is followed by chapter two, which presents an overview of the farming systems in Uganda, as well as the evolution of farming systems in the study area. It also highlights Uganda’s agrarian economy. Chapter three provides the literature reviewed in relation to analysis of smallholder farming systems, including the theoretical frameworks. Also, it includes literature on assessing farm household objectives as well as analysis of multiple objectives.

Chapter four presents the study methodology, that is, the description of the study area (the Mt. Elgon region), and data collection methods, including sampling procedures. The chapter also provides descriptive results concerning the characteristics of farm households. Chapter five describes farm households’ labour allocation decisions regarding their production goals. This is followed by an analysis of smallholder farming systems in chapter six. This chapter gives an extensive analysis of the diversity of farming systems that exist in the study area.

A multiple objective programming model, using compromise-programming is then presented in chapter seven. It describes the optimal cropping patterns for smallholder farming systems in the study area. Chapter eight gives a general conclusion of the study as well as the policy recommendations based on the study’s findings.

CHAPTER 2

2 FARMING SYSTEMS IN UGANDA

The aim of this chapter is to give a general review of the evolution of farming systems in Uganda. Specifically, it highlights some of the major trends in the evolution of the Mt Elgon farming system with a focus on the northern slopes of the mountain where the study was carried out (Kapchorwa district). In addition, it also looks at the factors that have led to the major land use changes in the area.

2.1 The agricultural economy of Uganda

Agricultural activities are a major part of Uganda's economy. For example, the agricultural sector contributed 24.2 percent to the country's Gross Domestic Product (GDP) in the fiscal year 2017/18 (UBOS, 2018) compared to 23.8 percent in the fiscal year 2015/2016 (UBOS, 2016). The agricultural sector is comprised of sub-sectors namely; crop, livestock, forestry and fisheries. Considering the crop sub-sector, cash crops contributed 2.1 percent to GDP in 2017/18, while food crops contributed 12.8 percent to GDP in the same fiscal year. Livestock activities on the other hand contributed 4.3 percent to GDP in that particular year and forestry activities contributed 3.5 percent.

The industry sector, which contributed 19.9 percent to GDP in the 2017/18 fiscal year grew by 6.1 percent in the same year compared to 3.4 percent in 2016/17. This growth was attributed to the increase in agricultural activities. This strong growth was mainly due to strong performance of the agricultural activities, which provided raw materials to the industries (UBOS, 2018).
According to (UBOS, 2018), among the formal commodity exports, coffee was by far the main export. This was followed by gold and gold compounds. Fish and fish products ranked third while maize ranked fourth. In addition, agricultural products such as maize, beans and bananas were mostly exported to Kenya.

Over 80 percent of the country's population is involved in agricultural activities. Smallholder farmers account for 89 percent of all Ugandan farmers, and they contribute more than 80 percent of the total agricultural output annually (FAO, 2017). Agricultural activities are also the main source of income for the smallholders. However, 27 percent of these smallholders still live below the national poverty line (FAO, 2017). Most of what the households grow is consumed within the household while part of the produce is sold for income. Besides growing crops mainly for subsistence, households engaged in agricultural activities hardly ever get external support to improve their agricultural activities. As such, they generally depend on their individual resources. This leads them to for instance, cultivate smaller land parcels. On a similar note, an average smallholder household in Uganda has been found to cultivate an average of 1.1 hectares (Anderson et al., 2016; FAO, 2017).

The major food crops grown in the country include beans, cowpeas, soya beans, field peas, plantains, maize, sorghum, millet, sweet potatoes, cassava and Irish potatoes while cash crops include coffee, tea, cotton, sugarcane, tobacco and horticultural products. The area under main crop groups in 2017 were; Cereals (1,788,017 ha), Roots and Tubers (1,348,565 ha), Plantains (970,308 ha), Oil crops (934,456 ha) and Pulses (762,999 ha) (UBOS, 2018). Figure 2.1 presents the total area (ha) allocated to selected crops in the country. Among all the major crops grown, maize was allocated the largest area (1,129,277 ha). This is because maize is an important food security crop and it is also a major commodity export for the country.

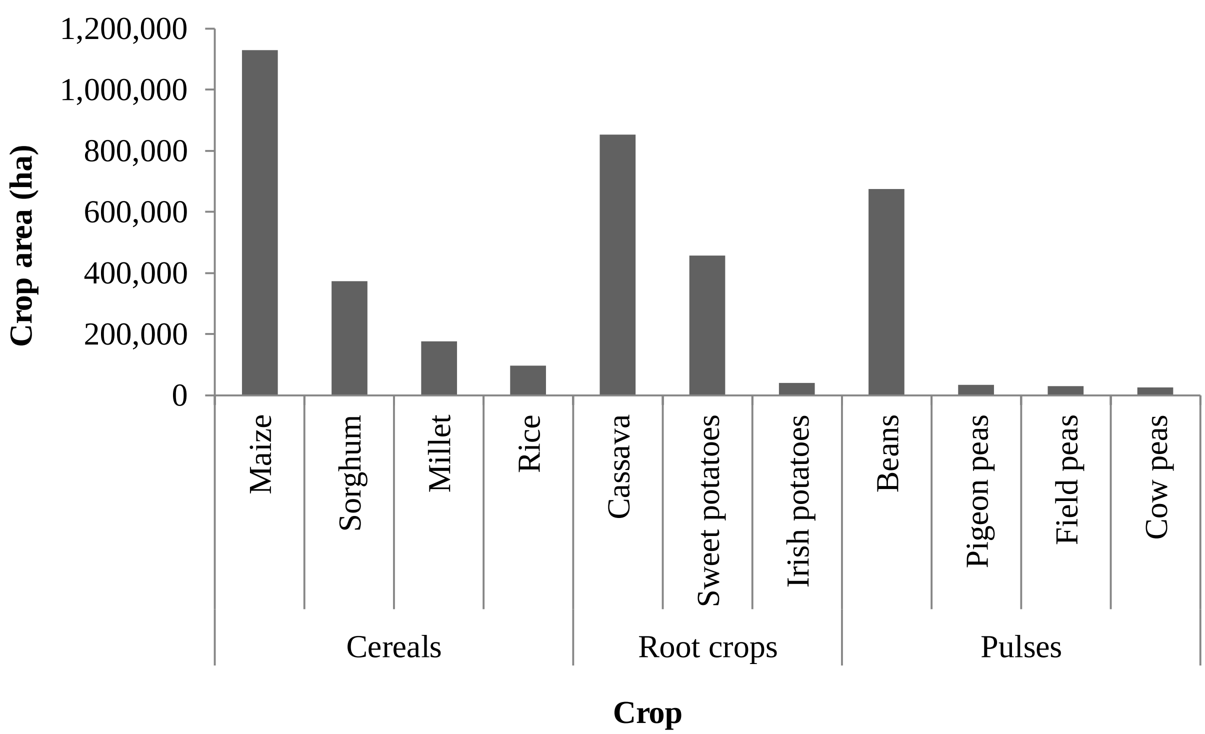


Figure 2. 1: Area (ha) under selected crops in 2017

Data source: Uganda Bureau of Statistics, 2018

Other crops that were allocated larger pieces of land included cassava, beans, sweet potatoes and sorghum. These are also important food security crops within the country and are grown for both household consumption and income. In an attempt to increase the production of such crops so as to meet their household food as well as income needs, some farm households practice agricultural intensification for example the use of inorganic fertilizers.

In Uganda, however, fertilizer use rates are very low with an average of 1.5kg/ha (Nkonya et al., 2008). Although fertilizer use rates are low, the use of fertilizer has been found to be highest in the Mt. Elgon region as compared to other regions in the country and it has been mainly used for maize production. Furthermore, the major sources of phosphorus and potassium in the Mt. Elgon farmlands were from inorganic fertilizers. The use of fertilizer in this region has been attributed to its close vicinity to Kenya. In Kenya, fertilizers are commonly applied to farmlands because the fertilizer market is relatively developed (Nkonya et al., 2008). Farm households in the area also apply organic manure to crops such as coffee and bananas. Besides that, due to the topography of the area, farmers construct soil and water conservation measures such as terraces, contours and trenches.

Also, land management practices employed in the region are mainly influenced by the kind of crops grown, size of plot allocated to crops and also the distance of the plots from the homestead. Although the use of agro-ecological approaches such as the use of organic manure, measures for conserving soil and water and other crop management practices are being promoted for environmental sustainability, smallholder farmers in Uganda are reluctant to apply these practices because of their labour intensity (Semalulu and Kaizzi, 2012).

In addition, farm households in Uganda have been found to carry out more crop diversification, with an average of four crops compared to other countries like Tanzania and Malawi where households only grew an average of two crops, which in turn had an impact on their nutritional status. Most of the commercialized households produced and sold food crops such as maize and beans. This was because of the portions of farm size allocated to these crops, therefore these crops had larger shares of production, indicating larger surpluses that could be sold (Carletto et al., 2017). On the contrary, a study carried out to find the impact of market production on rural household food consumption in Uganda, found that market production decreased caloric consumption of the households. The study found that households that produced rice for the market consumed less calories compared to non-rice producing households (Ntakyo and Van den Berg, 2019).

2.2 Evolution of farming systems in the Mt. Elgon region

Farming systems in Uganda were originally classified into nine major systems. These systems were largely determined by the rainfall pattern, soil types and cropping systems. Being dynamic in nature, farming systems in Uganda have experienced major changes due to factors such as population increase, political instability and livestock depopulation. Of recent, climatic variability has been one of the major factors that lead to changes in farming systems (Mukiibi, 2001). The Mt. Elgon region is classified under the montane farming system and it's characterized by high rainfall, Nitisols (soil type) and the production of perennial and annual crops (Osiru, 2006). In addition, the area is also characterized by high population densities and this is reflected in the low cultivable area per household. The major cash crops grown in the area are coffee and banana (Mukiibi, 2001).

Table 2.1 shows some of the major trends in the montane farming system. Initially, the people in the region were pastoralists who lived in the plains and in the lowlands. They also practiced a semi-nomadic agricultural production. Additionally, they cultivated mainly millet, sweet potatoes, cassava, yams, beans, maize and other vegetables. However, due to political instability in the country between the 1970s and 1980s, cattle raiding groups raided the area and seized cattle from these pastoral agriculturalists living in the lowlands. Consequently, households living in the lowlands started to shift to the upper slopes, which were covered with forests. They occupied the forested area and cleared land for agricultural production. On the other hand, some of the staple crops that they originally grew in the plains failed to perform well in the upland slopes (Himmelfarb, 2006; Vedeld et al., 2016).

As result, their focus shifted from crops such as cassava and millet to crops like maize, potatoes and beans. Since the terrain of the area had also changed, they also adopted farming techniques such as terracing, contour ploughing in order to prevent soil erosion in the upper slopes. From the 1990s (Table 2.1), intensive agricultural production began due to factors such as high population density, emergence of new markets and therefore some households shifted back to the lowlands. Increased access to markets led to increased cash crop production. And consequently, the use of inorganic fertilizers began in order to increase crop production (Himmelfarb, 2006; Vedeld et al., 2016).

Table 2. 1: Major trends in the Mt. Elgon region farming system

Period	Farming system	Drivers of change	Major crops
1960s-1980s	- Semi-mobile agro-pastoralists - shifting cultivation		- Millet, sweet potatoes, cassava, yams beans, maize, vegetables
	- Decline in livestock numbers - Change to settled agriculture - Clearing of forest for agricultural production - Adopted new farming techniques-soil conservation practices	- Political instability - Resettlement - Weather conditions - Topography	- Shifted attention from some crops, e.g millet, cassava - To-maize, - Maize, beans, bananas, coffee, vegetables - New crops-potatoes
1990s-2000s	- Combined agriculture and livestock - Intensive agricultural production - Increased cash crop production - Application of fertilizers/pesticides - Soil conservation practices	- Increasing population density - Soil fertility decline due to land degradation - Emergence and increased access to new markets - Government programs - NGO programs	- Maize, potatoes, beans, bananas, coffee, vegetables

Adapted from (Himmelfarb, 2006; Nkonya et al., 2008; Mugagga and Buyinza, 2013; Vedeld et al., 2016).

CHAPTER 3

3 LITERATURE REVIEW

This chapter gives a theoretical background of farming systems. It is upon these theoretical underpinnings that this study is based. It provides the theoretical background for analyzing farming systems. The literature focuses on how farming systems have evolved over time, peasant economies, decision systems, labor valuation, gender and labor allocation patterns as well as household crop production decisions.

3.1 Intensification of farming systems

Farming systems are dynamic in nature, and therefore evolve from time to time. With the increase in population worldwide, farming systems have shifted towards a high degree of intensification (Binswanger-Mkhize and Savastano, 2017). Also, these systems have become integrated with both crops and livestock. This transformation of farming systems has mainly been attributed to population pressures and market accessibility. These drivers usually force households to reduce the land under fallow, use organic and inorganic sources of nutrients to enhance the fertility of their soils.

Continuous cultivation and reduced fallows are practices linked to an increase in population density. The intensification operations however, increase costs to the farm households as they require huge investments. Such costs include labour and costs of purchasing farm inputs. Farm households however, carry out intensification operations because they have access to smaller parcels of land. According to Binswanger-Mkhize and Savastano (2017), these measures aim at increasing food production as a result of pressures on the small farmlands due to increased number of household members. These actions are also intended to increase farm household incomes, as it is assumed that households will be able to produce surplus output or produce for the emerging markets. The authors referred to these outcomes as the Boserup Ruthenberg (BR) predictions (Binswanger-Mkhize and Savastano, 2017).

As population densities increase and farms become connected to the market or new markets emerge, households intensify their production activities, thereby, leading to the evolution of labour intensive production methods (Pingali and Binswanger, 1986) first. Market access usually also increases farming intensity. On the contrary, extensive farming practices like bush fallows exist under conditions of poor market access (Pingali *et al.*, 1986). Increased farming intensity results in increased labour inputs for a given plot of land because cropping tasks for example, land preparation, which used not to be performed under the bush fallow stage have to be carried out. More so, certain tasks for instance, composting and manure application have to be added to the already existing tasks, thus increasing the number of cropping operations to be performed (Pingali and Binswanga, 1986).

Second, considering Boserup's view (Boserup, 1965) on the intensification of farming systems, increase in farming operations takes place as farming systems evolve from the initial stage of forest fallow to bush fallow, short fallow, annual cultivation and then to the multi-cropping system (Binswanger and Pingali, 1988). First of all, under the forest and bush fallow system, land clearing is carried out by fire, land preparation is not done and planting of crops is by broadcasting and use of sticks, though the use of hoes starts to emerge in the bush fallow system. Fields are fertilized with ash and kitchen refuse. In the forest fallow system, weeding is minimal and there is no use of animals. However, in the bush fallow system, weeding is required and the use of animals for ploughing starts because the length of fallow begins to decrease. The seasonal demand for labour is negligible in the forest fallow and only required for weeding in the bush fallow system.

In short fallow systems, land clearing is not done, land preparation and planting is by hoes and plows, manure, human waste and composting are used, intensive weeding is carried out and labour is demanded for land preparation, weeding and harvesting (Binswanger and Pingali, 1988).

As the systems evolve, land clearing does not exist anymore in the annual cultivation and multiple cropping systems. Land preparation and planting are carried out by draught animals, fertilization is done using manure, human waste, composting, green manure and use of chemical fertilizers. There is need for intensive weeding at this stage and likewise, labour is required for land preparation, weeding and harvesting. The seasonal demand for labour further extends to post-harvest activities in the multi-cropping systems. Additionally, there is intensive production of fodder in this final stage (Pingali and Binswanga, 1986).

Farming systems in Africa are also diverse in regards to culture, availability of labour and livestock among other factors (Ojiem et al., 2011). Binswanger and Pingali (1988) also add that differences in soils and climate make sub-Saharan Africa to have diverse farming systems. Also due to external factors such as changes in climate, farm households in sub-Saharan Africa have resorted to the intensification process by cultivating more than one crop (multiple cropping) in one plot of land (Amare et al., 2018). One notable characteristic of smallholder farming systems is their intensity in terms of plant diversity. This approach is practiced by smallholders as a way of reducing risks. It is practiced in several ways for instance, cultivating different types of crops and or different varieties of the same crop. It has also proven to be productive because crop yields are stabilized over time and increases dietary diversity at the household level (Altieri and Toledo, 2011).

However, there is a growing body of literature that agricultural intensification practices, used by some farmers to sustain production, such as continuous use of chemical inputs like fertilizers and pesticides, are linked to interferences with natural control of pests, nutrient cycling, water quality degradation as well as greenhouse gas emission. (FAO, 2014; Garbach et al., 2017). This has in turn constrained agricultural and ecological sustainability. On the other hand, Ruben et al., (2006), in their study to assess the link between nitrogen fertilization and labour use, found that higher amounts of nitrogen were available to be taken up by crops when proportional levels of fertilizers and labour were used, that is, the suppy of nitrogen increased with comparable labour use levels. In the same study, the authors noted that practices such as mulching were complementary with high labour use. This suggests that such agricultural intensification practices require a substantial amount of labour compared to practices like mulching. The use of chemical fertilizers for example, to enhance soil nutrients has also been found to be productive in the short run. In the long run however, this practice has been associated with soil organic matter depletion (Garbach et al., 2017).

3.2 The theory of peasant economy

One of the peasant household theories that links both consumption and production decisions is the Chayanov theory of peasant behaviours. Chayanov's theory is based on the theory of utility maximization of the peasant household (Ellis, 1993). In Chayanov's view, the objectives and the farm household's capacity to produce in order to meet the household's needs is dependent on the life cycle of the farm family. This is so because changes take place in the household in terms of producer-dependant ratio. The composition of the household in terms of age and sex of the household members also determine the household's total output produced. Furthermore, the variation in the amount of land cultivated by the family farm was strongly linked to the size of the family (Hunt, 1976; Ellis, 1993).

Various endogeneous and exogenous variables have been found to influence peasant household decisions regarding their farm production. Upton (1987) noted that the socio-economic and agro-ecological environment are considered the major factors influencing decision making of the farm household. According to Upton, (1987), farm management decisions are often related to decisions taken by the household regarding what to eat and how household time is spent. Additionally, decision making within the household may also be based on division of responsibility in such a way that certain crops are considered for women while men produce others. Chayanov also agrees that external factors like soil quality, climate, population density, market factors such as input and output prices are also key determinants of farm household output (Hunt, 1976).

With labour being the most important input in smallholder production systems, Chayanov, noted that household decisions are made based on the labour available in the household which can be expended in agricultural production in order to fulfill the household's consumption needs (Ellis, 1993). This also depends on the objective of the household. Chayanov himself, however, stressed that in peasant households, the labour market is non-existent or only just a few farm households hire in and hire out their labour mostly by in-kind payment. This theory has proved to be helpful especially in African farming systems for explanatory purposes, for example in explaining labour division within farm households (Ellis, 1993), because farm production activities are generally provided by family labour (Upton, 1987).

In some analyses of peasant households, households were found to derive their income from both farm and non-farm activities (Hunt, 1976). Farm households' are engaged in multiple activities, meaning they do not only carry out farming activities but also do participate in non-farm activities (Ellis, 1993). He is emphasizing that farm households make decisions concerning both farm and off-farm activities simultaneously. Chayanov's argument was that peasant households are embedded in larger societies and these societies do carry out marketing activities with larger systems, thereby making the peasant household production vulnerable to forces of the market. This implies that the households' capacity to participate in the market varies and they can as well withdraw from participating in the market and still have the means to survive (Ellis, 1993). Rola-Rubzen and Hardaker, (1999) agree that farm households are connected to the local, regional and national markets through the credit, labour, input and output markets. This linkage of the farm household to other markets may have an impact on decisions made by the farm household. For example, decisions regarding the kinds of crops to grow, this in the end, will lead to changes in cropping patterns and labour allocation among households. Additionally, these changes will in turn influence farm household time use, for instance time spent on leisure activities (Rola-Rubzen and Hardaker, 1999).

Chayanov for instance summarized peasant households as, " *households which derive their livelihoods mainly from agriculture, utilize mainly family labour in farm production and are characterized by partial engagement in input and output markets which are often imperfect or incomplete* (Ellis, 1993, 13).

It is important to note that the farm household therefore forms the primary unit of analysis because it is where production decisions are made and farm resources allocated. Upton (1987) posited that the development of agricultural production in a country therefore should take place at the farm household level.

3.3 The theory of labour value

Chayanov in his theory of peasant behaviours argued that peasant households do not employ hired labour and only use family labour because the value and therefore the cost of labour cannot be determined and consequently, returns from the various enterprises cannot also be measured (Hunt, 1976). The real value of labour in farm households has been of great concern in much of literature, because the local wage rate has been used to represent the value of labour insufficiently. This has been viewed as a misrepresentation of the value of labour and does not depict smallholder farmers' view of the actual value of labour because they seldom participate in markets (White et al., 2005).

According to Marx's theory of labour value, the cost of labour is actually the cost of living, for the labourer, i.e. in reproduction and not the cost of production of labour as the economists. A farmer had considered it to be (Marx and Engels, 1942) in analogy of the payment for a given amount of work. He puts it forward that the labourer puts his labour-power up for sale to the capitalist who in turn pays money for this commodity, labour-power. In other words, the labourer exchanges his commodity, power of work, for money. In Marx's view, the cost of maintaining the labourer is constituted in the wage paid to the labourer, and reflects the price of the commodity of the labourer, herein labour-power and not the price of labour (Marx and Engels, 1942). The rest is surplus.

In Marx's theory of labor value, labor-power has been defined as;
"*the aggregate of those mental and physical capabilities existing in a human being, which he exercises whenever he produces a use-value of any description*" (Hollander, 2008, 237).

Various authors have supported the idea that the value of labour lies in the human power. For example, Giampietro and Pimentel, (1990) also agree to this notion that the flow of applied power is provided by human labour and that the return to this human investment is the amount of energy output reaped from the farming system. For Thomas, (2010) production related activities have been found to employ human powers referred to as labour-power. Thomas (2010), reasons that the existence of labour-power or labour-capacity (in the living individual) occurs only as a capacity. In other words, it also implies the human's generic capacity working for food. In addition, since labour-power exists in the human body, it can therefore also be a commodity of the person owning it and can thus be exchanged for any other commodity, with less concern to use-values that would be attained from the exchanges (Thomas, 2010).

Marx's work in "Capital", views the owner of the commodity, herein labour-power as one who would therefore want to exchange his commodity for commodities from which he can derive satisfaction from its utilization if there is no other choice (institution) for survival. At the same time, he also wants to acquire a commodity, which is of the same value with his commodity. Therefore, like any other commodity on the market, the seller of labour-power recognizes the exchange value of his commodity and takes its use-value as a part of its equivalent (Marx, 2015).

Since the possessor of labour-power looks at it as his own commodity, it can thus be sold in the market, if the owner offers it up for sale, but only temporarily to the buyer. Therefore, in order to maintain this power or capacity (existing in the worker, such that it can be offered again the next time in the market for sale) the individual therefore needs a specific quantity of means for his sustenance. Marx argues that the value or cost of production of labour-power is thus established by the means of subsistence or price of the basic needs, needed in order to maintain the labourer and for his training and education (Marx and Engels, 1942).

The use-value of labour-power can also be assessed by the costs and expenses needed in maintaining the labourer in work. This labour-power is expended through exercising of human muscles, brain and nerves and thus need to be reinstated (Marx, 2015). This, according to Marx increases expenditure to the worker and therefore demands a high pay. Additionally, the labour time expended in the production of a commodity also determines the value of labour-power (Marx, 2015). The value of a commodity produced by the labour-power specifies the least possible value of labour-power, short of it, the worker or labourer cannot have his lost energy renewed (Marx, 2015).

Likewise, by setting the labourer off to work, the buyer of labour-power consumes it in producing commodities and also in producing commodities of surplus value (i.e profits). This, the capitalist achieves by receiving in exchange the productive action of the labourer and also more value given by the labourer to the amassed power he originally possessed (Marx and Engels, 1942). Thus the buyer of the labour-power benefits from the use-value and exchange value of the commodity alike. With reference to the above theory, this idea of labour value based on an individual's capacity to perform a task is of particular importance given the fact that farmers' value their labour efforts differently with regards to different tasks or cropping activities. In addition, the type and allocation of labour effort has been found to vary among several cropping practices (Rosalien et al., 2017). Similarly, Nuppenau (2015) notes that energy spent by peasant households varies in different crop production activities, and so if more food is in need to be produced by the household, more effort has to be expended in food production, in other words, the energy lost in production also increases.

3.4 Theory of decision systems

Figure 3.1 illustrates how decision systems are analyzed. The important aspects within a decision making model are the influencing factors, the decision processes and the implementation which involves management actions for example allocation of labour to cropping activities (Bongers et al., 2012). The outcome, which are the results of the management actions are the final aspects. Such results for example, within a farming system may include the availability of food for household consumption and income accrued to the household as a result of selling the "surplus" produce.

Farm households are seen as decision making units, which make decisions on production activities such as what to produce, how much to produce, which resources to use, how much and when to sell. These decisions are often based on endowments of the household and other external factors. Farm household decisions however, have been classified by Orr et al., (2014) under three different control categories, i.e, 'strategic', 'operational' and 'financial'. These categories all relate to having the power to control. First, the authors describe 'strategic' control as having the capacity to select how household resources are apportioned among crops grown. Secondly, operational control is defined as the capacity to select which crop management tasks are to be executed and when they are to be executed. Thirdly, financial control explains the capacity to determine who gets the benefits or income obtained from the sale of crops.

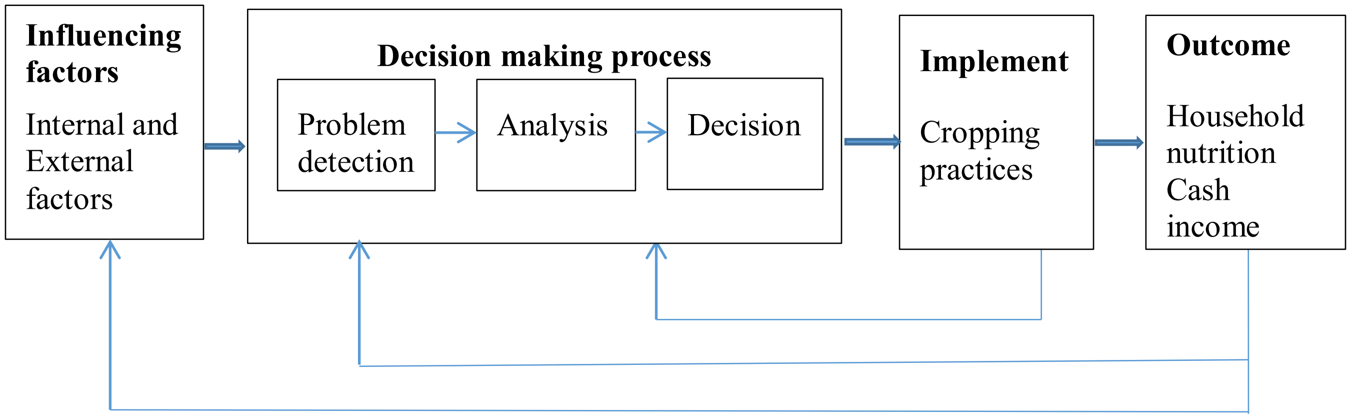


Figure 3. 1: Theoretical framework for decision systems

Source: Adapted from Ohlmer et al. (1998) and Bongers et al. (2012)

Furthermore, operational decisions, implemented by households, have consequences on the sustainability of the farm system as a whole. For example, the soil management techniques applied will determine the fertility status of the soils in the future. Consequently, soil management requires labour, which is a major ingredient for soil fertility improvement. Households are also faced with trade-offs when making these operational decisions. Such trade-offs may involve delays in planting of certain crops due to less labour being allocated to this activity. Consequently, this will have an impact on the crop yield (Tittonell et al., 2007).

3.4.1 Drivers of farm household crop production decisions

Decisions made by farm households are largely driven by household goals and or objectives (Wallace and Moss, 2002; Tittonell et al., 2005; Amare et al., 2018). Although these decisions exert influence on cropping practices implemented by households, certain production decisions are mostly affected by specific factors. Crop choice decisions in particular are to some extent influenced by household demographic characteristics (Amare et al., 2018). On the other hand, soil fertility management decisions are mainly influenced by the agro-ecological environment in which the farms are located. Therefore, based on the location of the farms, different soil and water conservation management practices are employed (Tittonell et al., 2005). However, some of these management possibilities are not practiced by some households owing to their high labour requirements (Ruben and Pender, 2004).

The presence of markets, especially for crops like vegetables that are perishable, also plays a substantial role in land use as well as resource allocation decisions (Tittonell et al., 2005). The distance of output markets from the farm, usually accounted for in terms of transport costs, has also been found to have an impact on land use patterns, for example the amount of land allocated to individual crops. Bowman and Zilberman (2013) cite the state of input and output markets as aspects, which influence production decisions of farm households. The state of input markets, for example the seasonal variation in labour demand, may hinder households from producing crops that are harvested during the same period, as the demand for agricultural labour is high during peak periods like harvesting.

On a similar note, the shape of the output market (exhibited in terms of output prices and transaction costs) determine whether a household will produce a particular crop or not (Amare et al., 2018). In light of the above, households however choose to reduce production risks by diversifying their crops through producing drought resistant crops, disease tolerant varieties, crops with varying maturity periods in order to lessen labor related risks (Amare et al., 2018). Variations in weather also pose challenges to smallholder farm production, as agriculture is mainly rain-fed especially in Africa. This affects farmers' crop choice decisions as they have to concentrate on crops that are resistant to such weather shocks, for example cassava, which grows under different weather conditions, as well as on soils considered relatively poor (Norton et al., 2015). Some farmers for instance, reduce the size of plots allocated to certain crops in order to reduce production risks (Amare et al., 2018).

Another example of the drivers of production decisions is access to irrigation facilities by Tanzanian farmers during the dry season. The access to irrigation facilities made the farmers to invest in high value crops and progress from subsistence to commercial production. Although the farmers were willing to diversify their production, the high input costs restricted crop choices for some farmers (De Bont et al., 2019). In line with this, Ruben et al., (2004) also agree that high transaction costs significantly limit farmers' willingness to diversify into high value crops. Furthermore, financial schemes that make cash accessible for the smallholders such that they are able to invest in production do influence cropping activities. These investments could include venturing into new crops and or technologies for instance the use of chemical fertilizers (Ebanyat et al., 2010; Bowman and Zilberman., 2013).

According to Morris et al., (2007) in sub-Saharan Africa, over 50 percent of all fertilizer is used on cereals, particularly on maize. Maize was mostly fertilized because it is a major food security crop in African countries and generally, cereal crops are very responsive to fertilizers.
Inorganic fertilizer application requires extra effort especially placement at the base of plants therefore labour availability is required prior to its use (Okoboi and Barungi, 2012). Wakeyo and Gardebroek (2013) agree that household labour is a complementary input and therefore its availability could increase the use of soil management practices like fertilizers.

Besides, Ouédraogo et al., (2001) found the practice of soil and water management activities playing a major role for increased economic gain of mineral, and or organic derived nutrient utilization under semi-arid conditions. The execution of these approaches, however, tends to be slow, given the fact that they are perceived by smallholder farmers to be labour intensive or viewed as undesirable labour tasks. For example, (1) application of manure, (2) measures for conserving soil and water, and (3) other practices related to crop management require quite more human effort and may seemingly lower returns to labour (Kruseman, 2000; Ruben et al., 2006; Lemken et al., 2017).

Farm household decisions on labour have been identified by many studies (White et al., 2005; Ruben et al., 2006) as having implications on farm productivity. However, such studies have not adequately valued farm labour and therefore farm budgeting assessments do not actually reflect the reality. Most valuation of labour has been based on the prevailing market wage rates, as a result, its value has been made lower and yet its value could be higher. Doss, (2018) also noted that farm labour is commonly measured as the number of days worked. This, according to the author, does not put into consideration the number of hours worked or the effort used in performing a given activity. Additionally, post-harvest activities are often excluded from the valuation of time spent in agricultural production activities (FAO, 2011) and yet these tasks are also part of production. Difficulties always arise in deciding which crop production activities are to be included in valuing labour-power expended in crop production.

Departing from the above-mentioned drivers of cropping decisions, other factors of cropping decisions include culture. A case in point was observed in Bolivia, where farmers cultivate a variety of potato vines, however, certain varieties are mainly needed during festivals for family and guests. Therefore, it is a cultural requirement for these potato varieties to be available during the festival season. This ultimately affects their cropping decisions (Norton et al., 2015).

3.4.2 Gender and labour allocation patterns in smallholder farming systems

Earlier research found that women contribute up to 50 % of the total labour input in agricultural activities in sub-Saharan Africa, with a contribution of slightly above 50% in East Africa although this excludes their labour input in food processing (FAO, 2011). With reference to Palacios-lopez et al., (2017), among the countries studied, Uganda had the highest estimated share of female agricultural labour at 56%. The number and composition of family members in relation to gender generally affected women's agricultural labour input. Also, reproductive activities like cooking, caring for children and the elderly are culturally regarded a female domain. Therefore, this ultimately affects women's labour input towards production activities.

Likewise, female labour input in production activities as well depends on the size of land allocated to crops cultivated by females. In certain cases, education differences between gender may make females allocate more labour to farm activities. This is because most females have no or low education levels and as a result, they are excluded from accessing off-farm jobs and therefore, have no option other than to resort to activities on-farm. Nkonya et al., (2008) adds that the use of land management operations is influenced by the education level of male and female household members. Doss, (2018) however argues that female labour input is much higher in reproductive activities and, therefore, females have less time to carry out farm activities.

In most African societies, especially in sub-Saharan Africa, women are commonly engaged in the production of staple food crops while the men concentrate mainly in cash crop production (Gladwin, 2002; Palacios-lopez et al., 2017). For this reason, they also cultivate smaller plots of land compared to their male counterparts. Female-headed households also, do not have many family members, and as such, there is less farm labour. Also, access to credit is limited in these households due to lack of collateral. Moreover, since cash crops are considered part of the male domain, these households definitely have less income compared to male-headed households (Gladwin, 2002).

In their quest to understand variations in farm productivity in relation to gender in Uganda, Peterman et al., (2011) noted that women were apportioned farmland that was relatively less fertile. These plots mainly had sweet potatoes and sorghum. The men's plots on the other side were comparatively more fertile and had crops like coffee and maize. Doss, (2018) agrees with this finding and adds that women usually have smaller and deprived plots of land. This definitely has an impact on the kinds of crops grown by the women, as certain crops require relatively fertile land.

In some parts of Uganda, men and women especially from polygamous households cultivated separate plots. Beans, for example, were cultivated on separate plots by men and women. Although the same crop was cultivated in these separate plots, the beans produced in the men's plots were for sale whereas those in the women's plots were for both household consumption and sale. As a result, the men grew bean varieties that fetched a higher price in the market while women cultivated varieties with low market potential. Even though in some areas women were involved in preparing beans for cash income, the husbands decided when and how much could be sold (Mukiibi 2001). Crop choices also vary among men and women, and this may be because women are less likely to have access to production inputs like fertilizers, pesticides, and have less access to market information. Therefore, they are inclined towards the production of crops that do not require these inputs (Doss, 2018).

Although time use surveys conducted by Palacios-lopez et al., (2017) highlighted vital differences in the time allocated to various crops and agricultural activities between different countries and also within countries. There are also differences in time allocated to various crops and activities across farmers and gender. Literature says that labour on farms is gender differentiated. Certain cropping activities are considered male activities. For instance, men are engaged in more physically hard tasks such as ploughing with oxen, land clearing and therefore are more inclined to choose crops with demanding tasks. Women on the contrary carry out cropping tasks which are less labourious such as weeding (FAO, 2011; Palacios-lopez et al., 2017). While looking at the land management practices employed by farm households in Eastern Uganda, Nkonya et al., (2008) found that male headed households applied more labour intensive practices such as manure in their fields because they had more labour. This is because, certain cropping operations, are performed by men. Nonetheless, accounting for female labour input in crop production has been a challenge as both men and women work together in the same plot as a household. In an effort to assign female labour input in production activities, various scholars have assumed that certain crops are specifically grown by women while others are produced by men (FAO, 2011).

3.5 Multi-attribute utility theory

Multi-attribute utility theory (MAUT) has been used recently to model farmers' behaviour. It is a tool linked to the analysis of decision processes (Butler et al., 2001). The theory helps to understand difficult decision problems that consist of several attributes as well as numerous objectives that may be in conflict with each other (Sanayei et al., 2008). Additionally, it values every alternative of the decision maker and examines the combined effect of the attributes

(Gómez-Limón, Arriaza and Riesgo, 2003). This is because, every alternative is considered important by the decision-maker. This has, in the end produced a logical analysis referred to as the multiple attributes utility analysis (MAUA). This analysis particularly aims at solving problems of trade-offs between the achievement of conflicting objectives in order to achieve overall maximum utility for the decision maker. In the theory, a decision maker can organise a difficult problem into a less complicated hierarchy and become able to assess various components when uncertainty exists (Sanayei et al., 2008).

Multi-attribute utility theory has been considered an extension of the expected utility theory (EUT) which was developed to assist decision makers to give values to their utility (Mateo, 2012). It has been considered as an extension because it considers more than one attribute of the decision-maker. In order to assign values, the preferences of outcomes of the decision maker have to be considered. The outcomes are assessed based on different attributes and then these are combined to obtain a general utility measure. The expected utility theory assumes that the preferences of the decision maker comply with the principles of ordering, independence and continuity. In addition, it also assumes that there exists a utility function, which gives values to every alternative. The expected utility theory has however been criticized because its application is only limited to a single attribute (Gómez-Limón et al., 2003).

Instead, the multi-attribute utility theory considers preferences of the decision maker using a utility function defined over a given set of attributes empirically grounded. Three stages have been identified in literature to determine the value of utility. These stages include; determining single attribute utility functions, verifying preferential and the circumstance of each utility, and deriving a multi-attribute utility function. These utility values may vary between zero and one, and express the level of importance in achieving a given attribute (Mateo, 2012).

A multi-attribute utility function in its general form can be written as $U\ [Z_1(x), Z_2(x),\ldots\ldots\ldots Z_p(x)]$, whereby the objectives defined as the arguments of the utility functions are also functions of the decision variables in the form $x=(x_1,x_2,\ldots\ldots x_n)$. In addition, one central requirement of the utility function is that it should thoroughly order alternatives for instance, if there are two alternatives, x^1 and x^2, then x^1 should be preferred over x^2, x^2 preferred over x^1 or both x^1 and x^2 are indifferent.

This study applies the multi-attribute utility theory, as farm households in the study area are considered decision makers who have several objectives that need to be met. Additionally, farm households do not attach the same value to every objective, as such, preferences are made according to the outcomes of these objectives.

3.6 Multiple objectives in farm household decision-making

This section investigates the different objectives that farm households seek to achieve. This is of importance because goals and objectives motivate the decision-making processes of the farm. Therefore, these farm objectives direct the procedure of optimization. In addition, various techniques of eliciting the objectives are discussed.

3.6.1 Identification of objectives in farm household decision making

In literature, the objectives or goals of a farm household have been greatly influenced by its phase on the farm life cycle (Wallace and Moss, 2002). These phases have been identified as; generation, maturation, decline and regeneration. Throughout the early phases of the life cycle, households have been found to place a high priority on the growth of the farm, for instance, going an extra mile of getting credit to attain growth goals. In this stage, less priority is placed on goals like risk aversion and leisure. As farms mature, households tend to place more emphasis on goals related to farm profits and efficient allocation of resources. At this level, risk aversion and time for leisure may be of priority. Through the decline phase, less priority is attached to the income maximization goal, as the household is more focused on security and less willing to take financial risks. Furthermore, more time is also allocated for leisure activities and time for farm work is reduced (Wallace and Moss, 2002). This is one way of explaining differences.

Alternatively, farmers' objectives have mainly been classified into two sets, that is, the economic and non-economic objectives. Farmers are known to have a wide range of objectives in which some are in conflict with each other (Costa and Rehman, 1999). These authors assert that eliciting farmers' objectives is not an easy task especially if a group of farmers is highly heterogeneous. However, they recommend administering open-ended questions to farmers in order to elicit their objectives, though they state that practically it has proved difficult for farmers to express their responses regarding their objectives.

In accordance with the above, a study conducted by Bebe et al., (2003) to obtain dairy farmers' reasons for keeping livestock and to identify their breed preferences, households were asked to mention their objectives for keeping cattle. Then they ranked the objectives. The objectives included; milk for household consumption, milk for cash income, animal traction, collateral for acquiring loans, attractive cattle looks, prestige and advice offered by extension services. From the rankings, households attached higher importance to milk production for household consumption, followed by milk for cash income.

In the same way, objectives such as maximization of profit, minimization of risk, minimization of total labour input and minimization of working capital were considered during the decision making process of crop production by farmers (Gómez-Limón et al., 2003). These objectives were obtained from a survey in which farmers were asked to reveal their crop production objectives. The objectives were then used to design a multi-attribute utility function which was then used to assess the importance of individual objectives in crop decision making (Gómez-Limón et al., 2003). Berbel and Rodriguez-Ocañ (1998) also generated a tentative set of farmer objectives after engaging in an interactive process with the farmers through a question and answer approach.

Sumpsi et al., (1997) however argues that eliciting objectives for modelling purposes should involve defining a set of objectives and their respective weights that are compatible to real behaviours of farmers other than those that are compatible with the answers that farmers provide in questionnaires. The authors suggest that a tentative set of farmer objectives should be formulated at the beginning and then these objectives tested alongside those revealed by the farmers. In so doing, a subset of objectives can then be obtained. Additionally, the authors also criticize the way objectives for modelling purposes are obtained. They claim that objectives are introduced with no empirical reasoning. In line with the above, they also comment on eliciting objectives through an interactive way of asking direct questions to the farmers, as this seems difficult (Sumpsi et al., 1997).

Following Sumpsi et al., (1997) view, Teufel, (2007) identified household objectives of smallholder farmers producing milk in the Punjab of Pakistan using a method known as numerical rating. This was done using a set of forty-six possible objective statements from which households evaluated every statement by considering its importance using a scale. Objectives were then grouped according to how related they were to each other and their grades based on their importance were then summed up. In a similar vein, Solano et al., (2001) also characterised objective profiles of Costa Rican dairy farmers using the Rokeach's technique. Seventeen objective statements were presented to the farmers from which farmers ranked them according to their importance. The statements included family, economic and personal objectives.

Other techniques of eliciting farmers' goals are also presented in literature. For example, (Fairweather and Keating, 1994) investigated farmers' goals in two phases in their study. First, they developed an inventory of farmers' goals. It included a list of statements of farmers' goals of farming. This was done by experts for example agricultural extension experts and the farmers. Secondly, the statements were presented to the farmers and they were asked to rank the goals and give justification for their rankings. In addition, the statements were then grouped into topics, i.e, those with similar content were grouped together. To validate the content of the statements, pre-tests were conducted with the farmers. Similarly, Costa et al., (1999) undertook a two stage process in their study to identify the objectives of cattle producers and the effect of the objectives on beef production systems in Brazil. In the first stage, experts were asked to provide a basis to formulate a hypothesis on the objectives of farmers. Secondly, farmers were then asked to mention their objectives of cattle production through a survey.

Departing from the identification of objectives, rankings have also been used to identify farmers' goal preferences. For example, Wallace and Moss (2002) identified farmers' goal preferences using paired comparisons and ranking exercises from a sample of dairy and beef farms in Northern Ireland. This was also used to categorize farmers into separate goal structures based on their primary objectives. Their results indicated that farm household life cycle has an influence on their goal rankings. In addition, the goal rankings were also converted to weights, which were then used in the multiple objective programming of the farms. According to Arriaza and Gómez-Limón (2003) the procedure of obtaining farmers' objectives involves direct communication with the farmers. In their study, farmers were also asked to rank their objectives. The top three objectives in their order of preference were maximization of profit, minimization of risk and minimization of farm labour.

Willock et al., (2008) however, used a farming objectives scale to determine the importance attached to farming objectives by the farmers. The farming objectives scale involved designing a questionnaire that included statements related to farmers' objectives. The farmers were then required to indicate the extent of their agreement with each of the statements on a likert scale. This was done in their study to identify the role that attitudes and objectives played in farmer decision making. The authors identified five factors that related to farmers' objectives from the survey. These factors included commercial goals, good quality of life, conservation, social status and non-farm goals. These factors represented farmers' objectives of farming. Furthermore, a five point Likert scale was used to measure the level of importance of the objectives. The examples mentioned above indicate that households not only have single objectives but rather multiple objectives and also not only do they have different objectives but also attach different preferences to the objectives.

3.6.2 Elicitation of weights of multiple objectives

Several methods have been used to determine weights of objectives in multiple criteria decision making. This is because not all objectives are of equal importance to the decision maker. Therefore, weights reflect the relative importance attached to the various objectives by the decision maker. These methods range from subjective to objective methods. Roberts and Goodwin (2002) identified three different categories used to determine weights of objectives. According to the authors, these methods require interviewing the decision maker and identifying statements that reveal the relative importance of the objectives. The responses are then used to establish the weights, which are in turn used to approximate the 'accurate weights' of the objectives.

Firstly, the direct rating method that uses direct numerical ratio judgment of the significance of an objective in relation to other objectives. Secondly, the point allocation method, where the decision maker has a defined number of points to assign among the objectives, finally, the rank ordering of objectives. Likewise, Wallace and Moss (2002) generated goal weights of multiple goals by converting goal ranks to model weights with the help of the rank reciprocal formula. Maggino and Ruviglioni (2011) also discuss the use of analytic hierarchy process to attain subjective weights of objectives. This relates to a pair wise comparison of the different objectives. It follows that, the rank ordering centroid (ROC) method has been suggested as a simple method of assigning weights to various objectives based on the rankings given to the objectives according to their importance (Zardari et al., 2015). Following Barron and Barrett (1996), in the ROC method, for the i^{th} ranked objective, the centroid weight is given by;

$$w_i\,(ROC) = \frac{1}{n}\sum_{j=i}^{n}\frac{1}{j}\,, \quad i = 1, \dots \dots, n \tag{3.1}$$

3.7 Review of Multiple Criteria Decision Making Approaches (MCDM)

Decision makers (DM) often have several objectives, and as such, it is imperative to optimize many objectives rather than optimising only a single objective. This is because, in reality, decision makers on a farm are rarely faced with a sole objective of profit maximization (Khan and Rehman, 2000). Decision-making problems are frequently depicted by multiple objectives, non-comparable and conflicting objectives. In certain cases, there is not always a hierarchy of objectives but also a hierarchy of sub-objectives (Haimes, 2009). Khan and Rehman (2000) also discuss that agricultural planning at farm household level is comprised of multiple objectives that need to be put into consideration when analysing these households. Agricultural households have various objectives and targets that need to be met, and for this reason, their behaviour cannot sufficiently be explained only in terms of profit maximization. The authors emphasize that only monetary objectives were maximized in the past due to difficulties in measuring the impacts of non-monetary objectives (Khan and Rehman, 2000).

In multiple objective optimization procedures, decision makers often aim at finding a set of optimal trade-off solutions, after which they can then utilize more information (e.g, qualitative information) to assist in obtaining the “best” choice. The trade-off solutions are the different values for the individual objectives after optimization. Figure 4 illustrates an ideal procedure for a multi-objective optimization problem.

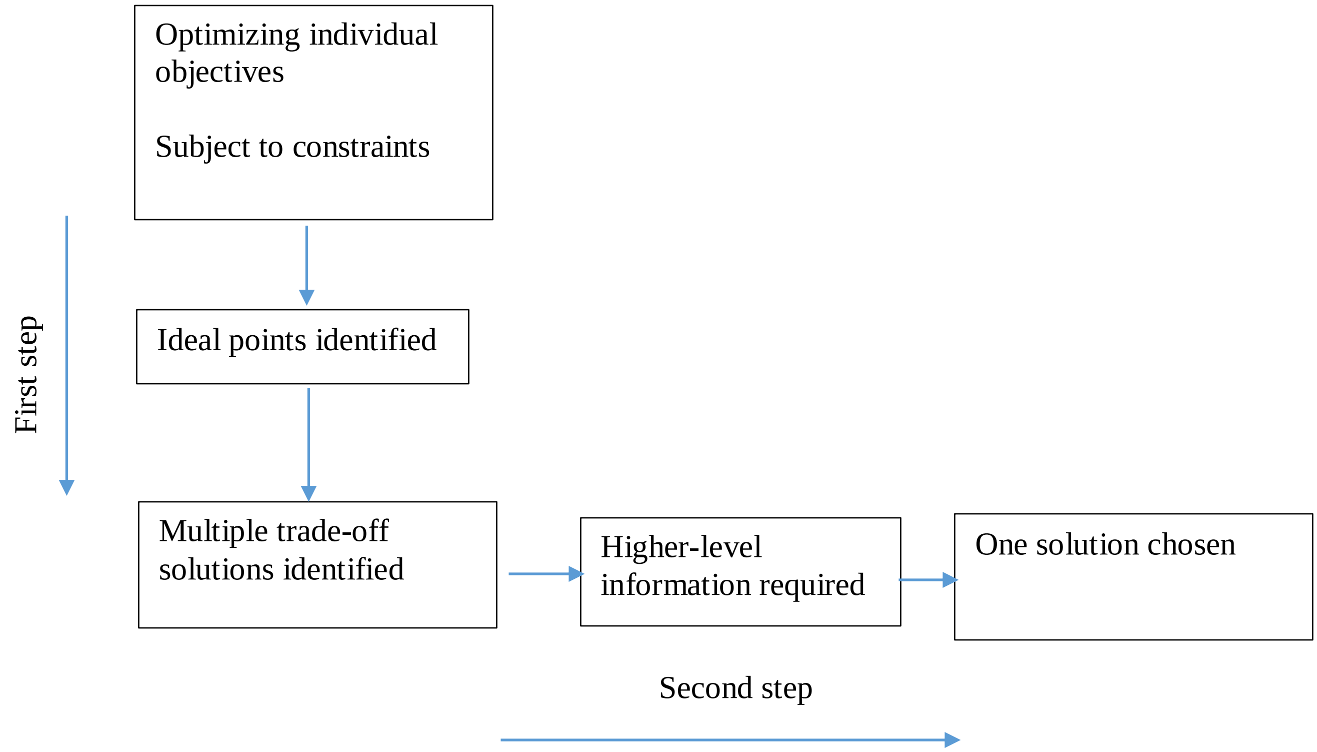


Figure 3. 2: Schematic outline of a multi-optimization approach

Source: Modified from Burke and Kendall (2005)

Given the existence of multiple objectives at farm household level, Multiple Criteria Decision Making (MCDM) approaches have been considered in the analysis of decision-making processes that consist of more than one objective. These approaches have been used to optimise household utility by simultaneously looking at different objectives (Teufel, 2007). Romero and Rehman, (2003) have explored the various methodological approaches used for analysing multiple objectives in agricultural decision-making. These approaches include Multi-Objective Programming, Compromise Programming and Goal Programming.

3.7.1 Multi-Objective Programming

Multi-Objective Programming (MOP) has been used to optimize a number of objective functions concurrently, and these functions are subjected to a set of constraints. In Multi-Objective Programming, a set of feasible solutions is generated from which all the objectives can achieve equal or even better results (Piech and Rehman, 1993; Berbel and Zamora, 1995). The feasible solution or efficient set are generated through the multi-criterion simplex methods, constraint or weighting methods (Berbel et al., 1991; Rehman and Romero, 1993). The efficient solution is a set that indicates the levels attained by every objective and gives information that is used to calculate trade-offs between the objectives. The efficient set can also be interpreted as the “production possibility frontier” of the objectives considered in the analysis. One advantage of the MOP is that it requires no prior preference of the objectives by the decision maker (Maino et al, 1993; Rehman and Romero, 1993).

This approach has been used in literature; one such example is Maino et al., (1993) who developed a Multi-Objective Programming model to analyze the potential impact of various technological interventions in peasant production systems in Chile. The approach proved useful in such a way that it highlighted the linkages between the various objectives of farmers. Furthermore, it emphasized the contribution of every production activity in the farm and the relationship amongst the activities.

3.7.2 Goal Programming

Goal Programming (GP) is the most commonly used MCDM approach. It is mostly used when goals for every objective attribute can easily be identified (Teufel, 2007). Again, it is also modified for decision makers whose decision-making processes relate to economic, social and environmental goals (Berbel and Zamora., 1995). According to Teufel (2007), every household targets to achieve a specific value for an individual objective, this target value is referred to as the goal. Equally, objective attributes refer to variables linked to the objectives. In Goal Programming, the deviations between the realization of the goals and the target goal levels are minimized. Targets are set by the decision maker and a satisfactory solution is found through the minimization of deviations from the set targets (Piech and Rehman, 1993; Wallace and Moss, 2002; Arriaza and Gómez-Limón., 2003). According to Khan and Rehman (2000), the targets are set by the decision maker because they reflect the decision maker’s aspirations to improve their wellbeing, for instance, improving their farm business.

Goal Programming involves two common variants, namely; Lexicographic Goal Programming (LGP), which necessitates that priority levels, be ordered and the Weighted Goal Programming (WGP) which does not need objective functions to be ordered (Berbel and Zamora, 1995; Teufel, 2007). In the WGP approach, weights are assigned to the different objectives to signify their relative importance to the decision maker and then put in one achievement function (Wallace and

Moss, 2002). Precisely, the Weighted Goal Programming (WGP) approach allows goal hierarchies and weights to be used in an accurate way (Khan and Rehman, 2000).

Pasic et al., (2012) illustrates the application of the Goal Programming technique in the optimization of feeding patterns of a reference man and woman in Bosnia and Herzegovina. The goals included meeting the daily nutrient needs of the reference man and woman and minimizing the daily costs of feeding. Their results showed zero for all the nutrient needs deviational variables, indicating that the nutrient needs for both the reference man and woman were met.

Certain studies have also used a combination of the approaches mentioned above, one clear example is Berbel and Zamora, (1995) who applied the Multi-Objective Programming (MOP) and Lexicographical Goal Programming (LGP) techniques to wildlife management in southern Spain. Their model sought to optimize the conflict between the economic and ecological objectives. From their analysis, the MOP showed a small conflict among the objectives, therefore, the LGP was used to enhance the suitability of a solution through stabilizing of species throughout the planning period. The study also illustrated the possibility of using both the MOP and GP techniques in natural resource management.

In a similar vein, Prišenk et al., (2013) combined the use of linear programming (LP) with weighted goal programming (WGP) to optimize feed rations for sport horses in Slovenia. The model included a classic LP, which was used to calculate the value of the least expensive feed, as well as a WGP, which gave the final feed equation. In their model, compared to the WGP, the LP only had a single objective that was to minimize the total feed cost. However, from their results, feed rations obtained using the WGP approach satisfied all nutritional requirements better as compared to the LP approach. Similarly, Khan and Rehman, (2000) demonstrated the performance of the LP and WGP models in their study to analyse the implications of introducing oilseed crops in the cotton zone of Pakistan's Punjab. Their results derived from the WGP models were closer to the actual situations of the representative farms.

Although Goal Programming is one of the most frequently used approaches, one main disadvantage of using it is that it requires normalization of the deviations of the objectives. Without normalization, it can cause distortion of results (Tamiz et al., 1998). According to

Arriaza and Gómez-Limón (2003), the deviations can be normalized by dividing the deviations by the articulated target levels.

3.7.3 Compromise programming

According to Romero and Rehman (2003), the compromise programming technique is a complement to the Multi-Objective Programming (MOP) technique. Compromise Programming (CP) finds the trade-off solution nearest to the ideal point, and is usually an unfeasible point. The ideal point is denoted by each objective's optimal point. This is done by introducing a distance function that minimizes the distance between every single compromise solution and the ideal point (Berbel et al., 1991, Berbel and Zamora, 1995; Piech and Rehman, 1993). This approach considers the subsets of the non-dominated set of objectives. This is done based on the importance attached to the objectives (obtained through weights) by the decision makers. Wegener et al., (2009) refer to a non-dominated set as a solution considered if no other solution containing a higher value for an objective function exists. The authors also state that Compromise Programming approaches calculate only non-dominated solutions in comparison to Goal Programming approaches. Compared to Multi-Objective Programming, Compromise Programming requires elicitation of objective weights from the decision makers, so as to represent their preferences. These weights are attached to the variations between the "ideal points" and actual achievements of the objectives. The "ideal points" represent the solutions where the objectives attain their optimum values (Rehman and Romero, 1993).

One example of Compromise Programming is demonstrated in Teufel (2007) who simulated potential technical improvements which included the introduction of new feeds, genetically improved animals, improvements in reproductive performance and veterinary health on small scale milk producers in the Punjab of Pakistan. Model results showed positive effects for most of the interventions in the ten improvement scenarios. Likewise, Fritzsch et al., (2011) also considered the Compromise Programming approach to take into account other objectives which were thought to be of importance to semi-subsistence farm households in Poland, Romania and Bulgaria. The objectives included maximizing net agricultural production, net farm income, credit balance and minimizing agricultural labour use of the household.

CHAPTER 4

4 METHODOLGY

4.1 DATA COLLECTION AND DESCRIPTIVE ANALYSIS

This section describes the study area and the data collection methods used in the study. Descriptive statistical results are also presented based on empirical data collected and it includes both household and farm characteristics.

4.1.1 Study area

The study was carried out in the Eastern part of Uganda, specifically in Kapchorwa district which lies north of the Mt. Elgon region. The region is located in the Elgon Highlands Agro-ecological zone. The regions of agricultural activities are in the highlands ranging from 2000 to 2500 meters (Tenyhwa et al., 2015), with the main soil type on the slopes being Nitisols (De Bauw et al., 2016). The region is mostly affected with soil degradation (Kansiime et al., 2013). Kansiime et al., (2013) noted that the region has a bimodal rainfall pattern with mean annual rainfall varying between 1374 and 2058 mm, and the rainfall distribution has been found to affect farm household decisions regarding crop choices and crop management practices. The main economic activity of the people in the district is farming, engaging more than 70% of the population, with coffee, bananas, potatoes, beans, maize and vegetables as the major crops.

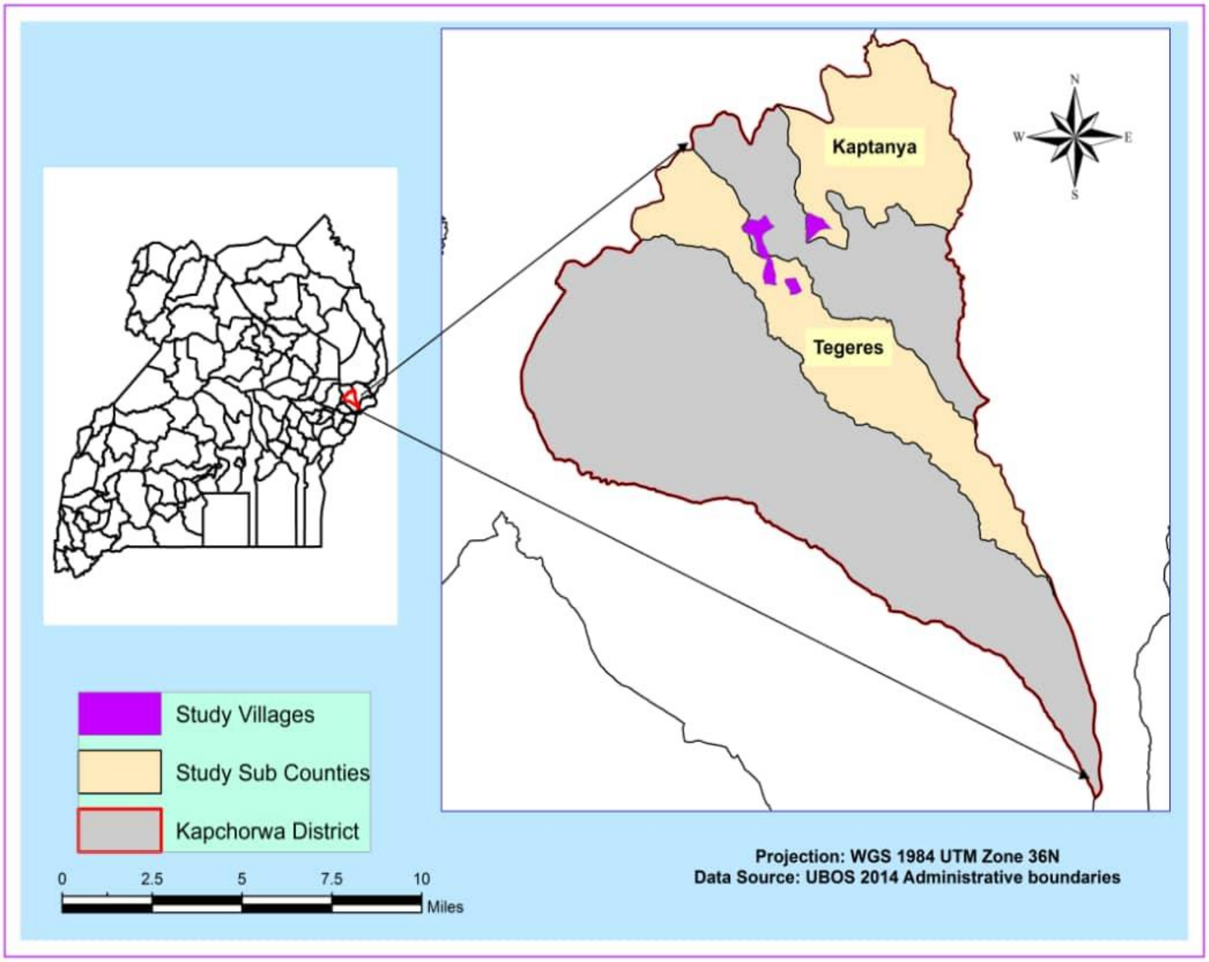


Figure 4. 1: Map of study area

Source: Author's own

Being a mountainous region, the district has three altitudes, i.e low, mid and high altitudes. However, the study focused only on the mid and lower altitudes because they are quite similar in terms of the farming system. Table 4.1 summarizes the altitude and population of the study sub-counties.

Table 4. 1: Population of the study sub-counties

Sub-county	Altitude	Population
Kaptanya	Low (1400-1700m)	2117
Tegeres	Mid (1700-2000m)	1768

Data source: UBOS (2014)

4.2 Data collection methods

This section gives a detailed description of the sampling procedures used in the study as well as the data collection techniques employed during the study. A summary of the data collected is also presented.

4.2.1 Sampling techniques and Sample size

The research was a cross-sectional study that used both quantitative and qualitative methods of data collection. The study was conducted during the period between September 2018 and February 2019. The population of the study was farm households located on the mountain landscape of Kapchorwa district. The sampling frame of the study included all farm households in the selected villages, with the farm household as the sampling unit.

The sampling technique included purposive and systematic. The district was purposively selected because of its high rates of soil degradation. Three sub-counties were purposively selected from the district due to their location on the different altitudes on the mountain landscape. Two villages from each sub-county were also purposively selected based on how far apart they were from each other. A systematic sampling method was employed to select the households for the survey because village data on households was not available.

Following (Israel, 2003), a proportional sampling method based on the target population was used to determine the sample sizes. A suitable sample size was calculated from the target population in the selected sub-counties. The formula is stated as;

$$n = \frac{N}{1 + (e)^2 N} \quad (4.1)$$

Where; n is the sample size to be projected, N is the population of the sub-counties and e is the significance level (0.05). From the above formula, the sample size was computed (n=363). However, a representative sample of 120 households was used due to the nature of in-depth questions. This gave a sample size of 65 households in Kaptanya, representing 54.2% of the total number of households (35 households in Molok village and 30 households in Kaptandar village) and 55 households in Tegeres representing 45.8% of all households (27 households in Seron village and 28 households in Kewel village).

4.2.2 Data collection techniques

Various techniques of data collection were employed during the study. These included key informant interviews, focus group discussions, household/field observations and household survey.

Key informant interviews

Key informant interviews were conducted to collect information on the agricultural system, agro-ecological details and markets in the area. Key informants included the district production officers, and the local leaders (village chairpersons from the four villages).

Focus Group Discussions

The focus group discussions (FGDs) included activities such as participatory system analysis and generating seasonal calendars. In addition, a checklist was used to collect the required information. Focus group discussions were conducted to gather data on the following;

- Crops grown by the households
- Crop combinations
- Labour requirements of various crops grown by farm households regarding cropping tasks/activities, in terms of time spent in performing an activity
- Labour costs
- Post-production activities.

Additionally, information regarding decision making within the household was also elicited. Eliciting this information involved asking the participants who (men or women) generally made decisions concerning particular activities within households. This included information such as; who makes decisions on the kinds of crops to be cultivated, sold, eaten and what influences those decisions.

Participants of the FGDs included both male and female participants who carried out general cropping activities and those who carried out exceptional cropping activities. Participants of the FGDs were identified through key informants. They comprised of a homogenous group even though they were able to offer variation in the data that was gathered. However, in eliciting information regarding food preparation activities, eight women were selected but only seven women participated in the focus group as earlier focus group discussions indicated that its women who mainly decide on the kind of food to be prepared and they are the ones involved in the food preparation process.

Seasonal calendars

The objective of creating the seasonal calendar was to get an understanding of the activities related to livelihood within the villages, livestock activities, crops grown and cropping tasks carried out throughout the year, busiest months and less busy months of the year as well as tasks related to gender (Table 4.2). Participants included both men and women who were identified through key informants. To identify the gender roles in various cropping tasks, participants were divided into two groups comprising of males and females, and each group listed the tasks that they carried out.

Participatory system analysis

Participatory communication theory forms the basis for the choice of method (participatory system analysis) used in this research. Participatory communication theory originated in the 1970’s and the theory explains the importance of engaging participants’ during the research process by allowing them to express their ideas and experiences (Literat, 2013). (Gonsalves et al., 2005) draws from this theory and gives more insights into participatory learning methods which build on a constructivist approach where both research participants’ indigenous knowledge and scientific knowledge are weighed equally. In addition, Cornish and Dunn, (2009) referred to participatory communication as a process whereby people share and express their experiences and knowledge. According to the authors, participatory communication values how people express their experiences and knowledge using visual materials. Literat, (2013) asserts that one of the applications of participatory communication is the use of visual methodologies.

The use of participatory visual techniques in research to generate data is considered advantageous as it includes the disadvantaged or marginalized community members such as the illiterate, who in most cases are also women (Parpart, 2000; Clark and Morriss, 2017). The inclusion of visual methods like collage in scientific research allows research participants to share their experiences and tell their stories, thereby creating new knowledge, giving meaning and insights to events (Gerstenblatt, 2013; Clark et al, 2017). The collage, a visual approach of inquiry, is a process by which images are cut and glued onto cardboard to illustrate a given situation (Butler-kisber, 2008; Fernández et al, 2010). The use of collage as an elicitation for discussion allows participants to generate several meanings and provide multiple interpretations (Butler-kisber, 2008). One advantage of using collages to generate data is that participants are able to change and reposition the photos. This enables participants to communicate their thoughts and allows them to express how they conceive circumstances (Kasemir et al., 2000; Roberts and Woods, 2018).

In order to elicit information concerning what drives farm households' decisions regarding which crops they grow, we used a participatory system analysis approach and adopted the collage as a participatory visual technique to aid in data generation (Figure 4.2). Using the collage to elicit information required the research participants to choose and arrange photos that they thought influenced their decision-making processes regarding their crop choices. The information acquired from this exercise was used to explore why households chose to cultivate particular crops.

Figure 4. 2: Participatory system analysis (Collage approach)

Photo: Author (2019)

Data collection process

The first phase of data collection focused on individual interviews with a household member, who was either the household head or spouse. The interviews necessitated the participant to identify the drivers, both within the farm household and outside, which influenced the kinds of crops cultivated by the households. Words that described the reasons why they grew particular crops were noted. Photographs that also best illustrated the drivers of crop choice decisions were taken during the interviews and through observations during field visits. The creation of the collages were then done in focused group discussions. This made use of the photographs taken during the interviews and field visits. Participants were then asked to choose and arrange which photos they thought influenced which category of crop (food crop, cash crop, both food and cash crop) they cultivated, and if it influenced more than one category, then arrows were drawn using a marker to indicate that it also influenced other crop categories. After completion of the collage, participants were then asked to explain why they chose certain photographs and placed them under the different crop categories. The participants of the focus group discussions included five males and five females. Two collages were created in each of the two sub-counties.

Household interviews

A semi-structured questionnaire was used to collect the household level data. The respondents of the questionnaire were household heads or spouses. Household level information related to general household characteristics, such as gender, age, household composition, education level, agricultural and livestock production, postharvest activities, food preparation activities and other income generating activities were collected. Detailed information regarding the food crops and cash crops grown by the household, size of farm, number of fields and plots, sizes of the field and plots, distance of the fields from the homestead, crop management practices carried out on each plot, kind of labour used on each plot, marketing of crop produce were also collected. A total of 120 household interviews were conducted.

Field observations

Field observations included observing the activities, which were performed by the household members/ hired labour. In addition, a checklist was also used and respondents were asked to explain their decision making processes regarding which crops to grow, why they decided to grow the crops, why on a particular piece of plot or field and why on a given area.

4.2.3 Summary of data collected

A summary of all the data collected during the study is presented in table 4.2. This also includes the method of data collection employed. Different techniques of data collection were employed in the study. These included key informant interviews, focus group discussions, field observations and household survey. Table 4.3 also shows the different production activities performed by households, with land clearing starting as early as January. Intensive activities are carried out between the months of March and April for first season crops and between August and September for the second season.

Table 4. 2: Summary of the data collection methods and data collected

Data collection method	Aim and Data collected	Location and sample size	
		Low altitude	Mid altitude
Key informant interviews	- Key informants included the district production officer and village chairpersons (4 villages) information collected to gain an understanding of the agricultural system, agro-ecological details and markets in the study area.	2	2
Focus group discussions	- Seasonal calendar- To get an understanding of the activities related to livelihood within the villages, livestock activities, crops grown and cropping tasks carried out throughout the year, busiest months and less busy months of the year as well as tasks related to gender. - Participatory system analysis- To identify the drivers which determine the kinds of crops cultivated by the households, decision making in relation to the kinds of crops cultivated, crops sold and quantity sold, food eaten - Mean labour requirements for cropping activities-both general and exceptional cropping activities as well as post-harvest activities - Food preparation activities and mean labor requirements - Focus groups included between 7-12 participants	6	5
Semi structured farmer interviews/ field observations	- Description of smallholder decision making process- To generate qualitative data	9	6
Household survey	- General household characteristics such as, location of household on mountain landscape, gender, age, household composition, education level of household head, livestock production, postharvest activities, food preparation activities and other income generating activities. - Crops grown by the household, size of farm, number of fields and plots, sizes of the field and plots, field distance from homestead, crop management practices, kind of labor used on each plot, crop harvest, marketing of crop produce	65	55

Table 4. 3: Seasonal calendar of crop production activities in Kapchorwa district

						Months						
			1st cropping season					**2nd cropping season**				
	January	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Cropping activities												
Land clearing	■											■
1st ploughing	■											■
2nd ploughing		■										
Nursery bed for coffee	■	■								■	■	■
Digging holes (coffee & bananas)		■	■									
Applying manure (coffee & bananas)		■	■	■								
Planting all crops, Maize, beans & potatoes with fertilizer			■	■				■	■			
Top dressing maize				■	■							
Ridging and top dressing potatoes				■	■				■			
Spraying maize				■	■	■						
Spraying beans & potatoes				■	■				■	■		
Weeding maize				■	■	■						
Weeding beans & other crops				■	■				■	■		
Weeding coffee & bananas	■	■	■	■	■	■	■	■	■	■	■	■
Harvesting maize								■	■			
Harvesting coffee									■	■	■	
Harvesting beans & other crops						■	■			■	■	■
Harvesting bananas	■	■	■	■	■	■	■	■	■	■	■	■
Digging trenches & terraces		■	■	■								
Planting grass along terraces			■	■								
Pruning and mulching bananas	■	■	■	■	■	■	■	■	■	■	■	■

4.3 Descriptive results for the study

This section presents results of the descriptive analysis from empirical data. The results give an understanding of the key elements of the study. A comparison of the variables such as crops grown, number of fields, field distances between farm households located in the different altitudes is presented.

Descriptive statistics such as percentages, means, standard deviations and t-tests were generated using SPSS and STATA computer packages to test for differences between the farm households in the two altitudes. This section describes the overall production characteristics of farm households in the study area. The results generated (in this section) are also used as input for further analysis in the subsequent sections, for example clustering of farm households.

4.3.1 Socio-economic characteristics of farm households

This sub-section provides comparisons between farm households in relation to their production characteristics. The comparisons are based on the location of the farms on the mountain landscape. The locations have been categorized as the low altitude and mid altitude. As mentioned earlier, the agro-ecological environment such as slope and soil conditions influences crop production in relation to the crop management practices employed. This subsequently influences labour allocation decisions. Therefore, the location of the households on the mountain landscape is used to categorize the farm households.

Figure 4.3 shows some of the characteristics of farm households located in the different altitudes on the mountain landscape. As shown in the figure, more households in the low altitude, that is, 49% of the sampled households hired land for crop production in comparison to 25% of the sampled households in the mid altitude. This suggests a scarcity of land in the mid altitude. Some of the survey respondents mentioned land scarcity in the mid altitude as a major reason for not hiring more land. Information from focus groups also revealed that land is available for hire in the low altitude compared to the mid altitude. It is worth noting that, for this reason, a higher percentage of households hired land in the low altitude.

Furthermore, the number of households that allocated part of their land for livestock keeping were higher in the low altitude (26%) compared to the number of households in the mid altitude (7%). This further indicates that the number of livestock owned by farm households in the low altitude is also higher compared to that owned by households in the mid altitude.

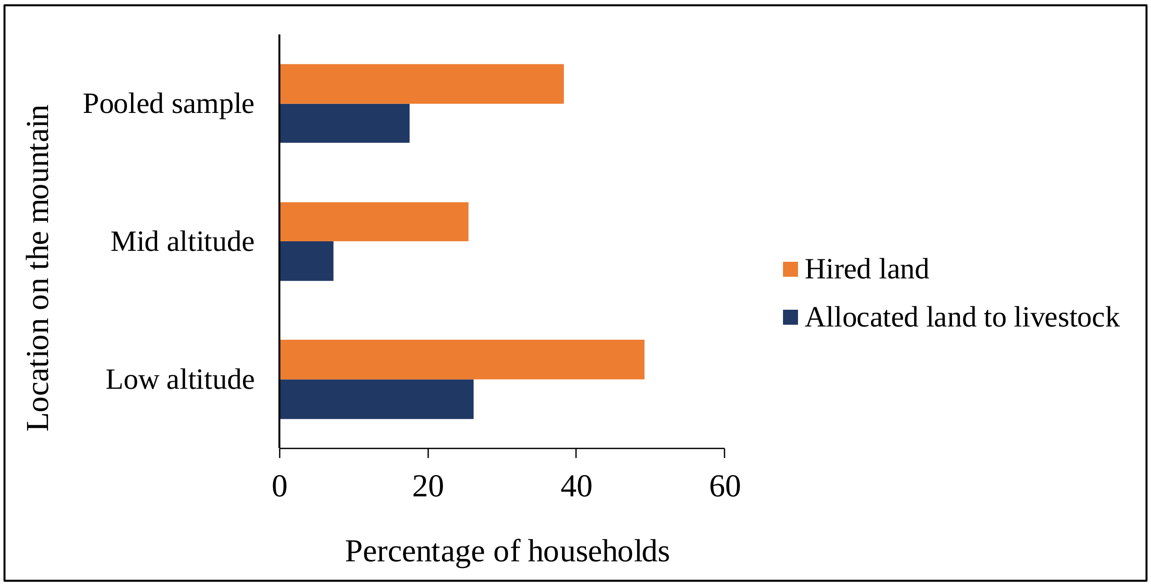


Figure 4. 3: Households that hired land and allocated land to livestock in the different altitudes

Source: Authors own computations based on survey data

Table 4.4 presents findings from a two-sample t-test. The results show a comparison between farm households located in the low altitude and mid altitude on the mountain landscape. The comparison is based on selected farm and household characteristics. These include; household size, number of household members by age group, amount of land owned and hired by the household, total amount of land accessed by the household, amount of land allocated to crop and animal production and livestock owned.

Based on the results, households in the low altitude had an average household size of seven members compared to six members in the mid altitude. Also, out of the sampled households, only 13 were female headed households. In literature, the composition of the household in terms of number, gender and age has been found to influence patterns in time use especially labour allocated to agricultural activities (Palacios-lopez et al., 2017). As such, it was important to study the household composition. The results also show a statistically significant difference in total accessed land, land allocated to crops and livestock owned by households located in the low and mid altitude. The average amount of land accessed by households located in the low altitude was one hectare as compared to 0.8 hectares in the mid altitude. Information acquired from key informants, focus group discussions and individual interviews indicate that there is scarcity of land in the mid altitude. This is attributed to more households settling in the mid altitude due to availability of social amenities, as such, less land is available for crop production and ultimately for rent.

Table 4. 4: Socio-economic characteristics of sampled households

Farm household characteristic		Location on the Mountain landscape Mean(SD)			P-values
		Pooled Sample (n=120)	Mid altitude (n=55)	Low altitude (65)	
Number of household members by age group	0-5 years	1.200 (1.001)	1.109 (0.994)	1.277 (1.008)	0.362
	6-15 years	1.866 (1.545)	1.574 (1.474)	2.108 (1.572)	0.061
	16-49 years	2.517 (1.566)	2.400 (1.582)	2.615 (1.558)	0.455
	Above 50 (n=43)	1.512 (0.551)	1.500 (0.589)	1.526 (0.513)	0.609
Household size (Number of people living in the household)		6.358 (2.869)	5.945 (3.033)	6.708 (2.697)	0.148
Amount of land owned by the household (ha)		0.826 (0.629)	0.753 (0.622)	0.888 (0.633)	0.246
Households that hire land (%)		38	25	49	
Amount of land hired by the household (ha) (n=53)		0.405 (0.250)	0.340 (0.201)	0.431 (0.264)	0.237
Total amount of land accessed by the household(ha)		1.006 (0.667)	0.846 (0.629)	1.144 (0.673)	0.015
Amount of land farmed by the household for crops (ha)		1.000 (0.691)	0.844 (0.634)	1.132 (0.715)	0.022
Amount of land used by the household for livestock (ha) (n=20)		0.230 (0.174)	0.340 (0.332)	0.203 (0.111)	0.163
Number of livestock owned by the household (TLU)		2.430 (2.315)	1.809 (1.564)	3.008 (2.730)	0.007

Figures in brackets represent standard deviations

Source: Authors own computations based on survey data

4.3.2: Field characteristics and crops grown by farm households

The number of fields or parcels owned by a household, as illustrated in Figure 4.4, has an impact on household labour resource use since farm households have to apportion their labour to the different fields. In this study, a field was defined as land that had one or more plots whereas a plot referred to a piece of land where a particular crop or mixture was cultivated. Majority of households in the low and mid altitudes had on average two fields, as shown in Figure 4.4. This was also a strategy employed by the households to spread production risks, although having different fields in various locations was mainly attributed to land scarcity.

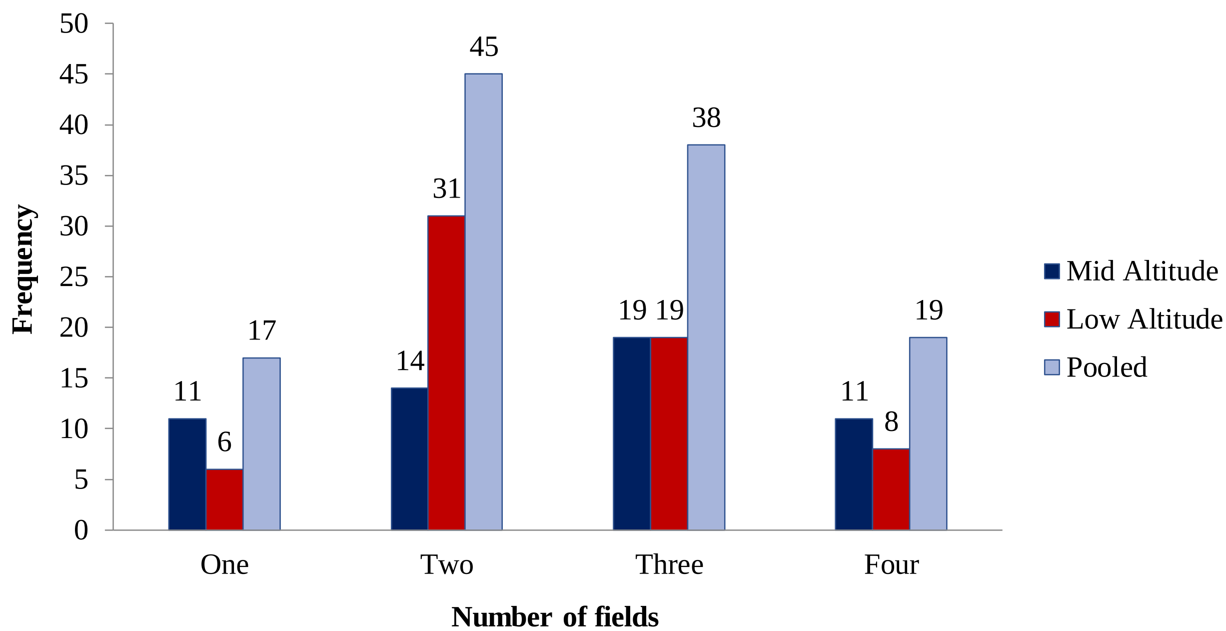


Figure 4. 4: Number of fields owned by households

Source: Authors own computations based on survey data

Nonetheless, households in the mid altitude had an average of three different fields compared to two in the low altitude. From the individual interviews, farmers attributed this to the scarcity of land in the mid altitude; as such, households own different fields located in different locations. This is so because it is difficult to get a large piece of land in one location for crop production. Additionally, out of the sampled households, notice 23 households from the mid altitude owned or hired fields in the low altitude.

Figure 4.5 shows field distances of the various fields owned/rented by the farm households. Distance of fields from the homesteads has been found to influence the allocation of household resources such as labour towards crop production activities (Tittonell et al., 2005). In addition, the authors also noted that the distance of the field from the homestead also had an impact on crop diversity, as the crop diversity decreased with an increase in field distance from the household. As such, it was imperative to look at the locations of fields that farm households cultivated. Four field distances; fields around the homestead, fields located 30 minutes away from the household (<30 minutes), fields one hour away (>30-60 minutes) and fields located more than one hour away from the homestead (>60 minutes) were identified.

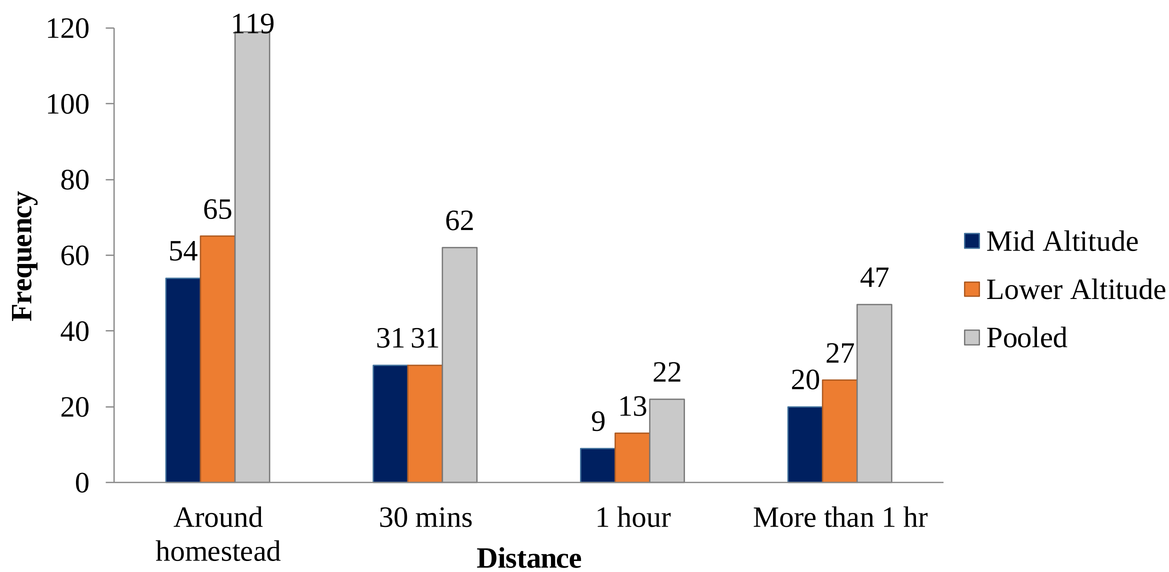


Figure 4. 5: Field distance from household

Source: Authors own computations based on survey data

Most of the households had home fields (Figure 4.5), that is, fields located around the homestead as compared to fields away from the homestead (outfields). The outfields may be comprised of one or more plots. These outfields were either located in the same village as the household, neighboring village or in a different altitude. Most of the home fields also included kitchen gardens, which were generally taken care of by the women. The kitchen gardens mainly had vegetables such as eggplants and pumpkins. Besides, the kitchen gardens were located near home and therefore, it was easy to apply manure. These fields thus, got a considerable amount of

organic manure and kitchen refuse. Households having one or two fields located around the homestead also meant more labour input in these fields. This is because these fields received manure, which is labourious to apply. On the other hand, it is difficult to transport manure to outfields, and so these fields were less taken of, implying less labour input in such fields.
From the individual interviews and field observations, other crops mainly grown around the homestead included bananas and coffee. These crops were planted near the homesteads for fear of theft.

The major crops grown by the households in the study area included bananas, beans, maize, coffee, sweet potatoes, cassava, eggplant, yams, Irish potatoes among others (Table 4.5). These crops were either cultivated as sole crops or as mixtures. Most of the crops were grown for both household consumption and cash income. However, the main aim of cultivating most of the crops was household nutrition. From the individual interviews, one of the respondents said *"I decided to plant maize because my stomach needs food, and I have free manure from my animals to add into the maize garden" response from a 50 year old male in Molok village*. Examples of crops grown for both food and cash included bananas, maize, beans. Banana was also considered a major food and cash crop for farm households because of its continuous harvest. Information from individual interviews also revealed that bananas were favoured because they provided feed for livestock through banana leaves, stems and peelings.
Typically, crops grown primarily for household consumption included sweet potatoes, cassava, pumpkin, yams and eggplant. On the contrary, crops grown primarily for cash were coffee and sunflower.

Table 4. 5: Crops grown by households in the different altitudes

Crop	Pooled sample (n=120)	Middle belt (n=55)	Lower belt (n=65)	Chi^2(P-value)
Coffee	90.830	92.730	89.230	0.4374(0.508)
Banana	100.000	100.000	100.000	
Beans	99.170	98.180	100.000	1.1917(0.275)
Maize	98.330	96.360	100.000	2.4037(0.121)
Irish potatoes	23.330	41.820	7.690	19.3945(0.000)
Sweet potatoes	53.330	34.550	69.230	14.4006(0.000)
Cassava	50.830	36.360	63.080	8.5061(0.004)
Sukuma wiki	22.500	20.000	24.620	0.3639(0.546)
Tomatoes	6.670	3.640	9.230	1.4985(0.221)
Cabbages	1.670	0.000	3.080	1.7210(0.190)
Onions	2.500	0.000	4.620	2.6036(0.107)
Pumpkins	37.500	32.730	41.540	0.9869(0.321)
Eggplant	55.830	61.820	50.770	1.4749(0.225)
Black nightshade	9.170	16.360	3.080	6.3165(0.012)
Sunflower	5.000	3.640	6.150	0.3975(0.528)
Yam	23.330	14.550	30.770	4.3834(0.036)
Passion fruits	5.000	9.090	1.540	3.5775(0.059)
Red pepper	0.830	1.820	0.000	1.1917(0.275)
Coco yam	5.830	3.640	7.690	0.8922(0.345)
Avocado	0.830	0.000	1.540	0.8533(0.356)
Field peas	5.830	5.450	6.150	0.0265(0.871)
Millet	2.500	1.820	3.080	0.1937(0.660)
Soybean	0.830	0.000	1.540	0.8533(0.356)
Barley	2.500	3.640	1.540	0.5379(0.463)

Source: Authors own computations based on survey data

The result in Table 4.5 also compares the percentage of farm households cultivating particular crops in the different altitudes (low and mid altitude). Certain crops are mainly cultivated at a given altitude. For example, more households in the mid altitude cultivate potatoes, mainly for cash, compared to households located in the low altitude. This was attributed to the cool temperatures in the mid altitude, which favored the growth of potatoes. On the other hand, this was the opposite for sweet potatoes and cassava, which required warm temperatures in the low altitude. Other than household nutrition and cash, additional reasons for growing the above crops included; less labour requirements for certain crops (bananas, eggplant, cassava, pumpkin), drought tolerant (bananas, sweet potatoes, cassava, yams, eggplant), cultural crop (bananas) and high output prices for some particular crops (coffee, beans and Irish potatoes). Furthermore, beans were also grown because the seeds were easily available for planting.

Some of the major crop mixtures are presented in figure 4.6. The most common crop mixture was banana and coffee. Other mixtures included maize and beans, bananas and beans among others. One main reason for carrying out mixed cropping was land scarcity. Other reasons for the various crop mixtures practiced by the farm households included soil fertility improvement, increase in production and risk reduction. Additionally, banana was mixed with coffee because banana provided shade for coffee. Shaded coffee has been found to produce higher yields and better quality cherries, which in turn fetches in higher prices for the coffee farmers (Jassogne et al., 2012). In a study carried out by Rosalien et al, (2017), farmers growing shaded coffee received a higher price per kilogram of coffee beans compared to farmers who grow coffee conventionally

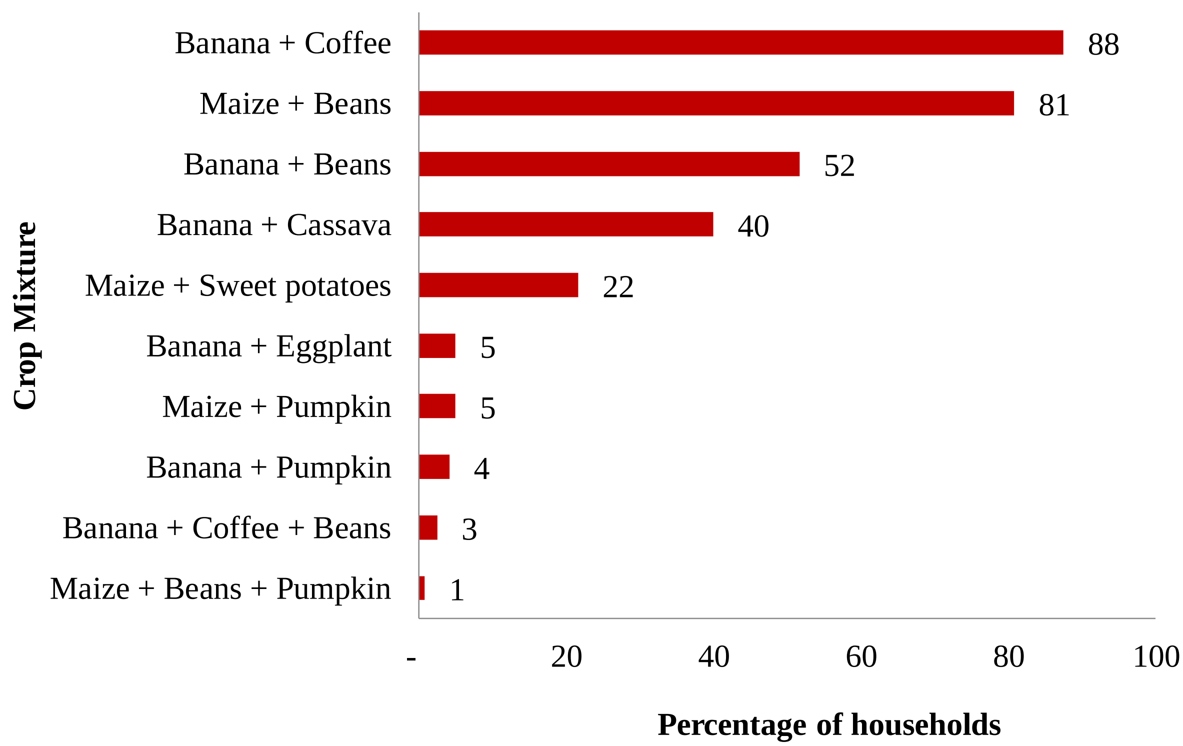


Figure 4. 6: Major crop mixtures grown by households

Source: Authors own computations based on survey data

One other strategy of managing production risks is crop diversification, which involves multiple cropping; that is, growing two or more crops in a given piece of land. Mixed cropping practices reduce the risk of soil erosion, control pests and also have a higher output (productivity) compared to mono-crops (Vandermeer, 2011; Lemken et al., 2017). In a similar vein, Altieri and Toledo (2011) also affirm that mixed cropping is one of the main characteristics of peasant farming systems. This is so because increased plant diversity at the field level stabilizes crop yields, increases household diet diversity and increases output.

In the same way, Lemken et al., (2017) documented that practices related to crop mixtures are thought of as appropriate for situations within developing countries whose labour costs are considered low. Moreover, the authors acknowledge that socio-economic studies related to crop mixtures are inadequate and mixed cropping practices, in particular, have been marginalized in smallholder farms. Likewise, some scholars, a case in point Altieri et al., (2012) assert that such practices intended for increasing plant species diversity in agricultural land as a means to improve agro-ecosystem services demand more labour and thus suitable for smallholder farms. In a similar vein, Rusinamhodzi et al., (2016) provide evidence for increase in labour demand in intercropping practices. The authors documented that weeding time increased in the maize-pigeonpea intercrop due to the need to carefully take care of the pigeonpea during weeding time, in addition to challenges faced while navigating through the intercrop during weeding. In certain cases, mixed cropping practices are thought to reduce weeding labour because they suppress weeds since there is more soil cover and crop biomass (Rusinamhodzi et al., 2016).

Households cultivated various crops as pure stands and also as mixtures. However, the mixtures were cultivated in different proportions. Other households on the other hand cultivated the mixtures in equal proportions. For example, maize and beans each occupying 50% of the land area allocated to the mixture. This was because majority of the households cultivated various mixtures in different proportions, which also translates to different labor requirements. Maize and beans mixtures were however grown in equal proportions by some of the households. Therefore, only households that cultivated the mixtures in equal proportions were considered. This was because household members estimated the labor requirements based on equal proportions of each crop. A total of sixteen households that had allocated land equally to both maize and beans in the mixture were identified.

Figure 4.7 illustrates labour input by households in a maize-beans cropping system. From the figure, households were grouped into three groups, depending on the level of labour input in the production of the crop mixture. The figure shows that households spent relatively more time in the production of maize and beans mixture, compared to the production of maize cultivated as a mono-crop. On the other hand, cultivating beans as a mono-crop required slightly more labour input, as compared to the crop mixture.

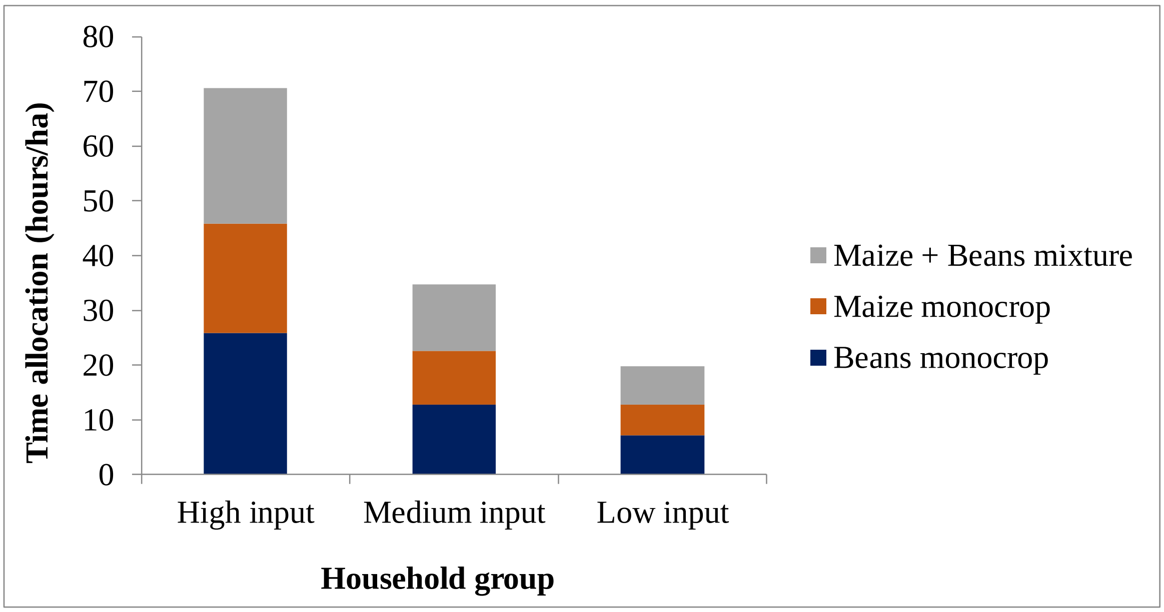


Figure 4. 7: Labour input in different cropping systems

Source: Authors own computations based on survey data

Departing from mixed cropping practices, households also preferred to grow certain crops as mono-crops. Such crops included sweet potatoes, yams and potatoes (Figure 4.8). Sweet potatoes were preferred as sole crops for easy management especially during weeding. According to information from individual interviews, yams were not intercropped with other crops because the roots of other crops penetrate the yam tubers thereby causing its poor yields. Importantly, yams were considered women's crop and only women are supposed to weed yams because they are more careful in carrying out the task. Children on the other hand were also not allowed to weed yams because they would cut the tubers thus reducing its yields. Equally, potatoes were mainly grown as sole crops for easy management because it requires various cropping activities such as weeding, heaping, spraying and fertilizer application. Therefore, more space was required when performing such activities.

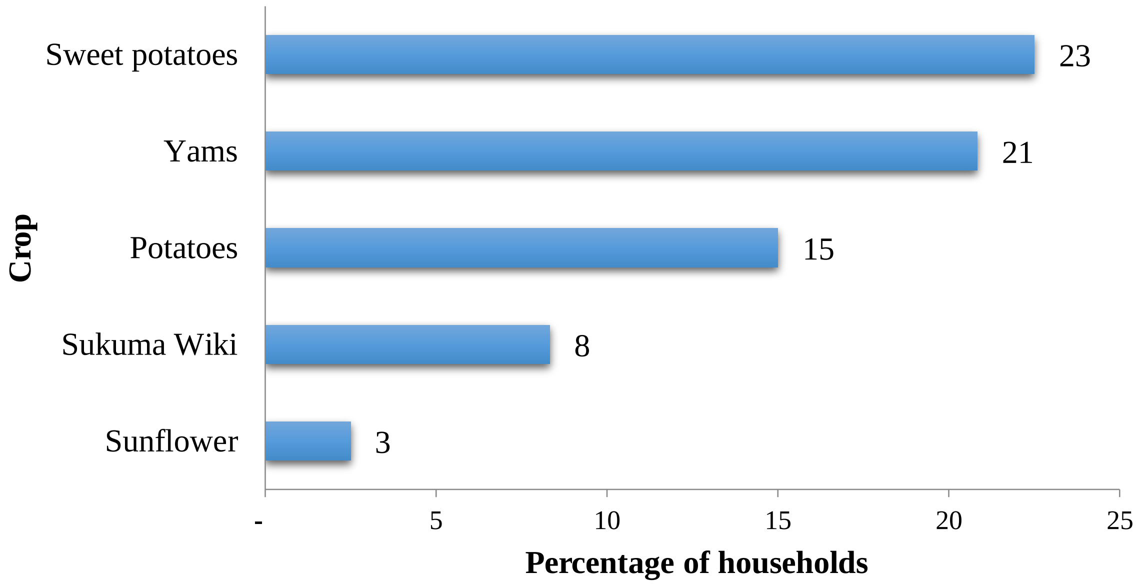


Figure 4. 8: Crops mainly grown as monocultures

Source: Authors own computations based on survey data

Although some households primarily practiced mono-cropping, especially for particular crops, this practice has however been criticized by some scholars. A case in point is Altieri et al., (2004) who argue that mono-cropping practices reduce biological activity and organic matter accumulation thus reducing soil fertility. Even so, Ritzema et al., (2019) mention that due to market forces, farmers allocate their production resources to mono-cropping practices owing to production specialization. This, the authors' note that, it is occasionally done without regards to biodiversity on the farm. Figure 4.9 shows a pictorial illustration of cropping practices employed by farm households as discussed above.

Coffee, banana, beans mixed cropping

Maize, beans mixed cropping

Banana, cassava mixed cropping

Sweet potatoes mono-cropping

Figure 4. 9: Examples of cropping practices implemented by farm households

Source: Author (2018)

4.3.3 Estimation of area allocated to crops grown by households.

In literature, the area allocated to various crops has been estimated either visually or through measurements. This is especially simple for mono-cropped fields. Under visual estimations, different methods have also been identified to estimate the area occupied by an individual crop under multiple cropping practices. An example of such a method is the allocation of part of the plot area occupied by the crops to each crop (Fermont and Benson, 2011; Sud et al., 2015).

This strategy was also used in this study to estimate the area allocated to different crops in a mixed cropped field. The area under an individual crop was visually estimated by the plot owner, by apportioning the area to each crop.

Figure 4.10 shows the proportion of land allocated to different crops by the households. The size of plot allocated to individual crops affects the land management practices and this ultimately influences the labour allocated to the different crops. Still, the size of land allocated to a particular crop also reflects the importance of the crop to the household, in terms of nutrition or income.

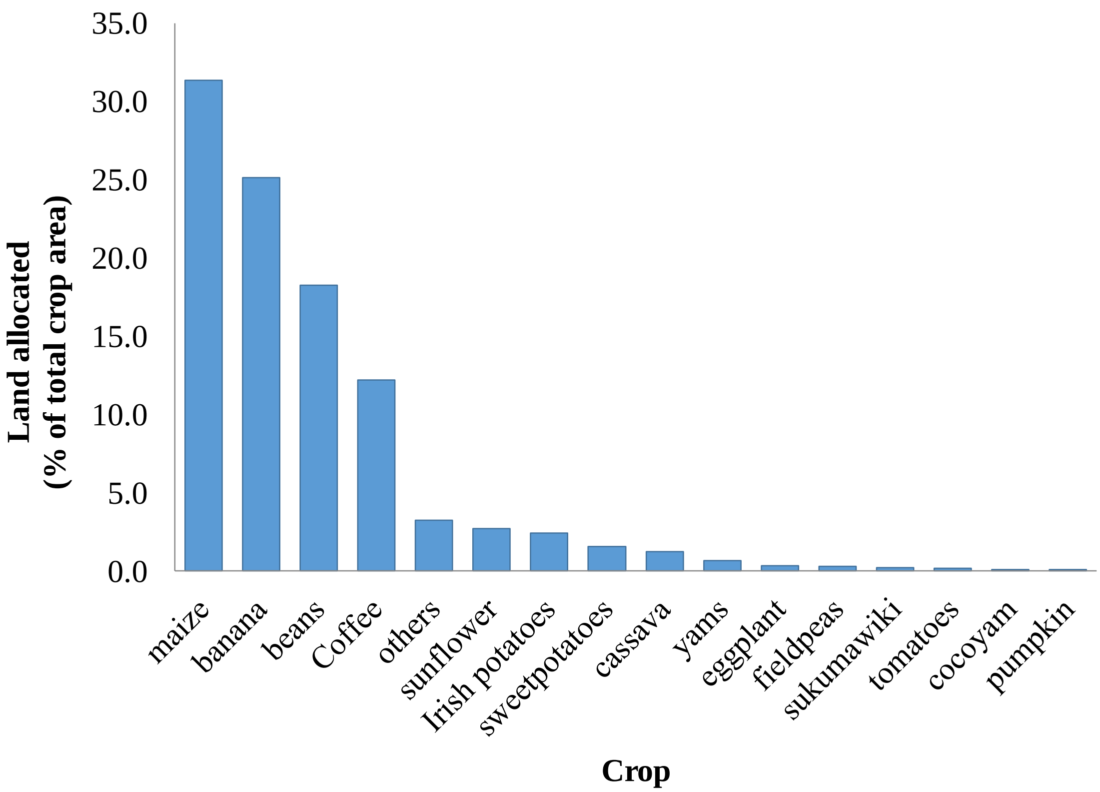


Figure 4. 10: Proportion of land allocated to crops

Source: Authors own computations based on survey data

From figure 4.10, the highest percentage of crop area was allocated to maize production followed by bananas, beans and then coffee. Maize, beans and bananas were cultivated on larger plots because they are the staples in the area and grown for both home consumption and for cash income. Coffee for instance was planted on a larger plot because of its high output price in the market and as such, provided income to the households. Crops like potatoes were also planted on relatively larger land sizes by some households because of its high market price. Table 4.6 shows findings from a two-sample t-test. The results show a comparison between the area allocated to selected crops by farm households located in the low and mid altitudes on the mountain landscape.

Table 4. 6: Land allocation to selected crops in the different altitudes

Crop	Location on the Mountain landscape Mean (SD)			P-values
	Low altitude (n=65)	Mid altitude (n=55)	Pooled Sample (n=120)	
Maize	0.446 (0.431)	0.258 (0.238)	0.361 (0.368)	0.008
Bananas	0.276 (0.212)	0.227 (0.196)	0.253 (0.205)	0.203
Beans	0.206 (0.131)	0.106 (0.105)	0.160 (0.129)	0.000
Coffee	0.136 (0.094)	0.132 (0.113)	0.134 (0.103)	0.859

From the table above, there was a significant difference in the amount of land allocated to produce maize and beans in the two altitudes. Farm households in the low altitude allocated more land to the production of maize and beans compared to their counterparts in the mid altitude. Although households in the mid altitude allocated slightly more land to the production of bananas and coffee, compared to households in the low altitude, the difference was however not significant. Generally, farm households in the low altitude cultivated larger farmlands compared to their counterparts in the mid altitude.

Other crops were cultivated mainly for home consumption thus planted in smaller areas. Such crops included vegetables like pumpkin, eggplant and Sukuma wiki, root crops like yams, sweet potatoes, cassava and cocoyam. Other reasons for planting certain crops on smaller land sizes included; land preparation requires deep holes which are tedious to dig (yams), difficult to get planting material and also hard to make the ridges (sweet potatoes). Crops that required a lot of labour such as tomatoes were also planted in smaller areas.

"Tomatoes require a lot of labour to stake, prune, spraying, and also picking the tomatoes is somehow a tiresome work and should not be planted in very large area, and at the same time tomatoes need a lot of capital for buying seed, fungicides, pesticides and even paying the labourers who help to stake and tie the tomatoes on the staking pegs, response from a 52 years old female, Seron village, mid altitude, Kapchorwa".

4.4. Concluding remarks

Chapter four gives details on the methods that were used to collect information for the study. It also provides results of the descriptive analysis. Subsequent analyses for the study are based on the descriptive results. The descriptive section included farm household socio-economic characteristics, field characteristics including the kind of crops cultivated by the households, cropping systems and area allocated to crops. The household and field characteristics are also compared across two different altitudes, i.e, low and mid altitudes. Significant differences are observed between the two altitudes in relation to the total amount of land accessed by the households, amount of land cultivated, the number of fields owed, the kinds of crops grown and the number of livestock units owned. These variables are presented in detail as they are of importance in relation to households' allocation of farm labour.

The next chapter provides information regarding labour input in crop production activities of various crops. First and foremost, it presents categories of cropping tasks in relation to their difficulty as well as who performs the task in the context of gender. Also, variations in labour input in producing a crop with different objectives are provided.

CHAPTER 5

5 LABOUR ALLOCATION PATTERNS AND VARIABILITY REGARDING CROP PRODUCTION GOALS OF FARM HOUSEHOLDS

From literature, labour allocation decisions in relation to crop production activities has been found to depend on household endowments (Nkonya et al., 2008), such as household labour. Lukanu et al., (2007) mentioned that the household labour available and the individual crop requirements will determine the area that can be cultivated by the household. Implying that, farm households will cultivate a smaller area if the labour requirements of a given a crop are higher.

How farm labour is allocated will ultimately affect crop productivity. Crucially, farm labour is also gender segregated in smallholder farming systems especially in the African context. Certain cropping activities are performed by a particular gender either due to cultural aspects or due to the difficulty in performing certain tasks.

5.1: Categorization and gender specificity of cropping tasks

Farm labour is gender segregated in the area, because certain cropping tasks are perceived by farmers to be laborious and can be performed by men who are thought to be more energetic. Therefore, the farmers categorized the cropping tasks according to their perceptions, in relation to the heaviness or strenuousness of the task. The identification of these categories were based on the classification of activities with different energy demand levels identified by the FAO (WHO, FAO and UNU, 2004). Figure 5.1 shows the different categories of cropping tasks according to their heaviness, as well as the associated activities.

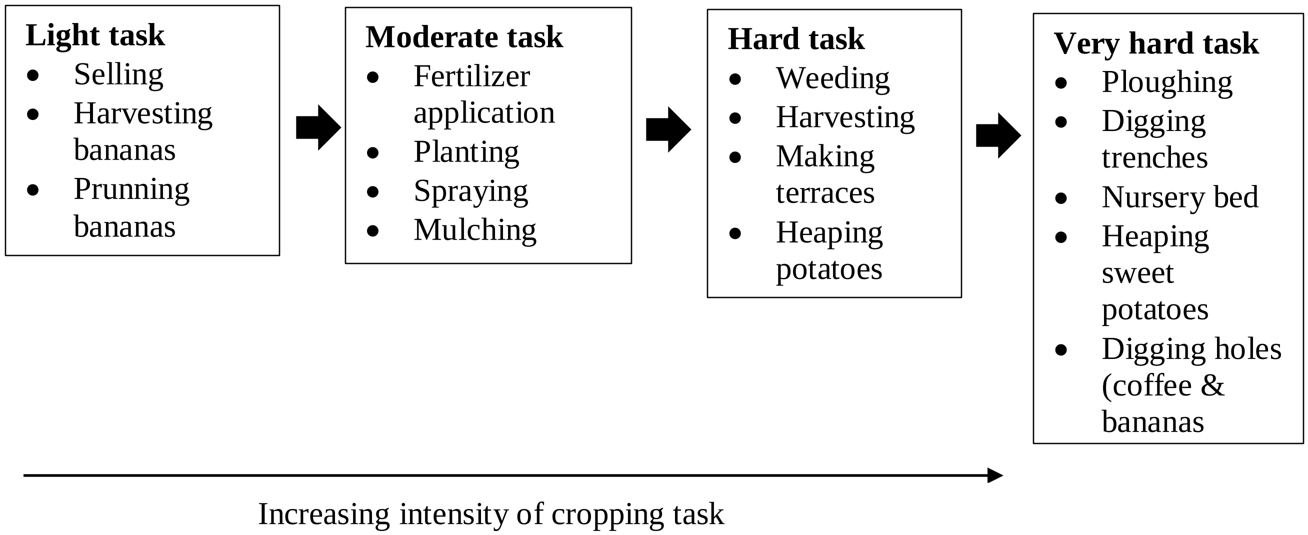


Figure 5. 1: Categorization of cropping tasks according to intensity

Table 5.1 shows the different categories of cropping tasks segregated by gender. Four different categories were identified and these included the light tasks, moderate, hard and very hard tasks. The farmers were then asked to group their production activities according to the identified categories, as well as which gender performed the activities. Women mainly carried out lighter tasks whereas the men performed very hard tasks. Among the tasks regarded as very hard were ploughing, applying manure, digging holes for bananas/matooke and coffee, heaping sweet potatoes and digging trenches. Ploughing of fields is done by oxen and the task is carried out by men. The women stay home and cook food for the men. After ploughing, the men come home for a heavy meal usually composed of posho (maize), beans and sukumawiki (kale).

Even households that do not own oxen do hire from their neighbors and payment is by cash or work together as a group with their neighbors to plough their fields. In certain instances, a household may own oxen but have no ox-plough, while another may have an ox-plough but no oxen, so households form groups to utilize their resources for their common good. A study conducted by Akter et al., (2017) in Southeast Asia also found that pesticide spraying, seedbed and land preparation were among the cropping tasks mainly carried out by men. The authors also noted that both men and women performed some tasks such as weeding, manual harvesting and post-harvest tasks. In certain areas, for example in eastern Zambia, weeding and harvesting is the sole responsibility of women (Norton et al., 2015).

Table 5. 1: Categorization of cropping tasks according to gender

Task	**Gender specificity of task**		
light task	Men	Women	Both
Selling			✔
Harvesting Bananas		✔	
Pruning Bananas			✔
moderate task			
Applying fertilizer			✔
Planting			✔
Land clearing	✔		
De-suckering Bananas			✔
Spraying	✔		
Mulching			✔
hard task			
Weeding			✔
Harvesting			✔
Heaping Irish potatoes			✔
Making terraces	✔		
very hard task			
Ploughing with oxen	✔		
Ploughing with hand hoe			✔
Digging holes for Coffee and Bananas	✔		
Planting with manure			✔
Digging trenches	✔		
Nursery bed for Coffee	✔		
Pruning Coffee	✔		
Heaping Sweet potatoes		✔	
Digging holes for Yams		✔	

Source: Author's own illustration based on FGD data

In the study area, there is a gendered segregation of crops. Interview respondents often referred to certain crops as "women's crops". "Women's crops" were referred to as; crops that women provided labour for their production. Examples of such crops include sukuma wiki (Kale), sweet potatoes and yams. Therefore, women carry out all cropping activities related to the crops. "*It is by culture that women plant sweet potatoes and yams, not men*", this was one of the responses from the men during the focus group discussions. On the other hand, men concentrated on marketable crops like coffee. Figure 5.2 illustrates some of the tasks performed by particular gender within the households.

Ox-ploughing carried out by men

Harvesting and selling bananas performed by women

Figure 5. 2: Examples of gender differentiation of tasks

Source: Author (2018)

The results of a study conducted by Johnson et al., (2016) in Uganda showed that the probability of adopting the orange flesh sweet potato was highest in farm households where women had influence in decision making processes. The same study also reported a low probability of adoption of the orange flesh sweet potato in plots of land that were entirely controlled by men. In this study, the men also noted that women do not have the expertise to carry out certain tasks like spraying which require measuring pesticides. They also mentioned that operating the sprayer requires some energy, which the women cannot manage.

5.2: Labour requirements for different crops

Different crops have varying cropping activities and therefore require shorter or longer time depending on how much effort is required to accomplish each of the individual tasks. Crop labour requirements are estimated as the number of hours it takes a person (s) to cultivate one hectare (ha) of land for a specific crop. To obtain the crop labour requirements for a given crop, the labour requirements of the various cropping tasks are determined and then summed up. For example, Table 5.2, shows cropping activities performed in maize production, each activity with corresponding time and number of labourers needed to carry out the task. These values were then used in the subsequent analysis to determine which crops households allocated more time or crops that were deemed labour intensive.

Table 5. 2: Labour requirements for production and post-harvest activities of maize

Crop	Category of activity	Activity	Total Number of hours/ha	Total number of labour (AEU)
Maize	Production	clearing land	14.82	3
		1st ploughing	24.7	3
		2nd ploughing	24.7	3
		planting	24.7	3
		1st weeding	14.82	10
		applying fertilizer	7.41	5
		spraying	7.41	2
		2nd weeding	14.82	10
		harvesting	12.35	10
	Post-harvest	threshing	12.35	5
		drying	7.41	2
		packing in sacks	7.41	2

Source: Author's own computations based on data from FGDs

i. Production Time Allocation = f(Production activities, Household Labour)

$$(a)\,Production\ factor = \frac{Total\ hours\ allocated\ to\ all\ cropping\ activities}{Total\ labour\ required\ (AEU)}$$

$$(b)\,Labour\ factor = \frac{Highest\ households\ labour\ required/plot}{Labour\ required/plot}$$

Production time allocation = a x b

ii. Post-Harvest Time Allocation = f(Yield, Household Labour)

$$(c)\,Yield\ factor = \frac{Household\ yield/labour(kg/AEU)}{Standard\ yield/labour(kg/AEU)}$$

$$(d)\,Post\ harvest factor = \frac{Total\ hours\ allocated\ to\ all\ post\ harvest\ activities}{Total\ labour\ required\ (AEU)}$$

Post harvest time allocation = c x d

Figure 5. 3: Analytical framework

Figure 5.3 illustrates the analytical framework of how the total time allocated to the production of each of the crops was derived. In addition, the total time required for post-harvest activities for major food and cash crops was also calculated. The labour input in the production of an individual crop was measured as the number of hours taken to accomplish all production tasks related to a particular crop. Household labour was measured in adult equivalent units (AEU). A labour factor was considered in order to account for the labour available in the household and the size of the plot cultivated by the household.

In order to obtain the time taken for post-harvest activities, a yield factor, which accounted for the labour available within the household to process the crop output was established. Additionally, an average standard yield for each crop (Mukiibi, 2001) was used to obtain the yield factor. Also, crop yields were obtained through farmer recall. According to Sud et al., (2015) and Fermont and Benson (2011), estimating crop yields involves the estimation of both crop area and the quantity of output harvested from the area. Therefore, crop yields were estimated by dividing the production of a crop (kg) by the crop area (ha). However, some of the crop outputs were measured in local units such as basins, sacks other than in kilograms. For that reason, conversion factors obtained from focus group discussions were used to convert the crop output to standard units.

Based on the above information, the labour input, measured as the total amount of time spent (hours) in the production of the crops cultivated by the households is shown in Figure 5.4.

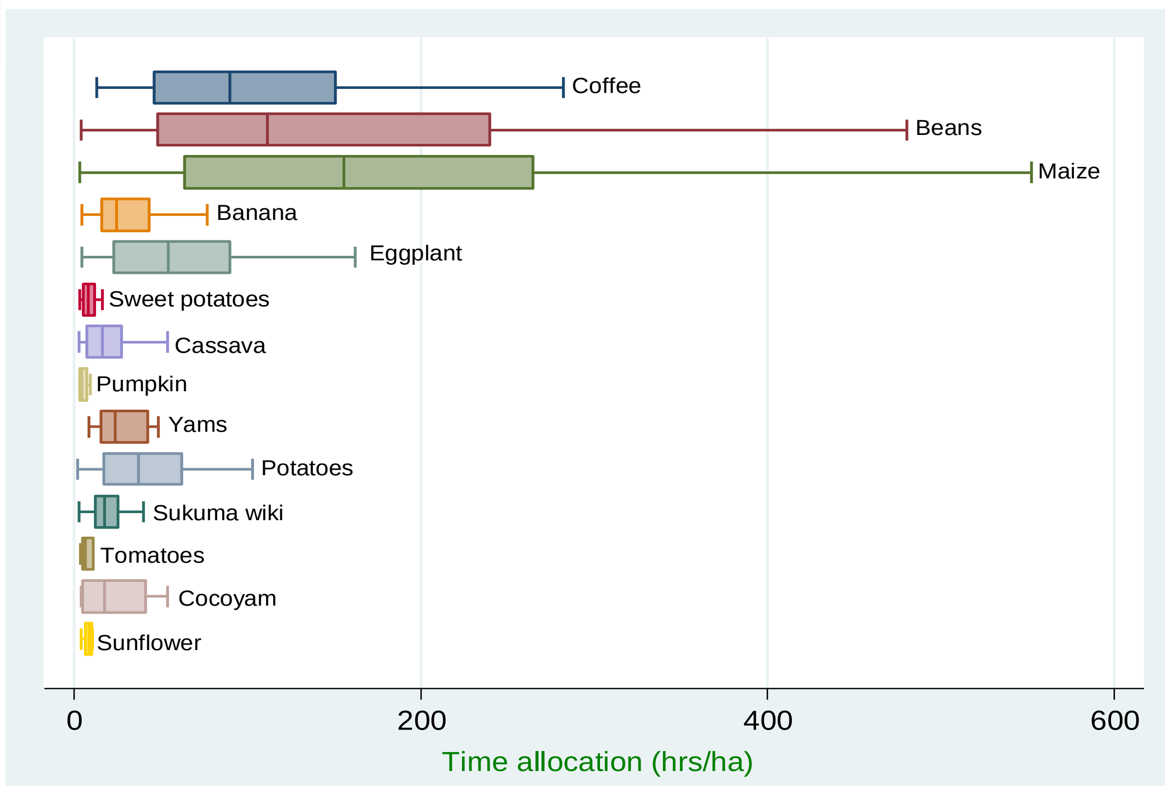


Figure 5. 4: Labour input in the production of various crops

Source: Author’s own computations based on data from the survey and FGDs

As shown in figure 5.4, the labour input (hours) in crop production for households was highest for maize per hectare, followed by beans and then coffee. This was because maize production required several activities that needed to be performed in order for the households to obtain higher yields. For example, planting with fertilizer, applying pesticides, top dressing with fertilizer and it had to be weeded twice. Comparing maize to beans, beans were only weeded once and do not require top dressing with fertilizer. Interviews with the households also revealed that maize requires fertile soil, which was not the case in these areas as the soils were of poor quality, and as such, needed enhancement. Maize is also cultivated only once in a year compared to other annual crops such as beans, which are cultivated in both the first, and second cropping seasons.

In addition, some households also use hired labour especially in maize production for activities that need to be performed within a specific period. Furthermore, labour input also varied more widely among the households especially in the production of maize, beans and coffee, mainly due to labour availability within the household.

Figure 5.5 shows labour input in the production of the various crops segregated by household type, i.e, male and female-headed households. Labour input was based on the total time a household type spent in producing the same crop. The female heads were widowed women while male heads were households headed by males.

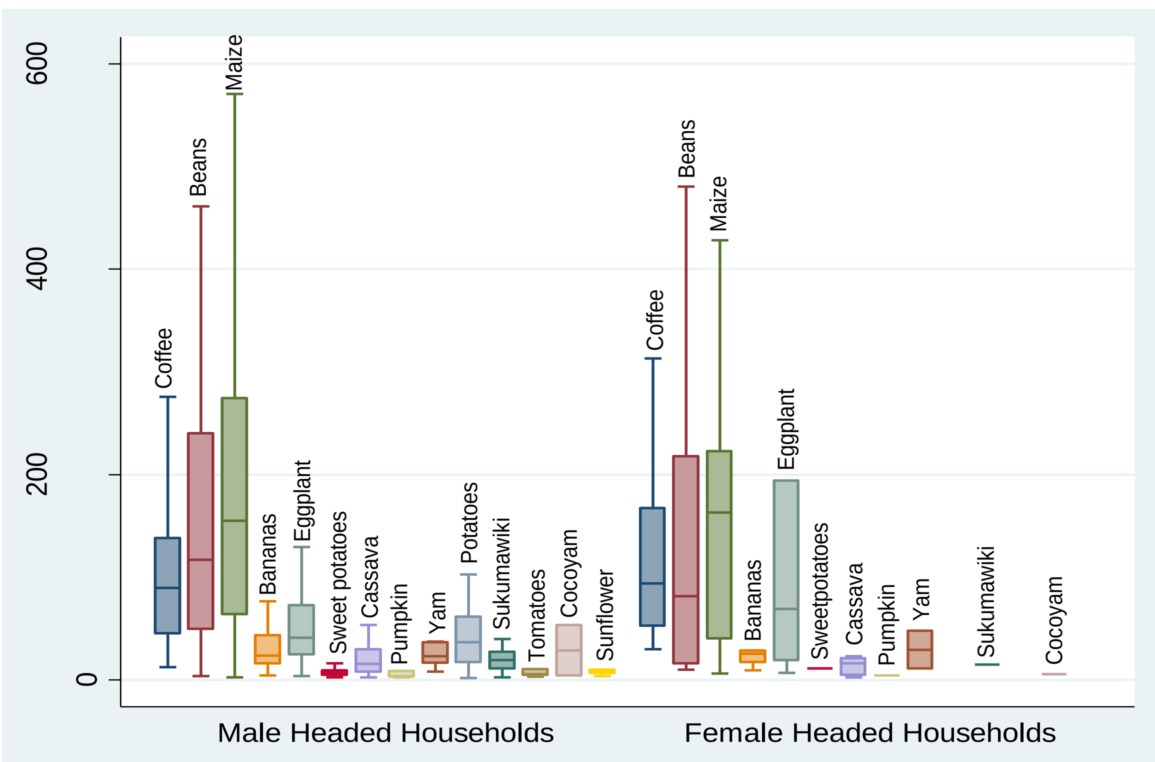


Figure 5. 5: Labour input in the production of crops between different household types

Source: Author’s own computations based on data from the survey and FGDs

In comparison to the male-headed households, the labour input in the production of most crops for example, maize, coffee and eggplants was higher in female-headed households. This was plausibly because the females took more time in carrying out particular tasks which are meant to be done by males, who were absent in these households. Certain crops such as potatoes were also not cultivated by the female-headed households. One possible reason could be that they require a large plot, which these households do not have access.

Likewise, Horrell and Krishnan (2007) found that female-headed households in Zimbabwe owned a little less land compared to the male headed households. In most cases, these households also have fewer members as such, there is shortage of labour therefore. They avoid cultivating such crops like potatoes, which require many tasks such as heaping, fertilizer and pesticide application, which are carried out twice. On a similar note, female-headed households are less likely to use modern farm inputs such as fertilizers because of money that needs to be spent, as evidenced in a study carried out by Sheahan and Barrett (2017).

In comparison with male headed households, female headed households have less income within the household (Horrell and Krishnan, 2007). Having less income sources can also explain why these households cannot engage in the production of these crops since they cannot afford to hire labour. Also, the variance in the labour input in the production of crops like sweet potatoes, pumpkin, sukuma wiki (Kale) and cocoyam was really small when compared to the male-headed households. These are also mainly food crops that are mostly produced by women.

In addition to labour input in production, the labour input in post-harvest activities for selected crops is also presented in Figure 5.6. This was assessed to find out which crops were labour demanding during processing, as post-harvest tasks are also considered part of crop production. The labour effort needed to perform the tasks was put into consideration, because some tasks did not demand more effort. The results revealed that labour input was highest in post-harvest activities of sunflower compared to other crops like coffee, beans, maize and potatoes. The post-harvest activities for sunflower included winnowing, drying and packing. Labour input was lowest for potatoes because no other post-harvest activity was carried out apart from sorting and packing. Although the labour input for processing the outputs differed slightly among the crops, there was also no large difference when the labour input for post-harvest and production activities were aggregated (Figure 5.6).

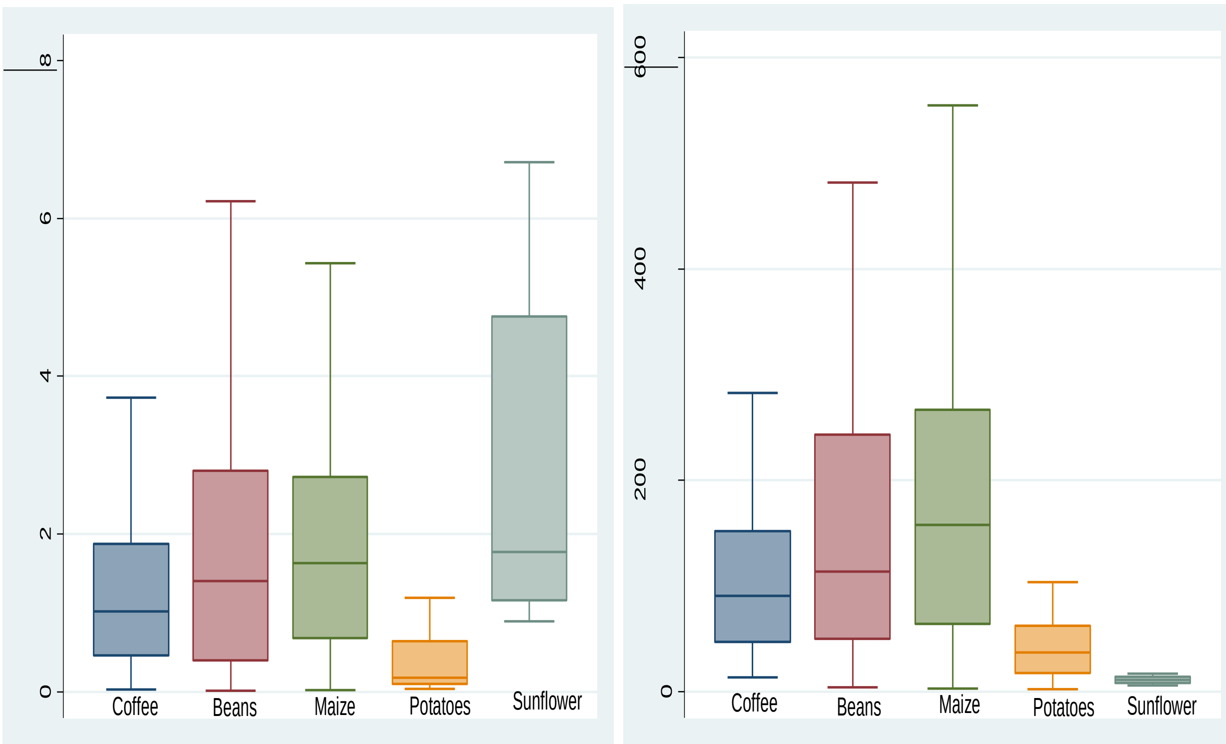


Figure 5. 6: Labour input in post-harvest activities (left) and aggregated labour input in production and post-harvest activities (right)

Source: Author's own computations based on data from the survey and FGDs

Some households also cultivated the same crop in different plots because of their different purposes. In order to look at intra household variability in terms of time allocation to different farm plots with the same crop, households with two different plots of the same crop intended for different purposes were identified (Figure 5.7). This was done for three crops, that is, maize, beans and banana. However, households that met the criteria were only 11 for maize, 11 for beans and 10 for bananas. There were also four overlapping households. This gave a total of 28 households, with 11 households located in the low altitude and 17 in the mid altitude. However, among these households, only one was a female-headed household. In addition, these households had an average farm size of one hectare.

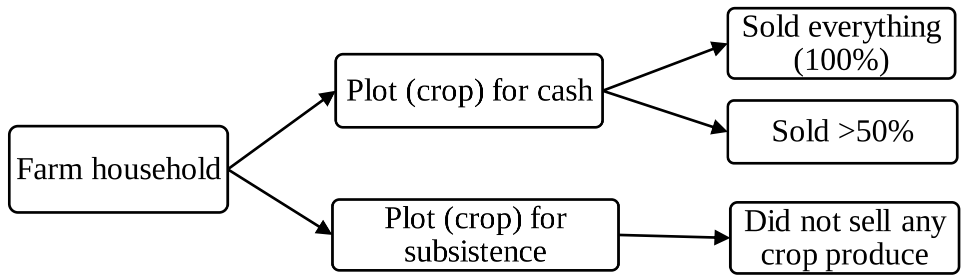


Figure 5. 7: Criteria for selection of households

Source: Authors own illustration based on survey data

These crops were purposively chosen because they were grown for both cash and subsistence and also, households allocated more land to these crops compared to other crops. As indicated in Figure 5.8, households allocated more land to plots of maize, beans and bananas intended for sale compared to plots intended for subsistence. For example an average of more than 0.4 hectares were allocated to cash plots of maize whereas only half of the cash plots were allocated to maize grown for subsistence. This could suggest that households needed cash income to meet other household goals therefore devoted larger portions of land for cash plots.

From the information obtained from household interviews, households allocated more land to the selected crops to earn cash income for paying school fees for their children. The cash obtained from the sale of these crops was also used to purchase goods like; salt, sugar, vegetable oil, soap, clothes and paraffin. Some households mentioned that the cash income was used to buy livestock. Households did not report any form of trade of produce with their neighbors. One of the reasons could be because most of the households cultivated similar crops.

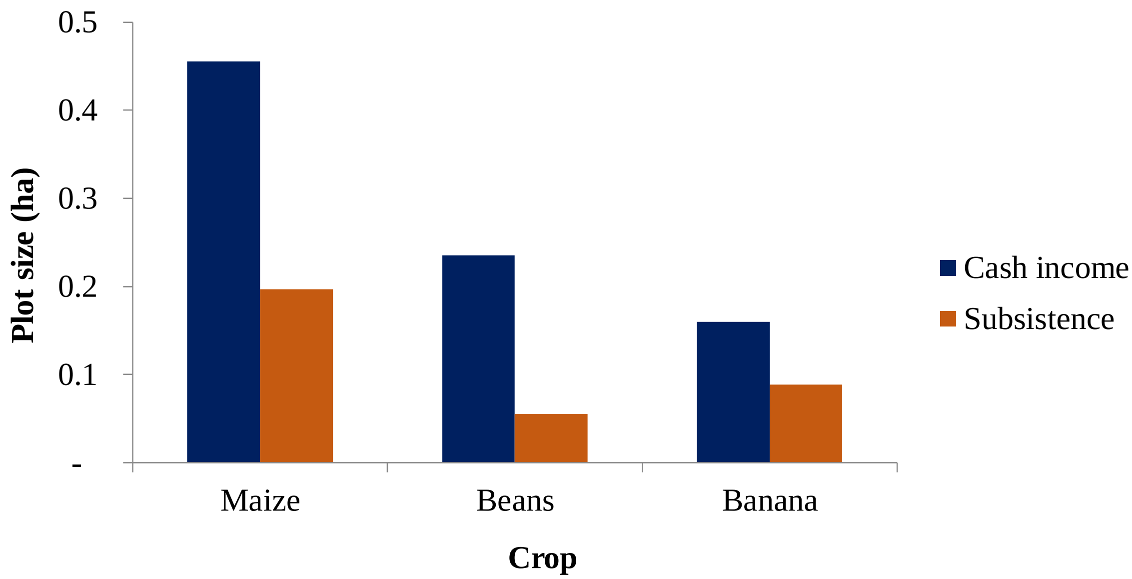


Figure 5. 8: Size of plot allocated to crops with different purposes

Source: Authors own computations based on survey data

Although more land was allocated to crop plots intended for cash, more effort was spent in the production of banana meant for subsistence (Figure 5.9). The average number of hours spent in banana plots for subsistence was 58.8 hours, compared to 21.6 hours spent on cash plots. The labour intensity on plots meant for subsistence could plausibly indicate the need for food for the household since banana is a staple food in the area. It is also probable that more time was invested in the banana fields for home consumption because they were located closer to the homestead compared to those intended for sale. As such, it was much easier to apply manure to the fields close by home. Fields near the homestead tend to be tended to more and thus tend to be more fertile than fields far away from home. This is so because in addition to manure that is applied to such fields, food residues and peelings are also poured in such fields. In line with the above, Ugandan women were also found to apply good soil and water management practices in intercropped plots of banana and coffee because the bananas were for home consumption (Jassogne et al., 2012). In addition, (Nkonya et al., 2008) found that organic matter was more likely to be applied on perennial crops like bananas and coffee as compared to annual crops like maize and beans which are always planted on distant plots.

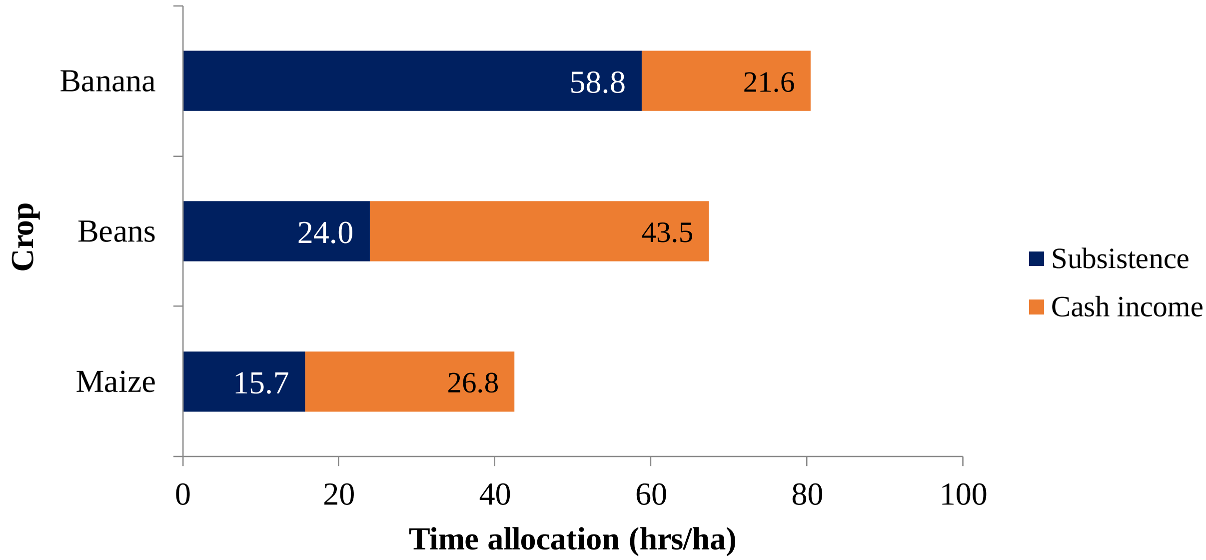


Figure 5. 9: Time allocation to the same crop grown in different plots for different purposes

Source: Authors own computations based on survey data

Tittonell et al., (2005) noted that the application of organic fertilizers reduced with increase in distance from the homestead, as a result of additional effort, needed to carry the bulky organic materials to plots located far away. The authors also assert that due to increased soil organic carbon provided by the manure in plots (close to the homestead), soil fertility gradients are larger in fields and farms owing to the different nutrient management practices employed by the households in different plots.

5.3: Concluding remarks

Chapter five gives information on crop production activities and the labour input of farm households to these activities. First and foremost, certain activities are performed by a specific gender and as such, the composition of the household in terms of gender plays a crucial role in determining labour allocation patterns in crop production. Results reveal that labour input in production depends on crop choice of the households, household type (male or female headed) and labour availability within the household. One likely reason for crop choice is the purpose (nutrition or cash) of the crops to the household. Therefore, the kind of crop grown will ultimately affect the effort expended in the production of the crop because different crops have varying activities, which may either be a few or many. The results further indicate that certain crops are not cultivated by female-headed households. Also, female headed households have a higher labour input in the production of most crops. Perhaps, due to the fact that males are absent to support farming activities.

CHAPTER 6

6 A TYPOLOGY OF SMALLHOLDER FARMS FOR THE IDENTIFICATION OF TYPICAL FARM HOUSEHOLDS

This section classifies the farming styles of smallholders in the Mt. Elgon region. The classification of the different styles gives an understanding of the diversity in relation to resource allocation patterns within the farming community. Although the information relates to the Mt. Elgon region, it may be applicable to other farming communities in Uganda in general.

6.1 The concept of farming styles

Van der Ploeg (1992) describes farming styles as a combination of ideas, norms and experiences common to a given group of farmers located in a particular region. This is reflected in the way the fields are laid out, farm structures and the way labour is disaggregated in and amongst farms. More so, it explains how farming should be practiced. In addition, the author notes that farming styles illustrate a unified communication of farming involving both mental as well as manual labour. Also, farming styles involve a structured labour process which ultimately results into distinct processes of production, that is, the relationships between social, economic and technical aspects. This equally leads to different structures of farm enterprise development. As such, the author alludes that scale and level of intensity of farms could be used to describe farming styles. Every farming style has its own coordination of production, reproduction, social, economic and institutional domains.

Therefore a farming style is a representation of all the dimensions (Van der Ploeg, 1992). As summarized by Vanclay et al., (1998), van der Ploeg's (1990) concept of farming styles was built on the idea that farming styles constituted a typical analysis of both agricultural intensification and extensification. Additionally, van der Ploeg contended that agricultural diversity was exacerbated by structural forces, owing to farmers' capacity to choose a combination of both intensification and extensification, other than only having one choice.

The farming styles theory views the farming community as having a diverse set of styles or farming strategies from which farmers can select a particular strategy that can guide their individual farm management. The theory is also referred to as an approach of farm management implemented by a landholder (Vanclay et al., 2006; Emtage, 2008). Likewise, Mesiti and

Vanclay (2006) describe the theoretical approach of styles of farming as having origins from the rural sociology field. Drawing on Vanclay et al., (2006), the farming styles theory of van der Ploeg looks at a style as an approach in which a farm is arranged and managed by a farmer and the same approach is also practiced by a particular group of farmers. As a result, the style evolves over time due to participation of the farmers. Importantly, these styles are set up as a result of socio-cultural and structural forces, therefore different farmers are represented by different styles based on their market conditions.

According to van der Ploeg, a style refers to a unity of shared values and ideas by a certain group of farmers, a structure of farming practice, which relates to their shared ideas. It also relates to the relationship between their farm enterprises and the external environment, such as, with markets, technology and government policies (Vanclay et al., 2006). In the same way, Mesiti and Vanclay, (2006) refer to farming styles as an approach of developing a typology of the different farming strategies of farmers. These strategies relate to the reasoning for decision making, in order to overcome certain circumstances such as low prices (Vanclay et al., 2006). The authors also mention that farming styles occur as paths of action for farmers' survival. Farming objectives and attitudes informed the various farming styles identified in a study by Schwarz et al., (2010). Therefore, the different farming styles may reflect different objectives of farmers.

On the other hand, the farming styles theory has been criticized because it classifies farmers into different styles based on market orientation only in many cases (Emtage, 2008). The author also criticizes the use of wealth rankings to categorize farmers, as these have less explanatory power to describe farmer groups. Farming styles considers the attitudes and knowledge of farmers. As such, the differences in the knowledge, concerns and attitudes of the farmers will have an influence on the adoption of various farm practices and innovations, thus leading to diversity within the farming communities Schwarz et al., (2010).

The farming styles theoretical approach has been used to gain an understanding of agricultural diversity that exists in farming communities. Accordingly, agricultural diversity is explained by a collective set of farming styles in a given area. One crucial attribute of farming styles is their ability to explain agricultural diversity in a given region and also clarify the survival of typical farming practices amidst globalisation (Howden et al., 1998; Mesiti and Vanclay., 2006; Emtage, 2008). In the same way, Vanclay et al., (2007) asserts that farming styles represent a theoretical form of classifying farmers based on their own judgements of world views. Equally, the farmers have knowledge on the diversity of farmers and thus can classify the various farmer types. From the authors' point of view, the approach sheds light on the diversity present amongst farmers.

Mesiti and Vanclay., (2006) add that the concept of farming styles involves several dimensions although agricultural extension only focuses on diversity in relation to farm characteristics or farmers' access to resources such as finances. Vanclay et al., (1998) delineates that farmers are not only aware of the existence of the diverse styles present in a particular region but are also aware of the collection of different local cultural aspects practiced in the various styles. From the authors' point of view, farmer behaviour is understood in such a way that farming is viewed as a social construction in which farming practices are initiated in various ways by different farmers. According to Vanclay et al., (2007), heterogeneity from the farmers' point of view is not a random occurrence, but involves clusters or different ways of farming resulting from particular strategies employed by the farmers.

Mesiti and Vanclay (2006), discuss that groups of farmers are clustered based on their ideas of farming, thus, it is a typology approach that takes into account farmers' farming strategies. Also, the styles consider various factors such as, geographical, environmental, agronomic and socio-economic factors. Emtage (2008) reports that typologies are used to give insights into the variation within a given community through gaining an understanding of the different factors that have a consequence on the different land management behaviours of farmers. According to the author, this helps to select extension programs for landholders in different social and economic groups. Howden et al., (1998) applied the farming styles theory in his research to the Australian context. The aim was to aid in the extension of agricultural research products especially the research carried out by the cooperative research centre for weed management systems. Farmers were classified based on their farming styles in order to identify different weed management strategies of the various farming styles. The aim was to reduce farmers' dependence on herbicides within the different styles, by promoting improved weed management practices.

The typification of farming systems in this study mainly draws upon this farming styles theory. The intention of this theory is to classify farmer groups based on their farm management practices and also on their shared views (Schwarz et al., 2010).

6.2 Approaches to categorizing farming systems at the ground

Heterogeneity exists at different levels of farming systems for example, differences in soil fertility arises due to the location of the farm on the landscape and due to management practices. Furthermore, differences in social status of households also creates soil fertility gradients amongst farms, for instance, households that own livestock have more nutrient flows compared to those that do not own livestock. In addition, households that are well endowed in terms of resources have more access to external inputs like chemical fertilizers and labour thereby leading to variability within farming systems (Giller et al., 2006). More so, these households do have access to credit markets. Chikowo et al., (2014) admit that household resource availability and resource allocation patterns are determined by the wealth of the household. The allocation of resources also depends on the household's production objectives. Thus, in terms of nutrient allocation, there will be a variation in soil fertility as well as productivity due to variation in resource endowments of the farms.

The approach of farming styles is employed to understand the diversity that exists in farming society (Mesiti and Vanclay 2006). Therefore, styles of farming reveal the fundamental structure of heterogeneity in farming systems (Kuivanen et al., 2016). Farming systems are heterogeneous and this heterogeneity relates to diversity in terms of space - which looks at household resources; (1) time - focusing on the dynamic nature of the farming systems and (2) strategy - relating to the decisions made by the households in terms of production and consumption (Kuivanen et al., 2016). Therefore, household decisions on the allocation of resources such as labour take place at different spatial and temporal scales (Table 6.1) and this leads to variability within farming systems.

Table 6. 1: Key issues relating to resource use efficiency that need to be considered at different scales of analysis

Space	Time			Category of diversity
	Short term (1 season)	Medium term (1-5 years)	Long term	
Field	Production efficiencies Crop (food and cash) production	Production efficiencies of crop rotations	Soil erosion Soil carbon content Yield stability	Biophysical diversity
Farm	Resource trade-offs Farm scale efficiency Labour allocation between fields and crops	Risk avoidance Rotating crops between fields	Livelihood stability	Management diversity

Source: Modified from Tittonell (2007); Giller et al., (2006)

In Addition, Tittonell (2007) points out that farm households go through separate stages in development, and as such, the location of the farm household on the developmental cycle of the farm represents a classification of farm household diversity used to distinguish livelihood strategies of the households. According to Tittonell (2007), different criteria are used to characterize farm household livelihood strategies across different areas. Such criteria include; household composition, production orientation of the household, household resources as well as off-farm income sources. Importantly, the identification of the different livelihood strategies of farm households is beneficial because it influences their decisions on resource allocation. A case in point is a study carried out by Ronner et al., (2018) in the Mt. Elgon region in Uganda to understand opportunities and constraints for introducing and expanding climbing beans in the farming systems.

In order to capture farming system diversity, farm households need to be stratified to a certain extent into homogenous groups for example in terms of resource base, livelihood strategies and constraints (Kuivanen et al., 2016). Household categorization through the construction of typologies brings to light the impact of resource endowments and objectives of various household types on resource allocation patterns (Tittonell et al., 2010). Therefore the disaggregation of farms into typologies helps to make the diversity more precise, and target interventions to a given livelihood domain (Alvarez et al., 2018; Aravindakshan et al., 2020).

Farm typologies aim at representing the heterogeneity between different farm types while at the same time observing some homogeneity within specific groups of farms. Thus, they refer to a way of classifying and explaining components of a farming system based on chosen indicators. This reduces the complexity of the systems as farms are categorized into homogeneous groups (Chikowo et al., 2014; Alvarez et al., 2018). However, the choice of discriminating variables for constructing the typology depends on the objective of the typology (Kuivanen et al., 2016). In a similar vein, Madry et al., (2013)), adds that classifying farms into clusters of homogeneous farms is useful for understanding the strengths and weaknesses of different farm types and for this reason, strategies for improvement can easily be identified.

Correspondingly, Alvarez et al., (2018) identifies four aims for the construction of farm typologies. First, farm typologies are built to aid in the selection of representative farms to be used as case studies. Secondly, they are used to target interventions through identification of interventions suitable for each farm type. Thirdly, to scale up or scale out technologies and lastly, it helps to identify evolution patterns of farms. In accordance with the above, Kuivanen et al., (2016) agrees that typologies are used to perform thorough analyses of farming systems through the selection of representative farms. Additionally, they may be used to model and simulate studies that assess the impact of particular interventions on farming systems. In their study, Righi et al., (2011) identified a representative farm from each farm type. Representative farms included farms, which had similar values to the group virtual farm. These values were variable values that contributed the highest towards similarity within groups while the group virtual farm had average characteristics of the whole group. Kobrich et al., (2003), however, notes that socio-economic variables are necessary when constructing farm typologies with the aim to identify representative farms.

Farming styles can vary and therefore, there have been a number of studies using typology to define farm types to categorize farming systems in different countries. These studies have highlighted various ways of constructing farm typologies. Iraizoz et al., (2007) identifies two different approaches that have been used in typology construction. Firstly, the a priori approach which depends on the researcher’s evaluations, and the quantitative approach, which employs multivariate statistical procedures. Farm typologies can be developed based on information obtained from local stakeholders or information from household surveys, focus group discussions (Chikowo et al., 2014; Alvarez et al., 2018), and also through expert knowledge guided by land cover maps (Madry et al., 2013). The use of expert knowledge to construct farm typologies is useful in cases where farming systems are not well developed or when experts are well-informed about the farming systems (Madry et al., 2013). Also, available literature in relation to the socio-economic and biophysical factors of farming systems can be used to construct farm typologies.

The use of qualitative approaches in defining typologies has however, been criticized in literature because they are subjective and are not likely to explain the diversity in farming systems (Kobrich et al., 2003). Many approaches have been critiqued because they do not take into account the data available since choices of data to be used are made by the researchers and are not based on statistical measures. Grouping farms with respect to their location is a typical example of the a priori approach. However, this approach also does not account for heterogeneity between farms located within a specific area (Kobrich et al., 2003; Iraizoz et al., 2007).

Therefore, statistical approaches have been preferred over qualitative approaches in defining typologies. Alvarez et al., (2018) noted that the use of multivariate analysis is among the most frequently used techniques to build farm typologies. Nonetheless, the authors suggest the use of a mixture of participatory approaches, expert knowledge and multivariate analysis in the construction of farm typologies. Statistical methods using the principal component analysis and cluster analysis are the preferred methods. The principal component reduces the number of variables to a few variables, referred to as principal components. These principal components show the differences between the groups, which are then carried on for cluster analysis (Madry et al., 2013). On the contrary, Righi et al., (2011) argues that the use of principal components or factors to explain the farm clusters does not provide insights on variables that are actually responsible for the categorization.

6.3 Intermediary conclusion

Nonetheless, various studies have applied the approach of multivariate analysis using principal component analysis (PCA) and cluster analysis (CA) to cluster farms (Goswami et al., 2014; Kuivanen et al., 2016; Kamau et al., 2018). This approach has been widely used because it can be compared over time and space and it can also be reproduced (Kuivanen et al., 2016). In addition, it has been favored over other approaches because many variables can be used to generate a typology. Sebatta et al., (2019) employed the methods of principal component analysis and cluster analysis to characterize coffee-banana systems in the Mt. Elgon region. These farms were classified based on input use intensity and production output, so as to identify strategies towards sustainable intensification. Similarly, cluster analysis has been widely used to segment farms because of its robustness in determining homogenous groups (Iraizoz et al., 2007).

Iraizoz et al., (2007) performed the cluster analysis to segment farms using variables associated with characteristics of the farms, to analyze agricultural trajectories as well as approaches used by farmers in Spain. Blazy et al., (2009) equally employed the agglomerative hierarchical clustering to build a typology in order to account for farm diversity so as to prototype banana based crop management systems in Guadeloupe. The authors highlight that gaining insights into different elements of farm diversity is helpful in defining different constraints for each of the farm types. These elements according to the authors are related to the farming context, performance and the technical aspects of the farm.

However, most clustering processes have used indicators that relate either to structural and functional characteristics of the farming systems. Structural indicators relate to household resource endowments, assets (wealth indicators). Functional indicators are related to production dynamics of the households as well as their livelihood strategies (Tittonell et al., 2010; Alvarez et al., 2014; Chikowo et al., 2014). (Lopez-Ridaura et al., (2018) selected and used variables that represented both the structural and functional characteristics of the farming systems in Bihar, India. Crop and livestock systems represented farmers' functional attributes in their selection.

Alvarez et al., (2014) suggests the use of internal variables that relate to the farming system such as household factors, crop and livestock systems and external variables, and are linked to the farming system. Such external variables include market and socio-cultural variables. Kobrich et al., (2003), however, criticizes the use of external variables in the construction of farm typologies and suggests the use of variables that internally influence the farming system. Typically, from literature, three to five farm types are usually identified, mainly based on factors like size of farm, livestock ownership, off-farm income sources as well as availability of assets (Chikowo et al., 2014).

Nevertheless, Tittonell et al., (2010) constructed a farm typology including, income sources and location of the household on the farm developmental cycle were considered. Such approach will be applied in this study. It was done to establish differences in soil fertility status and management practices employed in agricultural systems of mid and high potential in the East African highlands. Similarly, Bongers et al., (2015) constructed a typology of coffee farm systems in Uganda in order to evaluate farm diversity in terms of their resource availability, revenue and practices employed in the various farm types.

In a similar vein, Franke et al., (2014) used farm typology to investigate the potentials for the intensification of grain legume production in Malawi. The characteristics of the different farm types formed the base for the development of virtual farms, which were then used to exploit different cases of scenarios. Likewise, Righi et al., (2011) applied the farm typology approach to categorize vegetable farms in south Uruguay. The aim was to assist in scaling up results at the farm level, which would then be used to assess the effect of various approaches at the regional level. Importantly, Alvarez et al., (2018) proposed the need to formulate a hypothesis during the initial phases of typology construction, as illustrated by the authors during typology creation to capture farm diversity in Zambia.

Diversity in farming systems has also been assessed based on the production diversity of farms. From literature, production diversity has been measured by some studies (Sibhatu et al, 2015; Koppmair et al., 2017), as the number of crop species cultivated on the farm. However, Koppmair et al., (2017) asserts that crop species count does not thoroughly explain production diversity because it does not put dietary diversity into consideration. The authors propose the measurement of production diversity using the number of food groups cultivated by the farm household. However, Bogard et al., (2018) notes that production diversity does not take into account the nutritional attributes of the crops. Therefore, the authors suggest nutritional functional diversity as a measurement of nutritional quality of production systems. The authors define nutritional functional diversity as the nutrient diversity produced by a farm, in accordance to the various nutrients required for human nutrition.

Sibhatu et al., (2015) used the production diversity score to substitute the crop species count in their study to link farm production diversity and dietary diversity. In the same way, Luckett et al., (2015) referred to the number of food groups produced as nutritional functional diversity and described it as the level of functional differences between crops produced on the farm. The authors add that the functional differences of the crops depend on the crop nutrient profiles. Therefore, higher scores indicate more diversity within the production system.

Furthermore, if several crop species that belong to the same food group are produced by the household, the score will be equal to one. For instance, a farm producing sweet potatoes, cassava, and yams will have a lower functional diversity score compared to a farm producing sweet potatoes, beans and eggplants. Additionally, the production of non-food cash crops gives a nutritional value of zero even if many species are produced by the household. Likewise, a higher number of crop species within the same food group means less nutritional diversity within the household (Remans et al., 2014). According to DeClerck et al., (2011), the consumption of nutritious food increases with the production diversity provided by farming systems, given the fact that smallholders consume much of what they produce.

Therefore, five food groups were used in this study to measure the functional diversity of the different crops produced by smallholders. These groups included; plantain, cereals, roots and tubers, legumes and vegetables. The food groups were selected based on the food composition table for central and eastern Uganda (Hotz et al., 2012). Non-food cash crops such as coffee and sunflower were excluded from the food groups. In this study therefore, both crop species count and functional diversity were used to measure production diversity of the farm households.

6.4 Typology construction

This study applied a multivariate statistical methodology for typology construction. The principal component analysis (PCA) and cluster analysis (CA) were used (Kuivanen et al., 2016). The analysis was executed in R (version 3.6.1) using the package ade4. Quantitative variables (11) that described the household characteristics and their production systems were selected to identify farming system diversity in the study area. These variables were related to household size, labour, land use, production diversity, livestock and income (Table 6.2). Conversion equivalents of sub-Saharan Africa livestock were used to convert the number of livestock owned into Tropical Livestock Units (TLU) (Njuki et al., 2011). The survey included 120 farm households however, 12 households were deleted from the dataset as potential outliers, as outliers have a strong influence on the PCA results (Alvarez et al., 2014). Therefore, a sample of 108 households was retained for the analysis. These outliers were identified using box plots. The variables used in the PCA were normalized because of their different measurement scales. This was done in order to make the variables comparable. As such, the variables were scaled to have a range of zero to one.

Table 6. 2: Description of variables used for the construction of farm typology

Variable	Unit	Mean	SD	Min	Max
Household					
Household size	Number of people	6.02	2.28	1.00	12.00
Labour					
Household labour	Adult equivalent unit (AEU)	4.50	1.78	1.00	9.00
Total labour input in crop production	Hours per season	521.15	301.31	41.00	1256
Land use					
Total land accessed	Hectares	0.98	0.63	0.10	2.84
Total land cultivated (crops)	Hectares	0.94	0.58	0.10	2.43
Number of fields cultivated	Number of fields	2.51	0.92	1.00	4.00
Production diversity					
Crop count	Number of crops produced on the farm	5.08	1.33	3.00	9.00
Crop functional diversity	Number of food groups produced on the farm	3.65	0.86	2.00	5.00
Livestock					
Tropical livestock unit (TLU)	Number of TLUs	2.65	2.75	0.04	13.14
Income					
Income from non-farm activities	USD per year	208.52	376.04	0.00	1891.89
Crop sales	Percentage of crops sold	40.15	22.22	0.00	93.00

Adult equivalent unit: conversion factor, adult =1.0, child =0.5
Tropical livestock unit: total loading of the animals, bull =1.2, cow =1.0, goat =0.2, sheep =0.2, pig = 0.3, donkey =0.8, poultry = 0.04
US dollar: USD =3700 UGX

Source: Author's own computations based on survey data

Multivariate statistical analysis

The PCA plays an important role when variables are extremely correlated. Therefore, these variables are reduced to new variables known as principal components and then identified principal components with maximum variation are selected (Kassambara, 2017). Two different criteria were used to determine the number of principal components to retain. The first criterion was the eigenvalue greater than one (Kaiser criterion) (Alvarez et al., 2014).

Eigenvalues measure the amount of variation retained by each principal component (Table 6.3). Eigen values greater than one show that more variance is explained by the principal components than explained by the original variables. Secondly, the cumulative proportion of variance explained with the minimum taken at 70%. From the results of the PCA, out of the 11 components, four principal components (PC's) were retained for the cluster analysis. These four principal components explained 77% of the variation.

Table 6. 3: Eigen values and percentage variance explained by the four selected principal components

Principal component	Eigen value	Variance (%)	Cumulative Variance (%)
1	3.73	33.8	33.8
2	1.99	18.1	51.9
3	1.77	16.2	68.1
4	0.99	9.0	77.1

In order to interpret the meaning of the principal components, the coefficients of correlations (loadings) between the principal components and the variables were considered (Table 6.4). Correlation coefficients of 0.60 and above were considered. This loading cut-off was chosen based on the sample size and for easier interpretation (Yong and Pearce, 2013). Higher correlation coefficients indicated a stronger relationship between the variable and the principal component.

Table 6. 4: Correlation matrix between the selected principal components and the variables

Variables	PC1 (Land resources)	PC2 (Labour resources)	PC3 (Production diversity)	PC4 (Off-farm income)
Land access	**0.919**	0.150	0.145	-0.013
Land cultivated	**0.914**	0.161	0.127	-0.004
Number of fields	**0.640**	0.129	0.046	-0.421
Number of crops	0.283	-0.179	**-0.876**	-0.129
Number of food groups	0.279	-0.144	**-0.861**	-0.056
Household size	0.477	**-0.827**	0.176	-0.027
Total household labour	0.480	**-0.831**	0.188	-0.022

Labour input	0.576	**0.687**	-0.099	-0.102
Tropical livestock units	0.536	0.045	-0.139	0.371
Off-farm income	0.287	0.050	-0.106	**0.803**
Crop sales	0.568	0.148	0.346	-0.015

Source: Author's own computations

Figure 6.1 illustrates farms and the variables on the principal component plane PC1-PC2. It shows the distribution of the farms based on the variables. Therefore, the distance between the locations of the farms demonstrates the dissimilarity of the farms' variables measured by Euclidean distance. Farms closer to the origin have average values of a specific variable.

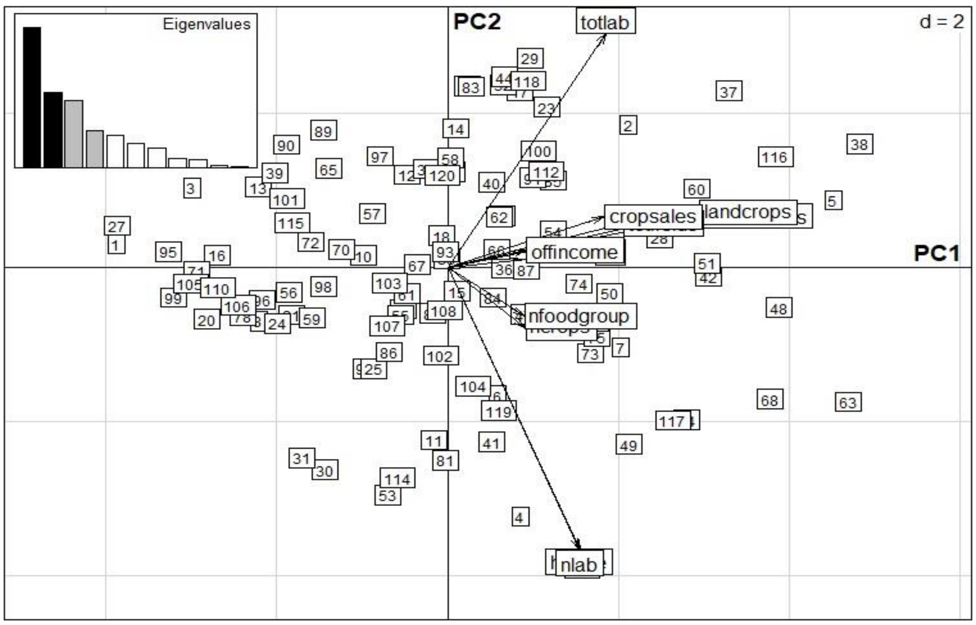


Figure 6. 1: Bi-plot diagram of farm characterization based on PC1-PC2 planes

Source: Author's own based on PCA results

The correlation circles represent the correlation between the variables and principal components (Figure 6.2). The distance of the arrows in the circles indicates the quality of the variables to the principal components. The results of the principal component analysis indicated that principal component one explained the highest variability in the data with a contribution of 33.8%. Principal component one (PC1) was related to variables that described land access, land cultivated and number of fields. Therefore, this principal component could explain the resource endowment of the farm households in terms of land resources (Figure 6.2A).

Principal component two (PC2) was related to variables which included household size, total household labour (AEU) and labour input. It thus illustrated the human capital of the farm households in relation to its labour resources (Figure 6.2A). The third principal component was highly correlated with the number of crops cultivated as well as the number of food groups. This component clearly indicated the crop production diversity of the farm households (Figure 6.2B). Principal component four (PC4) was linked to off-farm sources of income of the farm households (off-farm income) (Figure 6.2C).

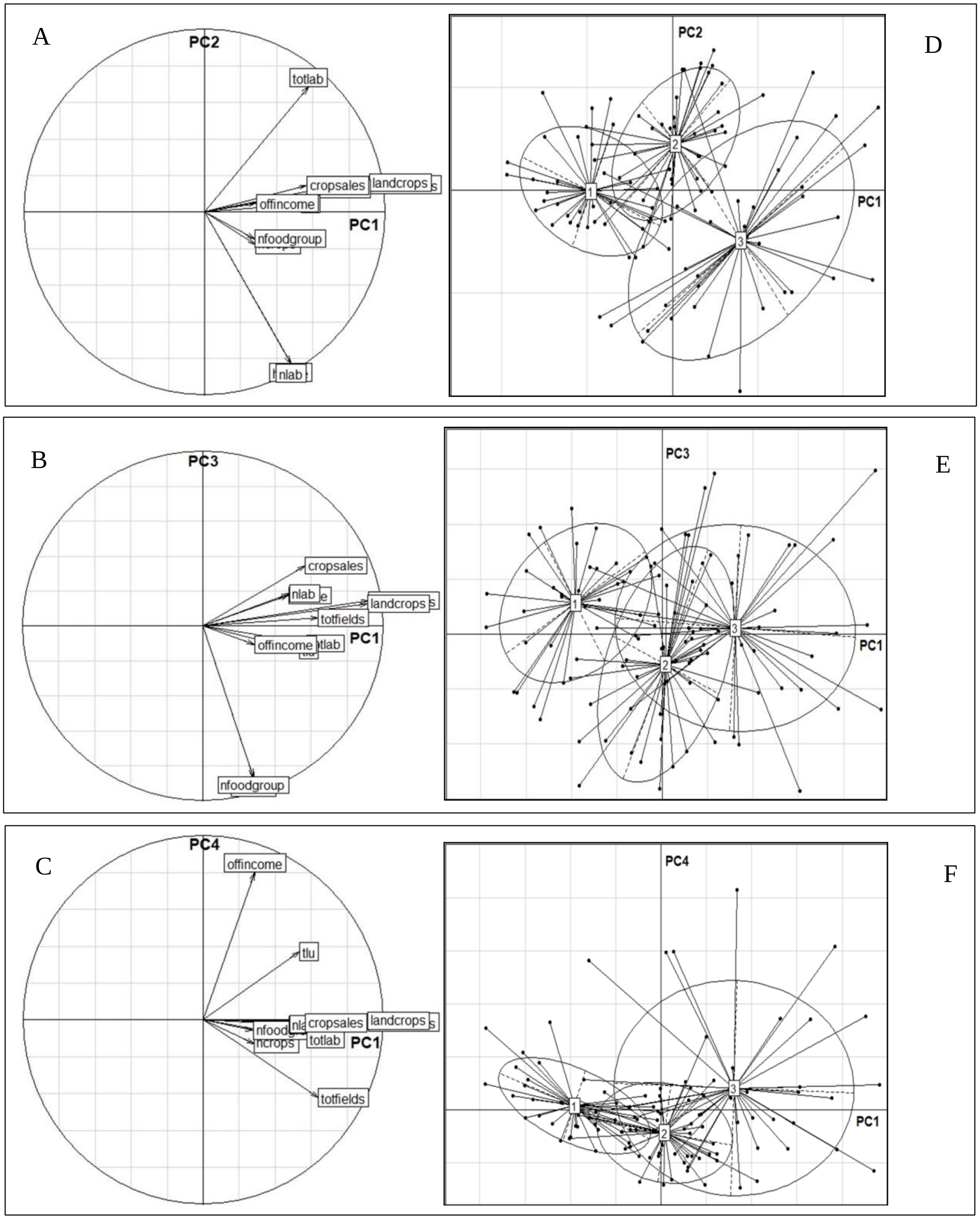


Figure 6. 2: Correlation circles (ABC) and clusters 1,2 and 3 (D, E, F) in the planes PC1-PC2, PC1-PC3, PC1-PC4

Source: Author's own based on PCA results

The hierarchical agglomerative clustering was then used to identify groups of farms with similar observations. This was done using the ward's criterion on the chosen principal components (Kuivanen et al., 2016; Kamau et al., 2018). The resulting clustering process is illustrated by the dendrogram, which gives various cluster solutions (Figure 6.3). The selected cut-off point resulted in a three-cluster solution, that is, farm types 1, 2 and 3. The vertical axis of the dendrogram illustrates the height or distance of the clusters at each stage. Height indicates the dissimilarity within clusters in relation to the number of clusters. Additionally, the scree plot was used to check a suitable number of clusters (Matsunaga, 2011; Goswami et al., 2014). The suggested number of clusters from the scree plot was three. Therefore, the farm households were grouped into three farm types based on both their structural and functional characteristics. These characteristics included their resource endowments, production diversity, and off-farm sources of income (illustrated in Figure 6.2 D, E, F).

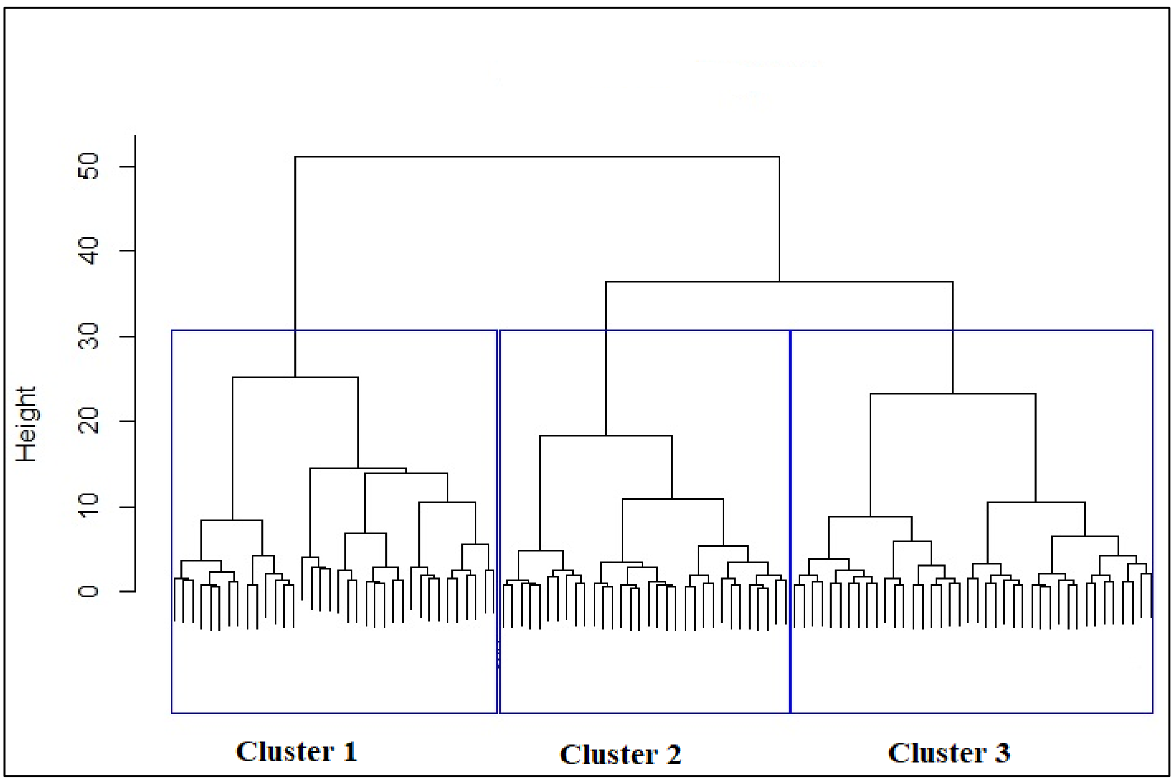


Figure 6. 3: Dendrogram showing various cluster solutions from Ward's method of cluster analysis

Source: Author's own based on cluster analysis results

6.4 Characterization of farm types

Farm type 1 "poor resource endowed farm households" accounted for 30% of the assessed households (Table 6.5). This farm type was characterised by farm households who had low access to arable land and cultivated smaller pieces of land. Farm households in this cluster had fewer number of fields cultivated. In addition, their production diversity on farm was also low. Income from on-farm produce was lowest in this farm type. Farm households in this farm type, had the least labour input in crop production relative to the labour input by farm households in other farm types. They had the least revenue from off-farm sources and owned less livestock. However, the household size and total household labour was moderate in this farm type.

Farm type 2 "medium resource endowed farm households" was represented by 37% of the households (Table 6.5). Farm household in this farm type had relatively more access to farmland and cultivated relatively large fields. They also cultivated relatively more number of fields. Production diversity was highest in this farm type, with more number of crops and crops in different food groups being cultivated. However, they had the least number of household members and total household labour needed for crop production. Furthermore, their labour input in crop production was the highest. Their revenue from non-farm activities was also not high. They had a relatively high number of livestock as well as income from own crop production.

Farm type 3 "high resource endowed farm households" accounted for 33% of the households considered for the clustering. This farm type represented farm households that had access to large farmlands and cultivated large croplands (apparently, categories in Uganda). They had more number of fields and cultivated more crops as well as crops in different food groups. Farm households in this cluster had the highest number of family members and total labour resources within the household. In addition, they also owned the highest number of livestock. Correspondingly, their labour input was lower compared to the medium resource endowed households. They were more engaged in non-farm activities and therefore obtained high revenue from these activities. With the income obtained from off-farm activities, they hired other labour for cropping activities. The income earned from the sale of on-farm products was highest in this farm type (Table 6.5).

Results generated from the farm types are presented in Table 6.5. The table shows the characteristics of the farm types and the p-values for a one-way analysis of variance for the variables (equality of group means). The lower p-values for the variables indicated that the variables were significant in generating differences between the farm types.

Table 6. 5: Characteristics of farm households in each of the three farm types and P-values of one-way ANOVA for the variables

Variable	Farm type			P-value
	1 (n= 32)	2 (n= 40)	3 (n= 36)	
Land access (ha)	0.46	0.98	1.42	0.000
Land cultivated (Crops) (ha)	0.46	0.97	1.34	0.000
Number of fields (number)	1.94	2.73	2.78	0.000
Number of crops (number)	4.16	5.53	5.42	0.000
Number of food groups (number)	3.12	3.92	3.81	0.001
Household size (number)	5.19	4.75	8.17	0.000
Total household labour (AEU)	3.70	3.52	6.29	0.000
Labour input (Hours)	311.78	701.80	506.53	0.012
Tropical livestock units (TLU)	1.15	2.41	4.17	0.000
Off-farm income (USD)	108.45	113.82	402.70	0.000
Crop sales (percentage)	29.50	43.00	46.44	0.002

Source: Author's own computations based on survey data

Figure 6.4 shows the distribution of the farm types in the study area in relation to their location on the mountain landscape. The distribution of the farm types varied between the low and mid altitudes as illustrated. Type 1 farms were predominant in the mid altitude. The concentration of Farm type 1, who were mainly farm households with low resource endowments in the mid altitude could be attributed to the high population density in the mid altitude. The high population density exists because of social amenities such as infrastructure in the mid altitude, as such, access to arable land is limited. Therefore, these farm households cannot produce more crop output and sell to the market. As already mentioned, they have limited land for rearing livestock, which is also an income source for example, the sale of animal products and/or hiring out of draught animals. On the other hand, very few of these type 1 farms were located in the low altitude.

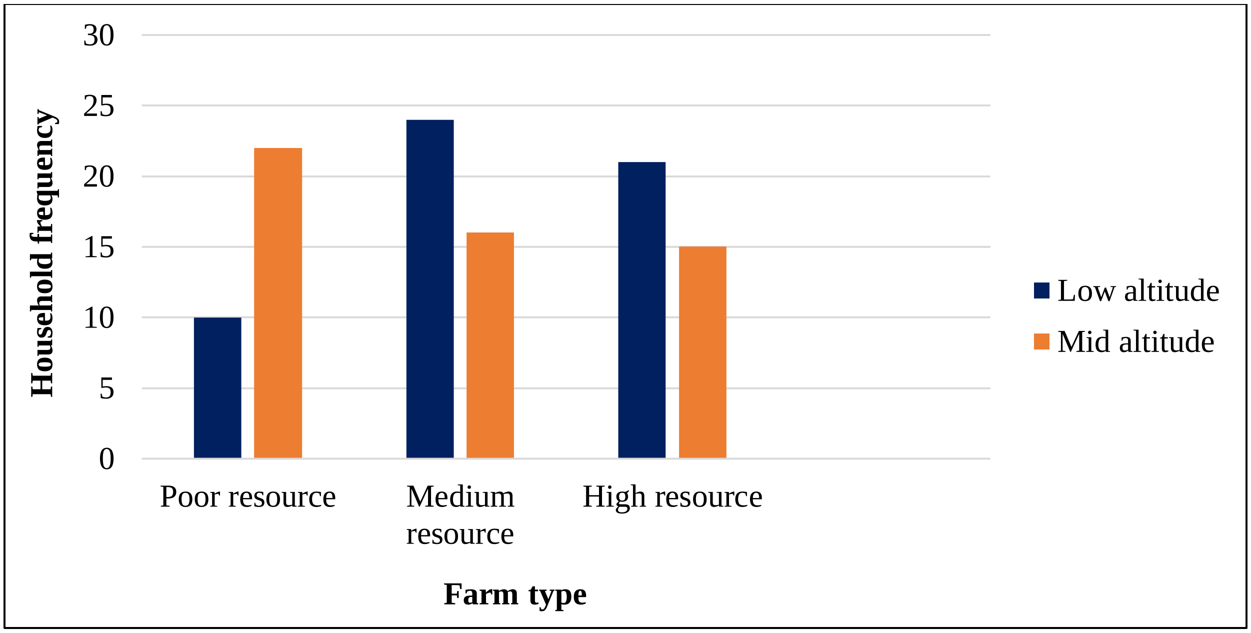


Figure 6. 4: Distribution of farm types by altitude

Source: Author's own design based on survey data

It can also be observed that although type 2 and 3 farms were found in both the low and mid altitude, the majority of them were mainly located in the low altitude (Figure 6.4). This variation could be explained by the fact that most of these farm households are located away from the centres where social amenities exist therefore they concentrate more on farming activities. This may also suggest that, since they are located away from centres with social amenities, therefore, leisure seems not to be important for them.

6.6 Variability among the different farm types in relation to labour expended in crop production

Farm households in the study area have different characteristics and therefore, we expect the work effort in crop production also to vary. Literature identifies a range of factors that influence labour input in crop production activities. These factors include; household related characteristics, household resource endowment, production orientation and off-farm sources of income.

Household characteristics such as the size of the household are closely linked to the labour input used in crop production. Households with higher numbers of members within the working age have more labour workforce to expend in cropping activities compared to households with fewer members of working age or households having more dependants. This is representative of farm type 3, which has the highest number of human capital (Table 6.5). Higher numbers of family members who can work on-farm translates to less use of outside labour. Larger household sizes on the other hand also imply that there is need for more crop output since the consumption demand of the household also increases. One likely reason for the increase in production in households with larger numbers of members is the availability of household labour to utilize in cropping activities.

Jogo and Hassan (2010) argue that household income diversification is also related to an increase in household size. That is, as the size of the household increases, the household tends to diversify its sources of income. Therefore, part of their farm labour is diverted to non-farm activities to increase household income to satisfy increases in consumption demand. Therefore, Conversely, some studies have confirmed that while older and young individuals tend to work on-farm, middle-aged individuals prefer off-farm jobs (Bagamba et al., 2007). This could be one likely reason why farm households in farm type 1 have the lowest percentage of crop sales (Table 6.5). One likely reason could be that they are engaged in off-farm activities but more remote, although their incomes are low. In addition, probably because they are mostly middle-aged individuals who want to stay next to centers with infrastructure.

Resource endowment in terms of ownership of assets such as larger farm sizes and productive assets like livestock influence the total labour input in production activities. Households owning larger farm sizes for example have been found to hire in external labour. This can be illustrated by households in farm type 3. Some households could have less labour capacity than what is actually required and therefore are forced to hire in labour outside of the farm. Rapsomanikis, (2015) noted that households with larger farm sizes sold larger proportions of crop output because of low transactions costs associated with larger quantities of produce. Farm households with smaller farm lands on the contrary tend to look out for off-farm employment because of constraints in accessing more farmland like those in farm type 1 (Bagamba et al., 2007). Furthermore, when the farm size is small, and not all household members can work on the farm, some of the members are compelled to sell their labour off-farm.

Farm type 1 (Table 6.5) households were not well endowed in terms of resources therefore their lack of access to resources could not allow them to earn income beyond the level of subsistence. Households belonging to this farm type could also be mainly young newly married couples who were just starting a family and had not accumulated capital that could allow them to invest in crop production activities, for instance hiring, or purchasing more land to increase their crop production. As such, their labour investments in crop production activities was also low since they farmed smaller pieces of land which was also not necessary for them to hire additional farm labour.

In accordance with the above, since these households owned smaller pieces of land, they possibly spent less time working on-farm because of the small farm sizes and they were possibly more inclined to practice mixed cropping systems. Information from focus group discussions, household survey and household observations, showed that, farm households in the mid altitude mainly practiced mixed cropping. This is also consistent with the study results, because majority of farm households in the mid altitude were in farm type 1. While looking at employment decisions among farm households in Slovenia, Juvančič and Erjavec (2005) found that increases in farm size led to decrease in off-farm employment. In the same way, a study by Bagamba et al., (2007) on labour allocation decisions in Uganda revealed that farm size negatively influenced time allocation to off-farm employment. The authors note that farmers engage in off-farm activities due to land constraints that hinder them from carrying out farming activities. This implies that households with large farm sizes tend to focus most of their labour effort on farming activities compared to non-farm activities.

Ownership of large numbers of livestock by type 3 farm households also enabled them to earn income from livestock through marketing of livestock products and hiring out draught animals for cropping activities to households that did not own the draught animals. Crucially, livestock provides manure, which is applied to these farms, leading to increased crop production and consequently increased incomes. The manure is mainly applied in banana fields, the banana stems, leaves and peelings are in turn used as feed for the livestock. It is perhaps worth noting that ownership of livestock for instance also helped these households to overcome the drudgery of farm labour, thus reducing labour input in crop production activities (Table 6.5). This can enable family members to engage their labour in other productive activities such as off-farm work thereby leading to an increase in household income.

Jogo and Hassan (2010) provide evidence from Southern Africa that the labour input in production activities by well-endowed households is less, compared to households that are not well endowed with resources. The authors point out that, poor-endowed farm households allocate more labour in the production of food crops, in order to meet the food needs of their households. They emphasize that the well-off households have access to productive resources for example, land and livestock, which increase farm productivity. This finding is in line with the results obtained in this study with regard to farm type 3 households. Farm type 3 had the highest percentage of crop sales (46%), implying they had more surplus production compared to farm type 1 and 2. In addition, households with resources (assets) are more likely to have access to credit due to possession of collateral, as such, they can invest in crop production activities for instance hiring of labour, purchasing agricultural inputs and farm implements.

It is likely that the production orientation of farm households also determines their labour allocation decisions in production. This could also be reflected in the production diversity of the farm, although small farms can also have high sales (by specializing in the production of particular crops) and but cheap food. However, farm type 1 households, which were also small in size, had the lowest production diversity. For instance, farm type 3 households had the highest percentage in terms of sales of own produce. The high sales of crop produce could probably be related to the need to pay school fees for their children since the group also had the highest number of family members, who could have been children of school going age. Their high income earning capacity in relation to crop sales may be linked to their better endowment of resources in terms of arable land. These households had the capacity to hire in labour for crop production activities since they had high revenue from both on-farm and off-farm sources. In certain cases, a farm household's labour input in production activities may be high because of the priority given to nutrition security compared to other household objectives.

Revenue to the household in the form of off-farm income is of importance because it mitigates constraints related to household liquidity. For instance, farm type 3 households earned the highest income from off-farm sources, compared to farm type 1 and 2. This implies that, they were in a better position to invest in farm inputs like fertilizers, and also hire farm labour. In the study area, off-farm employment is mainly in the form of salaried employment for example teachers, self-employment like buying and selling of produce and casual wage employment. On the other hand, women are involved in cooking and selling activities, and this as well has impacts on farm labour. This is especially so, because literature says that women perform the majority of farm work in Africa (Palacios-Lopez et al., 2017). However, participating in off-farm employment varies between farm types and is also influenced by the composition of the farm household (Donnellan and Hennessy, 2012). Davis et al., (2017) documented that higher diversification into off-farm income sources by high resource endowed households could relate to the use of profits from one activity to overcome entry barriers into other activities. Although revenues from off-farm income is lowest in type 1 farm households, evidence suggests that households located closer to centers with social amenities such as infrastructure and markets have better chances of being engaged in off-farm activities.

Off-farm income to the household can also be linked to increases in crop output because households have the ability to invest in crop production. On the other hand, access to off-farm activities may lead to low agricultural production due to low incentives to carry out crop production.

6.7 Selection of representative farms

The complexity of farming systems necessitates the identification of homogeneous subsystems, which can be used to develop solutions and target recommendations. Farm typologies as discussed above were constructed in order to identify representative farms in the study area.

Different methods have been employed to identify a typical farm household from a homogeneous group. One clear example is Wallace and Moss (2002) who selected a representative farm household by identifying the household with average resource endowments within each of the clusters. Khan and Rehman, (2000) similarly identified a representative farm household for building a farm model based on the similarity of the households to the average farm conditions of each of the identified clusters. This was done by computing the total distance (of every variable) between the average farm and the observed farm, where the farm with the lowest aggregate distance was chosen. In a contrary manner, Parminter (2018) selected representative dairy farms from each of the five identified cluster farms in New Zealand by calculating medians of attributes of each farm within every cluster. The identified representative farm was one that was nearest to the centre of each one of the clusters. In the same way, Wegener et al., (2009) in their study to assess the effect of certain European Union rural development actions on semi-subsistence farm households in Poland, identified one real household from the farm types by selecting a household whose variables were similar to the median values of each farm type.

In line with the above, this study identifies representative farm households by assessing the total distance between each of the farm households and the average farm household. The average farm household had the mean values of each of the clusters. The total distance was computed as the aggregate of the squared standardized difference between each of the variables of the farm household and its cluster mean (Table 6.6).

Table 6. 6: Deviations of the selected representative farm households from the cluster mean

Variable	**Farm type**		
	Standardized deviations		
	1	**2**	**3**
Land access (ha)	0.56	0.59	-0.01
Land cultivated (Crops) (ha)	0.57	0.65	0.12
Number of fields (number)	0.08	0.36	0.23
Number of crops (number)	-0.21	-0.40	-0.32
Number of food groups (number)	-0.17	0.09	-1.04
Household size (number)	0.45	-0.55	-0.62
Total household labour (AEU)	0.27	-0.61	-0.48
Labour input (Hours)	0.01	2.09	-0.04
Tropical livestock units (TLU)	-0.83	-0.94	0.52
Off-farm income (USD)	-0.71	0.13	-0.38
Crop sales (percentage)	-0.59	0.36	0.56
Total squared standardized deviations	2.53	2.89	2.60

Source: Author's own computations

6.8 Concluding remarks

Chapter six explores the different kinds of farm types in the study area. First, a typology of smallholder farms was constructed using multivariate statistical methods of principal component analysis and cluster analysis. In addition, in order to compare the means of variables in each of the farm types, a one way ANOVA (equality of group means) was performed. All the selected variables were significant in differentiating the various farm types. Variables used to develop the farm typologies included amount of land accessed and cultivated by the farm household, number of fields cultivated, number of crops and food groups' cultivated, household size, household labour measured in adult equivalent units, livestock size, off-farm income and percentage of crop sales.

Based on the classification above, three farm types were identified. These farm types included; (1) poor resource endowed farm households, who had less access to arable land and did not sell much of their crop produce, (2) medium resource endowed farm households, who had average land sizes and their crop sales were also average and finally, (3) high resource endowed farm households, who had access to larger crop lands and their sales from own crop production was highest compared to the other farm types. Moreover, the different farm types were also identified based on their location in the study area in relation to altitude. From the results, it was observed that majority of farm households that fell in the category of low resource endowment were located in the mid altitude while most of the households in the type medium resource endowment and high resource endowment were located in the low altitude.

These distinct farm types also indicated that their labour allocation patterns varied based on their different production strategies. With the above identified farm types, a representative farm household was chosen. The classification of farm households into similar groups was to identify a representative farm condition for the construction of a representative farm model.

CHAPTER 7

7 APPLICATION OF COMPROMISE PROGRAMMING MODEL TO OPTIMIZE CROPPING PATTERNS OF SMALLHOLDER FARM HOUSEHOLDS

This chapter concentrates on resource allocation decisions made by farm households in the mountain Elgon region of Uganda using a formal programming model. It focuses on developing an optimal cropping pattern for a typical farm household. The chapter highlights the decision-making processes and the conflicts that exist between the different farm household objectives identified, that is: (1) household nutrition, (2) cash income and (3) leisure. It examines the trade-offs among farm household objectives using a multi-objective linear programming model.

The model aims at identifying (1) nutritious food and (2) income, for the farm household, as well as a crop production plan. A cropping plan shall provide more leisure time. It works for a representative farm household. In order to identify the best compromise solution amongst the three household objectives, four analytical steps were followed. First, household objectives were optimized individually, to establish the ideal and anti-ideal points of the objective functions. Secondly, a set of efficient solutions was generated through a constrained optimization. The third step involved obtaining the deviation between the objective values and their ideal points. Lastly, the compromise solution was generated by introducing a distance measure. The distance function was used to minimize the distance between each of the solutions and its ideal point. The reason behind the application of this concept is that a farm household would aim at choosing a solution that is as close as possible to the ideal solution.

Therefore, this study employs a compromise programming model to generate feasible plans at farm household level. Furthermore, these analytical methods provide results that help decision makers, in our case farm households, to make informed decisions through choosing proper alternatives. This enables them to allocate their household resources, for example labour resources effectively.

7.1 Identifying household objectives and weights

7.1.1 Selection of a representative farm

Farm typologies (see Chapter 6) were used to construct representative farms in the study area. A farm in this study is referred to as a family holding that is engaged in the production of subsistence crops as well as a cash crop or two. Mostly, the study deals with smallholders. The complexity of farming systems necessitates the identification of homogeneous subsystems that can be used to develop solutions and target recommendations. The aim of the study is to develop optimum crop choice plans for a representative farm household that has multiple objectives. Therefore, the study applies a mathematical programming model to achieve the optimal crop combination that maximises crop output in order to meet household objectives, taking into account household production constraints. Based on the farm household categories identified in Chapter 6, multiple objective linear programming models for typical farms with different resource endowments were developed.

7.1.2 Identification of household objectives

Household objectives were elicited through focus group discussions, by asking participants to mention their objectives. These objectives were taken into consideration by the households during crop decision making processes. Pairwise ranking was then used to identify the most important household objectives, following the method of Bebe et al., (2003), stated in literature review. Pairwise ranking is a matrix-ranking tool, which aids decision-making and helps to prioritize choices. It compares various choices in pairs. Potential choices are listed in a matrix table and then each option is compared with the other separately. The number of times it was chosen over the other is then added up (Gay et al., 2016). Finally, the option that has the largest number is considered the most important.

7.1.3 Pairwise ranking exercise

The pairwise ranking tool was used in a focus group discussion which had ten participants. The participants were identified through a key informant and were selected from the same village. One focus group discussion was conducted and this included five men and five women. The group included farmers who grow crops mainly for subsistence, sell part of their produce and farmers who sold most of their crop produce. Therefore, the group was representative of the different categories of farm households in the village. The exercise was demonstrated to the participants before starting.

The exercise began by asking participants to mention their household objectives. They suggested a set of their household objectives, which included nutrition, cash, social status, building a house, better standard of living (good beddings, medical care, good dressing) and educating their children. A matrix was then created using the set of objectives (Table 7.1). The diagonal cells were shaded because an objective was not compared to itself. The participants discussed the pairs of objectives presented by each cell and then chose which one was preferable. The number of the preferred objective was written in the cell. In a case where the participants could not come to a compromise over which objective was more important, participants voted for the objective that was more preferable.

In order to prioritize the objectives, the scores were ranked. The objective with the largest score was ranked first. The participants agreed to the rankings and then discussed why different options were selected over the other.

Table 7. 1: Pairwise ranking matrix of farm household objectives

	Objective						**Score**	**Rank**
Objective	1 Nutrition	2 Cash	3 Social status (leisure)	4 Building a house (permanent or semi-permanent)	5 Better standard of living	6 Educate and have learnt children		
1. Nutrition		1	1	1	1	1	5	1
2. Cash			2	2	2	2	4	2
3. Social status (leisure)				3	3	3	3	3
4. Building a house (permanent or semi-permanent)					4	6	1	5
5. Better standard of living						6	0	6
6. Educate and have learnt children							2	4

Source: Author's own illustration based on FGD data

From the participant's discussions, nutrition was considered the most important objective of the household. This was because good nutrition kept them healthy by preventing diseases and they were in a better position to work in their fields if they were physically strong, in line with results from chapter five, that presents labour allocation patterns in production activities. Cash was ranked second because it was needed to attain all the other remaining household objectives, including buying food items that the household did not produce on-farm. Once the cash objective has been attained, then social status can be achieved because cash could be used to buy and cultivate more land and also buy livestock. The participants mentioned that these all make the household to earn respect in the community, the reason for ranking social status third. Enjoying leisure activities also enhanced their social status in the community, therefore, it was viewed as a means to an end. Educating and having learnt children was ranked fourth because education was perceived to bring development to the community. In addition, according to the participants, having educated children also brought respect to the household. Having a permanent or semi-permanent house was ranked fifth because it provides security to household property and also improves household hygiene.

Better standards of living ranked sixth because all the preceding objectives were assumed to bring about a better standard of living. The pairwise ranking of the household objectives aimed at getting the important objectives and deriving their weights. The weights of the objectives were therefore, computed based on the share of the scores. Nutrition had the highest weight indicating that among the household objectives, nutrition was the most important objective and contributed highly to the total decision-making process.

From the rankings, the most important household objective was to have nutritious food. The households, however, also desire to have enough food throughout the year. The participants indicated that their major household objective was to consume adequate foods from different food groups. In addition, the participants also mentioned that they did not want their children to go hungry and so, they needed to have food that was available every-time. Crops that were mentioned by the participants, as those that eliminated hunger included bananas, maize and beans. Banana for example eradicated hunger because of its continuous harvest throughout the year. Similarly, maize and beans could be stored for a longer period after harvest, as such, provided food to the household for a longer period thus reducing hunger. Beans, as mentioned, were mainly eaten with maize (posho) or with banana. Likewise, maize (posho) was mainly eaten to provide energy and it made them feel satisfied and therefore, they were able to work longer hours during production activities that required a lot of effort such as ploughing.

Additionally, the participants also mentioned that they included vegetables in their diet and this was mainly kale (Sukumawiki) or eggplants and it was mainly cultivated by the households themselves. However, certain households also sold these crops in order to earn cash income. The reason why cash was considered the second most important objective of the household was that it could be used to achieve other household objectives. Examples of other household objectives that required cash in order to be attained included; paying school fees, acquiring assets like land, livestock and buildings, paying back credit and purchasing other foods in order to have a balanced diet. Information from the focus group discussions revealed that households mainly purchased other foods from the market for a balanced diet when (1) children complain that they are tired of eating the same food and need to eat another kind of food, (2) had visitors, or (3) had a sick family member. Therefore, the households did not trust in the local markets to buy food, for example after selling coffee because the foods could not be in stock at fair prices. As such, they preferred to consume from their own farms. Furthermore, responses from the focus group discussions indicated that men made decisions concerning the returns from coffee, and the income was seldom given to women, or used for purchasing food. Therefore, women had to provide food, which was mainly from their own farms.

Nevertheless, the households' aim was to consume "good" food or "eating well". The "good" food is what they referred to as a balanced diet in terms of food diversity (having a variety of foods). To the households, eating a variety of foods was considered as achieving a better standard of living, which was also another household objective mentioned by the participants. Having a good standard of living meant that the household was able to afford (from cash) a variety of food types. However, it was not considered among the most important household objectives. Implying that, other household objectives could only be realized after the "most important" ones have been achieved. So it is reasonable to assume that some objectives are a means to achieving other objectives.

According to the participants, having a balanced diet means eating different types of foods to acquire energy, protein and vitamins. This, according to the participants could be acquired by purchasing some of the foods that were not available to a particular household and therefore cash income was needed. From the participants' perspective, the households had the desire to produce and consume various kinds of foods for good nutrition, however, they were constrained by labour to produce such foods or had cash constraints to purchase such foods. This was mainly related to what they locally produced, which also depended on the resources available to the household such as the labour available to cultivate a particular kind of crop and/or land availability to produce a number of crops from different food groups.

Participants of the focus group discussion also recognised the fact that although households had the desire to increase their production diversity to be able to have a diverse diet, farm labour was limited to cultivate the desired crops. In light of the agro-ecological situation, other crops could not perform well because of the fertility status of the soils whereas other crops were perishables and could not be stored for a longer period. The availability of land to cultivate a number of crops was also a major challenge for the households, as such, some households only cultivated a few crops which were consumed by the household from time to time. This is so because most of the households often consumed what they produced. As stated by some of the participants, change in diet was only possible under certain circumstances for some households, for example, when a family member was ill or when the family had visitors.

Although households understood the importance of having food in the home, some mentioned that it brings happiness and peace in the home, and that it makes them healthy so that they are able to perform productive activities. From the pairwise ranking exercise, participants were able to prioritize their household objectives.

This section has provided a review of the objectives of farm households in the study area. Although the household members mentioned a number of objectives that they would seek to achieve, they were not all included in the model because most of them were related to the identified three objectives included in the final model.

7.1.4 Estimating Weights of household objectives

Weights are assigned to objectives within a multiple programming model to normalize the objectives in the model and to specify the preferences of the household (Tamiz et al., 1998). Therefore, in order to assign weights to the household objectives based on their relative importance, the rank order centroid (ROC) method was applied. This was applied to three household objectives. These objectives were selected from among the objectives ranked by the households and were considered necessary. They included; nutrition, cash income and leisure. From literature, leisure is considered as one of farmers' most common objectives after risk and returns Berbel (1988), as such it was imperative to include leisure as an objective in the model.

Among the household objectives identified, the three most important ones were selected. Based on the rankings of the objectives by the households, nutrition was ranked first, followed by cash income and then leisure was ranked third. For the case of multi-objective scenarios, the objective ranks were then converted to model weights using the rank order centroid method proposed by Barron and Barret (1996) as already discussed (section 3.6.2). The ranks and weights of the household objectives are presented in Table 7.2.

Table 7. 2: Ranking and estimated weights of household objectives

Rank	Objectives	Weight
1	Nutrition	0.61
2	Cash income	0.28
3	Leisure	0.11

Source: Author's own presentation based on FGD data

7.2: Decision making framework and model overview

A representation of decision making of a smallholder farm, based on the farming system of the Mt. Elgon is presented in Figure 7.1. The aim of the farm household is to efficiently utilize its resources, that is, land, labour and capital. However, the problem is allocating the resources to production activities in such a way that the household objectives will be satisfied. As identified in the previous section, the farm household has multiple objectives that are often in conflict. Therefore, to be able to manage the farm, the farm household desires to achieve the best level of satisfaction from its multiple objectives. With no doubt, some of the objectives will compete with each other, for example enjoying leisure activities versus cash income. These all compete for household labour. As such, the household has to attain its satisfaction by trading off one objective against another.

These decisions are not any different from the decisions made by other farm households elsewhere. Consequently, the farm households need to make choices in the way they use their resources to achieve their objectives. For instance, they are faced with choices as to whether to produce diverse and nutritious crops for household consumption or sell part of their output to gain cash income. In the end, the decisions undertaken as well as the available options usually have impacts on the goals of households.

As shown in Figure 7.1, labour (time) is of utmost importance since it is required to meet the objectives of the household. Social obligations within the community also do have an impact on the use of time and these ultimately decrease production time. These obligations may either be set by the community or by individual interests (Holden, 1993). The obligations for instance are seen as spending leisure time.

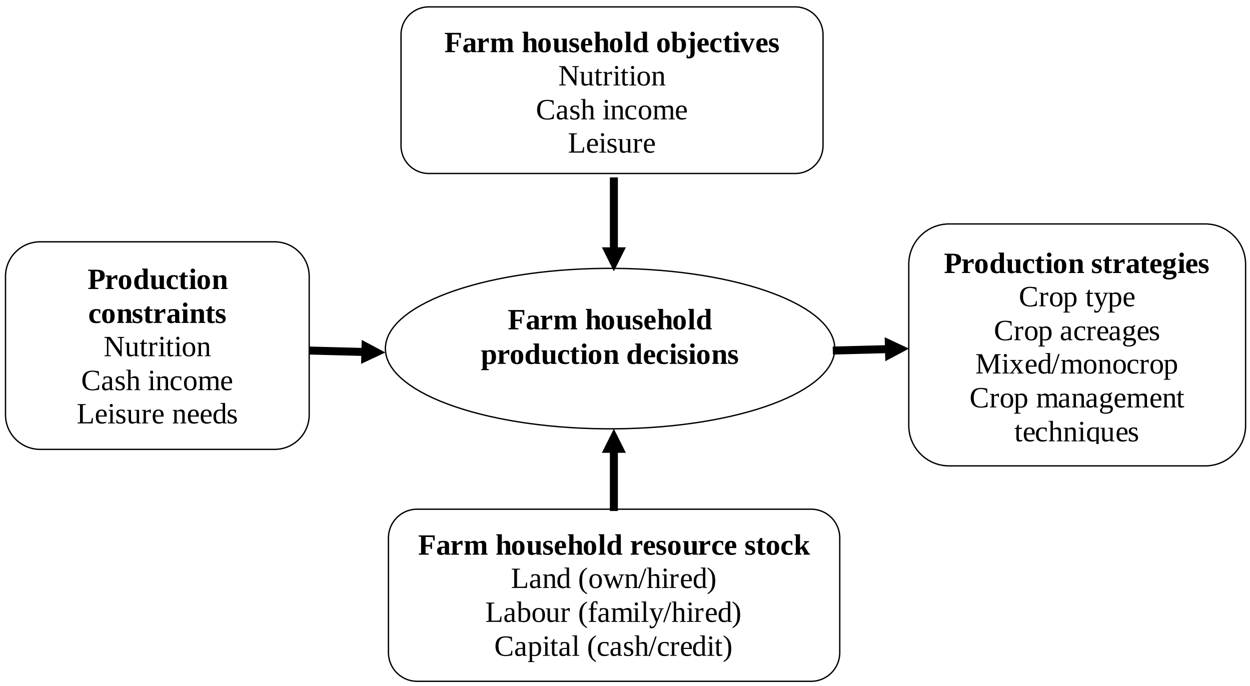


Figure 7. 1: A decision-making framework of a smallholder farm in the Mt. Elgon

Source: Author's design

Farm households in this study referred to leisure as time spent on relaxation activities as well as time expended in social commitments. These activities included drinking local brew with friends, visiting relatives, community activities and clan meetings. The households also viewed leisure as a way of enhancing their social status, which was one of their household objectives. When households spend their time performing these activities, it means this time is not available for cropping activities. Kowalski (2016) considered leisure activities as consumption activities that did not necessitate compulsory time input, and these activities were found to vary amongst individuals.

Sendi and Brouwer (2004) state that the amount of time individuals are willing to trade-off in favour of leisure, is reflected by the marginal rate of substitution between the time spent working (income) and time consumed for leisure activities. The authors base on the neoclassical labor theory and claim that the marginal value of leisure is therefore, related to an individual's wage rate.

7.2.1 Analytical framework

As said, the reason for constructing the model for developing optimal cropping patterns in smallholder farming systems is that farm households have multiple objectives. The objectives considered in this model are household nutrition, household income, and leisure. These objectives compete for the use of farm resources like land and household labour. Most of the foods consumed by the households are self-cultivated and the “surplus” production is sold to generate cash income for the household. Therefore, changes in crop production will affect household food requirements and consequently the cropping patterns. Since the household consumed most of what it produces, therefore the assumption is that changes in the demand of food can largely be met by adjusting the volume of food production. Also, the model does not include buying of food crops because the households consumed mostly what they produced on-farm.

Additionally, crop production activities are mainly carried out by household labour. As such, the availability of household labour specifically during peak periods of cropping activities, for example during planting, weeding and harvesting periods is considered a main constraint. This ultimately determines the pattern of cropping activities undertaken by the smallholders. On the other hand, farm households also strive to have enough cash available within the household to meet other household requirements throughout the year. This is done by allocating their resources (land and labour) to activities that generate cash income. At the same time, they need to allocate part of their time to consume leisure activities. Farm households are therefore, forced to allocate their labour (measured in time) to the various household activities to achieve their objectives.

Therefore, an optimizing household model should consider all the above three household objectives, that is, finding a good compromise between the three household objectives, instead of optimizing only one objective. The flow chart of the model that seeks to achieve a compromise solution amongst the above-mentioned household objectives is presented in Figure 7.2 below.

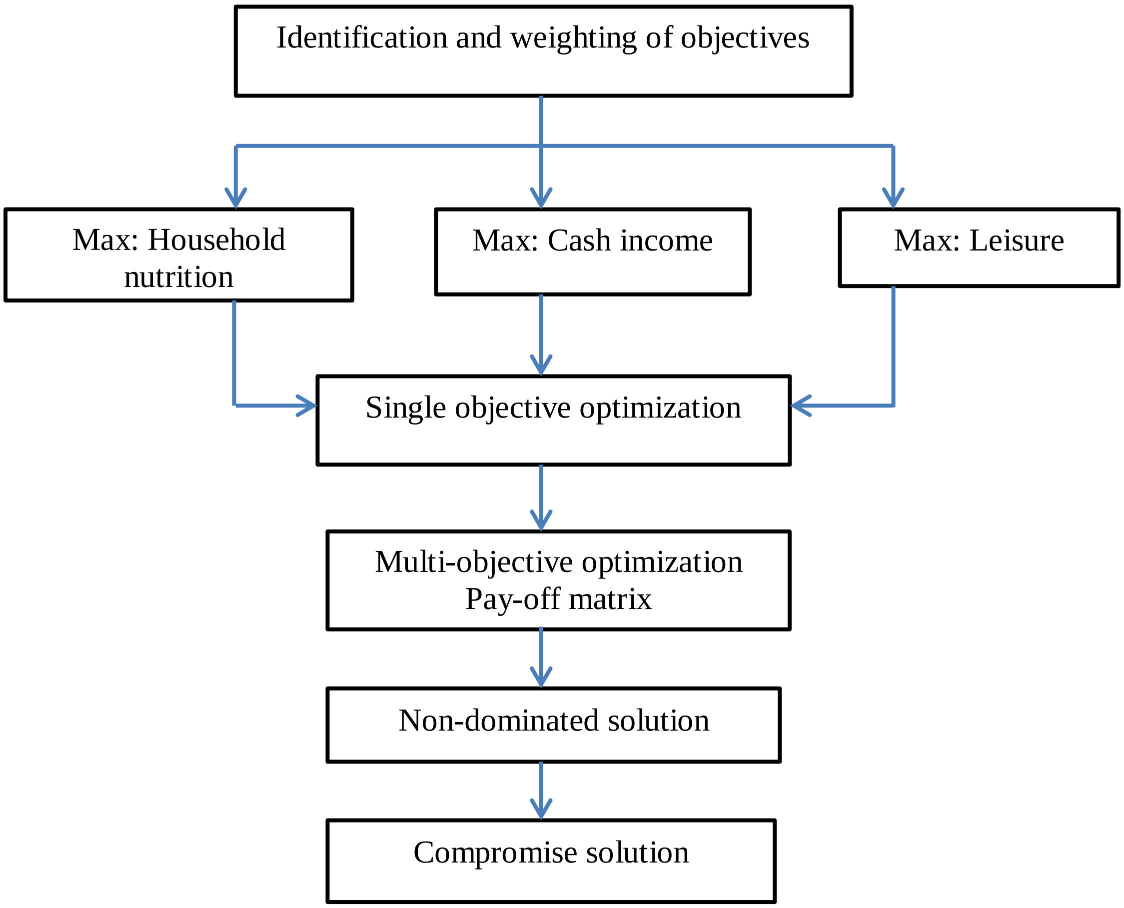


Figure 7. 2: Flow chart of the Compromise Programming model

Source: Author's own presentation based on literature

This study attempts to model the decision-making processes undertaken by typical farm households as well as the conflicts between the objectives that these households seeks to achieve. Moreover, because these objectives compete for household resources, such as labour and land resources, therefore they are in conflict with each other. In such a situation, it is not possible to optimize one objective without another objective being adversely affected. Therefore, with the use of compromise programming, a trade-off analysis is carried out to determine a desired level of crop output and leisure time that leads to the best satisfactory solution regarding the three household objectives considered.

In trying to achieve the best satisfactory solution, compromise programming is used to choose a sub-set of optimum cropping plans from a set of efficient cropping plans. The first step involves establishing the 'ideal point', which is represented by the optimum values of each of the three objectives considered in the study. And since the ideal point is by no means feasible, therefore an efficient cropping arrangement that is closest to the 'ideal point' is selected as the optimum or best compromise cropping plan. To achieve the compromise solutions, distance measures and weights attached to the different objectives are used to determine deviations between every objective value and its respective ideal value (Romero and Rehman, 2003). The detailed analytic procedure of the model used in this study is illustrated in the next section.

7.2.2 The compromise programming approach

Mathematical programming models have been used over the years to support farmers in their cropping plan decisions by efficiently allocating farm resources. This is because these are the main decisions made by farmers in farming systems. They include decisions such as crop choice, area allocated to the crops and location of the crops within the farmland. More so, these decisions are made based on the decision maker's objectives and constraints. According to Delforce (1994), typical smallholder production systems are particularly constrained and as such, the use of mathematical programming models for modeling crop plan decisions are deemed appropriate. These crop planning models are also used as support tools to help policy makers and stakeholders in outlining plans that allocate limited resources efficiently (Dury et al., 2012). Agricultural planning decisions often involve multiple objectives and as such, a decision often regarded as 'satisfying' is generally sought instead of maximizing objectives (Gupta et al., 2000).

Compromise behaviour presumes that the household is concerned with realizing a compromise from its household objectives. As such, to meet their income objective, they target their labour resources to the production of profitable crops but hardly increase the area under these particular crops. Farm households often intercrop food crops and cash crops, as a strategy to maximize food output from the small plots of land. This practice demonstrates the conflict among the household's need for nutrition and cash income, and subsequently, which crops to allocate its labour effort (Conelly and Chaiken, 2000). This may also be the case, where farm households not only want to reduce their labour effort in production activities but also want to increase their leisure time.

The kind of crop cultivated by the household determines the labour intensity of the production process, since labour intensity varies among crops. Consequently, the cropping practices performed on the individual crops have an impact on farm productivity (Nolte and Ostermeier, 2017). In farm households where labour is limited, crops that are less labour intensive are chosen, or the more labour intensive crops are allocated smaller plots of land. For example, certain crops require two weedings while others need to weeded only once. A study by Amare et al., (2018), in Uganda, found that the size of the household had a positive and significant effect on the share of land allocated to the production of pulses and cereals, whereas it had a negative effect on the share of land allocated to the production of tubers. Implying that, pulse and cereal production are more labour intense compared to the production of tubers. Hence, crop labour requirements determine the size of plot to be cultivated for a given crop. Therefore, since crop choices are shaped by competing uses of labour, farm households have to make a compromise on their objectives.

Unlike other multi-objective programming techniques such as the goal programming which necessitate that achievement targets be set, compromise programming technique on the other hand does not require the setting of achievement targets and other approaches such as the lexicographic. Goal programing requires that household goals are introduced into the model in a sequence (Teufel, 2007). Also, getting information on realistic targets is quite difficult. As such, compromise programming was selected as the most appropriate technique, because it only requires a set of weights that describes the importance attached to the objectives by the decision makers. With the above background, in order to achieve the ‘best’ compromise solution, the compromise programming model, followed the steps described below (Lakshminarayan et al., 1991; Romero and Rehman, 2003).

The first step in the compromise programming model is to identify the ‘ideal’ solution, which is the optimal solution vector, Z(X) achieved by optimizing the different objectives independently. It represents a shared position of the maximum values of each of the individual objectives (Poff et al., 2010). However, the ideal solution set is not always feasible. Therefore, the ideal solution set acts as a standard from which the compromise solutions can be assessed.

In the second step, a pay-off matrix is generated. The pay-off matrix helps to quantify the level of conflict that exists amongst the various objectives under consideration. The elements in the pay-off matrix are obtained by solving the ordinary linear programming model as many times as the number of objectives considered, and their values computed in each of the optimal solutions. In each of the solutions, the optimal value of the objective optimized is accompanied by the values of the other remaining objectives at that particular solution (Romero and Rehman., 2003). Therefore, the elements in the major diagonal of the pay-off matrix represent the ideal solution (utopia) whereas from each row of the matrix is the anti-ideal solution (nadir-point). The anti-ideal solution indicates the solution where all objectives attain their worst values. Between the ideal and anti-ideal points lies a range of points for each of the objective functions.

In detail, according to Romero and Rehman (2003), to establish the efficient set, the model is formulated as;

$$Eff.Z(X) = [Z_1(X), Z_2(X), Z_3(X)] \tag{7.1}$$

$$Subject\ to\ X\ \in F$$

Where Eff represents the search for efficient solutions, X indicates a vector of decision variables and F denotes the feasible set.

The household's objectives are;

1) Maximize Cash income (Z_1)
2) Maximize Nutrition (Z_2)
3) Maximize leisure (Z_3)

To generate the efficient set, also referred to as the pareto-optimal set, the constraint method is used. This is done by optimizing one of the objectives while the other objectives are specified as constraints. Through parametric variation of the right-hand side (b_1, b_2) of the elements of the constraints representing the objectives, the efficient set is then obtained. Generally, the generic elements of the efficient set are obtained by solving;

$$Max\ Z_1(X)$$

$$s.t\ Z_2(X) \geq\ b_1$$

$Z_3(X) \geq b_2$

$X \in F$ (7.2)

In a model consisting of two objectives to be optimized, the boundaries of the feasible set are illustrated as in Figure 7.3.

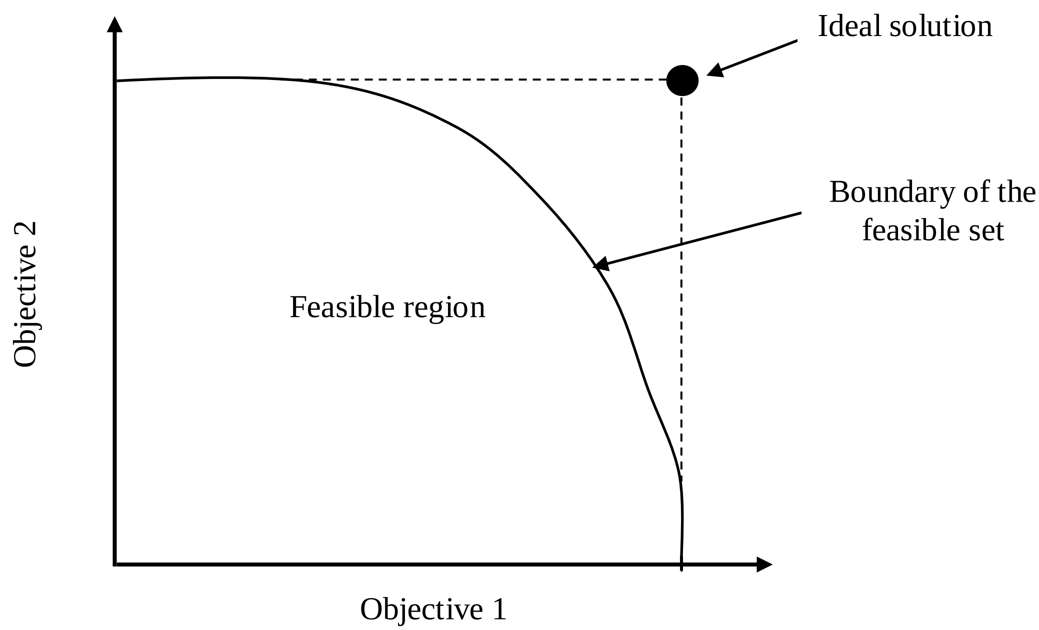


Figure 7. 3: An illustration of the decision variable space

Source: Modified from (Alfredo, 2000)

The third step necessitates obtaining the deviation between the objective value and its ideal point. As mentioned earlier, the decision maker aims at choosing the feasible solutions as close as possible to the ideal solution, herein referred to as the best compromise solution. As such, the closeness between the j^{th} objective value and its ideal denoted by d_j is given by;

$$d_j = Z_j^* - Z_j (X) \quad (7.3)$$

When the j^{th}objective is maximized, or it is defined by the expression below when the j^{th} objective is minimized;

$$dj = Z_j(X) - Z_j^* \quad (7.4)$$

Z_j^* represents the ideal value.

To overcome the problem of incommensurability, that is, when the objectives are measured in different units (for example in this study, cash income is measured in dollars, nutrition in percentage and leisure in hours), a normalization factor is used. Therefore instead of using absolute deviations, relative deviations are used in order to get consistent results (Piech and Rehman, 1993). When the deviations are normalized, the degree of closeness between the ant-ideal (nadir) point and the objective value are bound between zero and one. Thereby implying, when it is zero, then an objective has achieved its ideal solution. On the other hand, when it is one, it indicates that the objective has achieved its anti-ideal solution. In addition, it assesses the percentage achievement of an objective with reference to its ideal value (Romero and Rehman, 2003). Thus, the level of closeness between the j^{th} objective value and its ideal is given by;

$$d_j = \frac{Z_j^* - Z_j(X)}{Z_j^* - Z_{*j}} \tag{7.5}$$

Z_{*j} represents the anti-ideal point for the j^{th} objective. This anti-ideal point is defined as the smallest or largest value of the objective function j in the pay-off matrix when the objective function is optimized (maximized or minimized).

In an optimization model comprising of two objectives, the deviations can be illustrated graphically as in Figure 7.4.

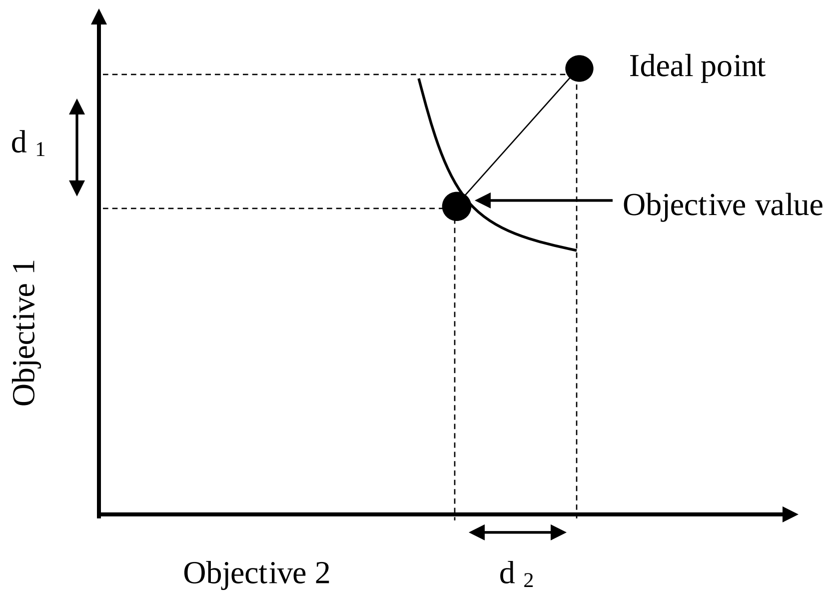


Figure 7. 4: Graphical illustration of the deviation between the ideal and objective values

Source: Modified from Alfredo, (2000)

The last step in generating the compromise solution is introducing a distance measure or family of distance functions referred to as the family of L_p metrics. The distance function is used to minimize the distance between each of the solutions and its ideal point (Piech and Rehman, 1993). In this step, weights representing the relative importance of the objectives are attached to the relative distance measures so as to determine the extent of relative decline in the distance measure of an objective that can be compensated by making another objective better (Teufel, 2007). Reaching this compromise solution is also considered as reducing the decision maker's disappointment for not achieving the ideal solution (Poff et al., 2010). According to Berbel and Gutiérrez-Martín, (2015), compromise programming introduces a family of distance functions defined below;

$$L_p\,(w,k\,) = \left[\sum_{j=1}^{k}(w_j d_j\,)^p\right]^{1/p} \tag{7.6}$$

Where w_j weights the importance of the deviation between the j^{th} objective and the objective's ideal value.

Therefore, in order to compute the distance that exists between a solution and its ideal point, the L_1 metric was used in this study. For the L_1 metric (where $p = 1$), representing the longest geometric distance, the best compromise solution for the metric is attained by minimizing the following LP problem (Romero and Rehman, 2003);

$$Minimize \quad L_1 = \sum_{j=1}^{k} w_j \left(\frac{Z_j^* - Z_j(X)}{Z_j^* - Z_{*j}} \right) \tag{7.7}$$

$Subject\ to\ X \in F$

$X \geq 0$

Where F is the feasible set, X denotes the vector of decision variables, Z_j^* is the ideal value and Z_{*j} is the anti-ideal value for the j^{th} objective, $Z_j(X)$ indicates the j^{th} objective function and w_j is the weight assigned to the j^{th} objective.

7.2.3 Specific household objectives

Compromise behaviour assumes that the farm households are concerned with realizing a compromise between three objectives, that is, nutrition, cash income, and leisure. Achieving the leisure objective necessitates a minimization of labour in crop production operations. However, the production systems employed may have an overall effect on the household objectives.

Household nutrition

Farm households in the study area are the primary beneficiaries of the production system in relation to the consumption of own farm produce. The main traditional staple crops consumed by the households include beans, cooking banana (matooke), and maize, cooked as “posho”. The maize is ground into flour. Other dishes consumed include root crops such as cassava and sweet potatoes, and vegetables like sukumawiki. The staple crops represent the bulk of the energy and nutrient intakes of the households in the study area. Achieving minimum nutrient needs of the family was vital for the households in study area, as mentioned by the household members during the focus group discussions. As such, minimum food nutrient requirements were incorporated in the model.

Quantifying household nutrition

Information on the nutrient requirements of household members is needed when looking at the quantity of nutrients available for consumption within the household. Therefore, the total nutrient requirement of the household is estimated as the summation of each household member's recommended food nutrient requirement. Minimum intake of nutrients per adult equivalent per day is based on the World Health Organization (WHO) recommended nutrient intake levels (Omiat and Shiverly, 2017). This study therefore looks at the caloric, protein and micronutrient consumption of foods of farm families in relation to their production because smallholders consume most of what they produce. This is done by assessing the nutrient composition of the different crops produced by the farm household. In addition, cropping patterns which attempt to reduce malnutrition may be preferred by households.

Minimum nutrient requirements, that is, energy, protein and vitamins were included in the model. This implies that the household ought to satisfy its recommended values of nutrient intake through its production of the different crops. Improvements in terms of other nutrients that have low intake or whose deficiencies are prevalent may also be included. However, this was not taken into account in this study. The minimum requirements account for nutrients required to meet household consumption in a year. This is so because farm households not only seek to maximise farm income but also have an objective of making certain that their family will survive in terms of nutrition. If the food consumed is produced on the farm, then the household can meet the nutrition objective. This is so, because the households mostly consume what they produce and do not usually purchase food from the market. Nutritional yields of different crops cultivated by the households were estimated from the values for grams of nutrient in 100g of a particular crop, obtained from the nutrient composition table for Eastern Uganda. Table 7.3 presents the recommended nutrient intake levels per adult equivalent per day based on the World Health Organization (WHO).

Table 7. 3: Recommended nutrient intake level per adult equivalent per day

Nutrient	Unit	Quantity (per 100g)
Energy	Kilocalories (kcal)	2990
Protein	Grams (g)	56
Vitamin A	Micrograms (μg)	900
Thiamin	Milligrams (mg)	1.2
Riboflavin	Milligrams (mg)	1.3
Niacin	Milligrams (mg)	16
Vitamin B6	Milligrams (mg)	1.3
Folate	Micrograms (μg)	900
Vitamin C	Milligrams (mg)	90

Source: Omiat and Shiverly (2017)

The model also includes crops grown as mixtures, and these were maize intercropped with beans, and banana intercropped with beans. Therefore, to obtain the total yield from a plot with maize and beans mixture, that is, to make the yields of the two different crops comparable, the yield of maize was converted to kilocalories (kcal) and thereafter to corresponding kilograms of beans. The same was done for the field that had a mixture of banana and beans. This method of obtaining a single yield from a field with mixtures was also applied by Kowalski (2016).

Based on the food composition table for Eastern Uganda (Hotz et al., 2012), one kilogram of maize has 3690 kcal/kg, one kilogram of bananas has 1220 kcal/kg whereas one kilogram of beans has 3470 kcal/kg. Therefore, a ratio of 1.06 and 0.32 is obtained when maize is divided by beans and bananas divided by beans respectively. This implies that one kilogram of maize is equivalent to 1.06 kg of beans while one kilogram to bananas is equivalent to 0.35 kg of beans. Thus, the yield of maize was converted to beans equivalents by multiplying with the ratio and the yield of bananas was converted to beans equivalents in order to attain the total yield from the mixed cropped plot. Furthermore, estimates of the nutrient contents of selected crops in the model are presented in Table 7.4 below.

Table 7. 4: Nutritional content of selected foods per 100 grams edible portion

Food	Nutrient								
	Energy (kcal)	Protein (g)	Vitamin A (μg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)	Vitamin B6 (mg)	Folate (μg)	Vitamin C (mg)
Maize	369	7.3	0	0.140	0.050	1.000	0.198	30	0
Beans	347	21.4	0	0.713	0.212	1.174	0.474	525	6.3
Bananas	122	1.3	56	0.052	0.054	0.686	0.299	22	18.4
Cassava	160	1.4	1	0.087	0.048	0.854	0.088	27	20.6
Sukuma Wiki	50	3.3	769	0.110	0.130	1.000	0.271	29	120

Source: A food composition table for Central and Eastern Uganda (Hotz et al., 2012)

The figure below (Figure 7.5) illustrates that a household requires different kinds of nutrients (n), in a specified quantity described in “Nutrient requirement”. The household nutrient requirement is based on the composition of the household in adult equivalent units (AEU). Furthermore, cultivated crops provide crop products, which have definite contents of a number of nutrients (n), specified in “Nutrient content” (Valkenhoef, 2014). Therefore, the nutrient component balances the nutrient requirements with the availability obtained from the nutrient content of the crop products, as demarcated by the dotted circle.

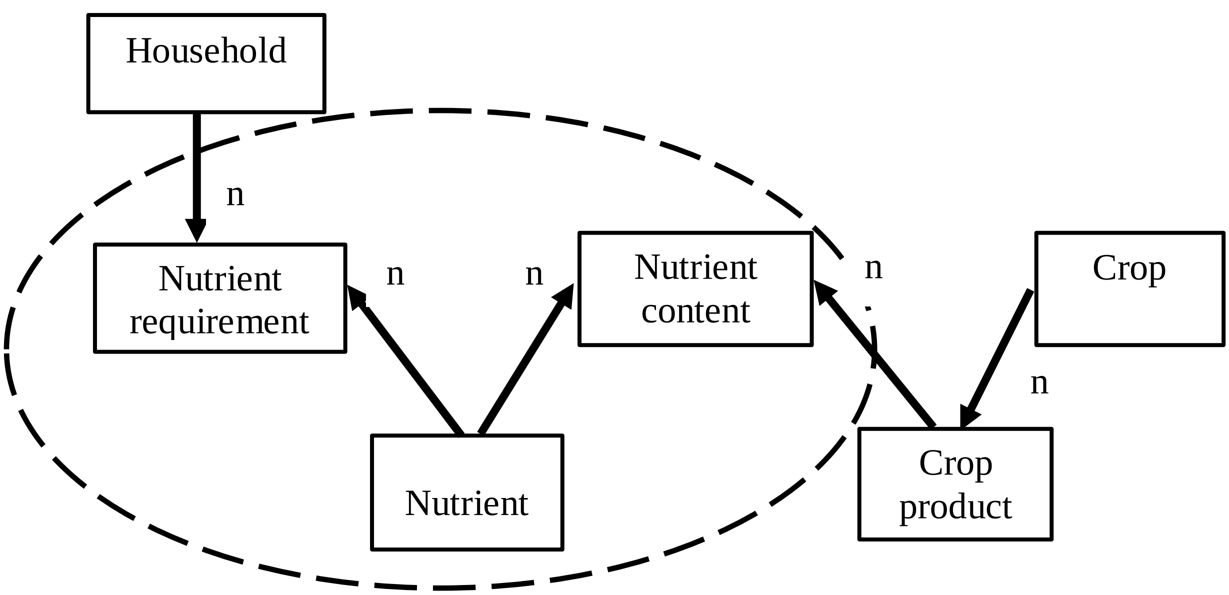


Figure 7. 5: Schematic representation of the nutrition component of the model

Source: Modified from Valkenhoef (2014)

Nutritional adequacy

Nutritional adequacy has been defined as the achievement of daily nutrients through the consumption of various foods considered as nutritionally balanced (Habte and Krawinkel, 2016). One of the indicators of nutrient adequacy is the mean adequacy ratio (MAR). It has been used as an overall measure of nutritional quality (Torheim et al., 2003). It is calculated from nutrient adequacy ratios (NARs) for energy intake and other nutrients. The NAR for a particular nutrient is the ratio of intake to the recommended nutrient intake. The MAR is therefore calculated as the mean of the NAR of nutrients considered. The MAR is represented as a percentage. For a household to achieve a MAR of I00 percent, it implies that the household nutrient intake is equal to its recommended intake. Therefore, the MAR should be met to ensure that the household attains its recommended nutrient requirements.

A cap of 100 percent is placed on the NAR such that a nutrient with a high percentage (NAR) cannot compensate for a nutrient with a low percentage, by masking (covering up) for a nutrient with a low percentage. Therefore a NAR of 100 percent indicates that the intake of a given nutrient is equal to or exceeds the recommended nutrient intake (RNI), whereas a NAR below 100 percent indicates a lower than the recommended nutrient intake (Torheim et al., 2003).

$$MAR = \frac{Sum\ of\ NAR}{Number\ of\ nutrients} X\ 100 \qquad (7.8)$$

To measure the overall nutritional quality of the household, the MAR was used and it was estimated from the NAR for energy and protein intake, and seven micronutrients.

Household cash income

This objective is crucial for the farm households because it reflects their desire to maximize profit, and measures how profitable the different activities are. Additionally, households invariably choose cropping patterns that provide more profit and therefore usually sell part of their crop output to generate income. This income is used to purchase other household items or products not produced by the household. Therefore, cash “surplus” realized at the end of the crop production period needs to be maximized.

Cash income is defined as the gross revenue less the variable costs of crop production. Crop outputs defined in terms of physical yields, and producer prices were used for computing the seasonal crop production gross margins for the crops produced by the households for the 2018 January-December cropping season. These were estimated based on data collected from the household survey and focus group discussions. Cash income from the sale of the crop produce was mainly used for paying school fees, medication and purchasing other household necessities like soap and not for buying food for nutrition.

The net cash income of the household is attained by getting the difference between the gross income and the total variable costs used in producing a given crop. These costs include costs for hiring labour, pesticides and fertilizer. For own family labour effort expended in production, farm households consume own produced crop output in return.

Leisure requirements

This objective allows adequate time for leisure activities. Household members usually portray a desire to minimize their labour in production activities especially if their incomes start increasing well above their sustenance, and the required menial work is lessened. As a result, they desire to have more leisure time. However, the amount of time taken for leisure activities is constrained by the bulk of farm (productive) work that needs to be done, as well as the total available household time needed to be allocated between cropping activities and leisure. Therefore, this objective deals with the maximization of leisure time. Leisure is incorporated in the model using the constraint “family labour’. Time spent on leisure activities implies that, that time will not be available for productive work, implying that households minimize their time for productive activities. Therefore, households may decide to “buy” leisure from casual labourers for particular production activities.

7.2.4 Relationship between model components

A farm is considered as a management entity that consists of various components. These components compile details concerning a particular element of the model. Examples of farm components in this study include; nutrition, time and cash. Figure 7.6 illustrates the linkages between the various farm components of the model.

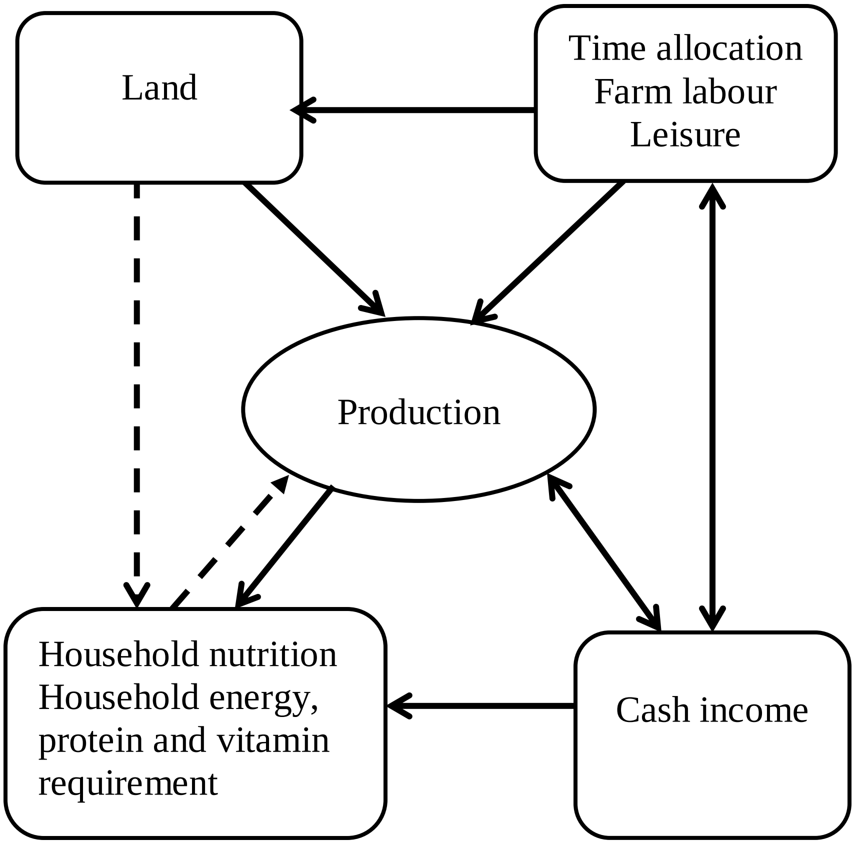


Figure 7. 6: Schematic representation of the relationship between different components of the model

Note: The bold arrows illustrate direct relationships while the dotted arrows denote indirect linkages

Source: Author's own design

Farm households can either allocate their time to leisure activities or to crop production. When their time is allocated to production, it, in turn, produces crop products, which can be utilized either for household nutrition or for generating cash income for the household through the sale of crops. Household members may also engage their time in off-farm activities, or sell their labour to their neighbors' farms to generate cash income. The cash generated from these activities is also re-invested back into the production process, for example through the purchase of farm inputs like fertilizers and pesticides, or through hiring of farm labour. Cash may also be used for consuming leisure time or purchasing of foodstuff like cooking oil from the market to improve nutrition.

Production plays a major role in contributing to nutrition and health of household members, and therefore farm households, as producers, are important in this linkage because they perform the role of both producers and consumers. Any health or nutritional status shocks therefore lowers the household's ability to engage in productive activities and consequently their ability to produce food and generate cash income. For instance, poor health may result in losing work capacity and this may lead to adjustments in cropping patterns, as households may not be able to actively participate in agricultural production. This can be seen in a shift from more labour intensive crops to less labour intensive crops such as cassava, which also have relatively low yields, low prices and low nutritional value (Fan et al., 2013).

7.3 Farm household model structure

As discussed in the previous section, the mathematical programming approach chosen was the compromise programming because it is consistent with the farm production structure in the Mount Elgon. The approach also requires that the relative importance of the farm household objectives are specified, that is, each objective (nutrition, cash income, leisure) under consideration is assigned a weight. Therefore, in a Mount Elgon smallholder farm, compromise programming can suitably include farm characteristics, which are considered crucial to the farm and thus influence changes to the farming system.

The construction of the model involved designing the model in mode of a matrix. This involved quantification of the coefficients in the matrix and the constraints, using data collected form the household survey, focus group discussions and secondary data. Subsequently, the matrix consisted of 26 activities and 40 constraints. Table 7.5 gives a representation of the model structure. The rows and columns in Table 7.5 represent the constraints and activities in the matrix respectively. Activities included are production, consumption and selling activities. The 'C' and 'S' in the table represent consumption and selling activities of the different crops.

Transfer between farm to household

The model intends to optimally allocate the household's fixed resources (land size and family labour) to activities that will fulfil its objectives. The farm household has a given farm size that is assigned to the production of crops meant for both household nutrition and cash income. Therefore, requirements for different production activities are supplied by the resource stock of the household. The farm household integrates both production and consumption, because it is the main recipient of the system both in consuming output from the farm and also cash income from sales of surplus output. As such, the household attains its objectives through (1) own consumption of crop output from its farm (nutrition), (2) selling part of its output (cash income), and (3) the allocation of its time for leisure activities (leisure). Cash income is mainly realized from crop sales and it stems from the crop gross margins. Farm households prefer to consume own produced food, mostly because in the study area, the price at which food is sold at farm gate is quite different from the price at which they would buy food from the market. The model considers achieving a nutrition level that fits to minimal nutrient requirements from consumption of own produce, by placing lower bounds on the household nutrient intake. Note; the crop products are needed to meet household nutrition requirements throughout the year.

All these activities that the household performs, that is, (1) producing crops for consumption (2) producing crops for sale, and (3) participating in leisure activities, all compete for labour throughout the cropping season in a year. In addition, the production of these crops demands land, also assigned in the model. Furthermore, specific production activities for the different crops demand different labour effort. Labour requirement for crop production is determined by the total labour requirement of the crop per hectare. Labour requirements on a monthly basis were estimated from these production phases; land clearing, planting, weeding, mulching, manure, pesticide and fertilizer application, digging trenches and harvesting.

The total labour available for production activities includes both family and hired labour. The household has alternatives of hiring outside labour to increase its resource supply. For farm households to consume own produced crop output, they need to expend effort measured in labour time. The farm household is assumed to have a total time endowment of eight hours a day for production activities, therefore, if part of this time is used for leisure activities, then it is not available for production activities.

Table 7. 5: Outline of matrix activities and constraints

	Cap		Unit	Production activities					Consumption and selling activities								
Constraints				Co	Ba	Ma	Be	Suk	Co S	Ba C	Ba S	Ma C	Ma S	Be C	Be S	Suk C	Suk S
	GM		$	-70.2	-38.7	-261.7	-487.2	-158.4	0.27	0	0.14	0	0.19	0	0.22	0	0.14
Area	0.61	≥	Ha	1	1	1	1	1									
Maximum_area_sukumawiki	0.01	≥	Ha					1									
Labour_January_FL	832	≥	mh	61.8	33.4	39.5	51.9	59.3									
Labour_January_TL	832	≥	mh	81.5	92.6	118.6	185.3	170.4									
Labour_February_FL	832	≥	mh	26.4	37.1	24.7	24.7	14.8									
Labour_February_TL	832	≥	mh	45.7	92.7	74.1	74.1	148.2									
Labour_March_FL	832	≥	mh	14.8	59.3	24.7	32.1	101.3									
Labour_March_TL	832	≥	mh	37.1	148.2	74.1	96.3	622.4									
Labour_April_FL	832	≥	mh		44.5	44.5	22.2	81.5									
Labour_April_TL	832	≥	mh		111.2	185.3	103.7	348.3									
Labour_May_FL	832	≥	mh	24.7		37.1		4.9									
Labour_May_TL	832	≥	mh	24.7		163		14.8									
Labour_June_FL	832	≥	mh	14.8			29.6										
Labour_June_TL	832	≥	mh	14.8			74.1										
Labour_July_FL	832	≥	mh		32.1												
Labour_July_TL	832	≥	mh		76.6												
Labour_August_FL	832	≥	mh			24.7	51.9	59.3									
Labour_August_TL	832	≥	mh			123.1	185.3	170.4									
Labour_September_FL	832	≥	mh	49.4	9.88		24.7	14.8									
Labour_September_TL	832	≥	mh	123.5	9.88		74.1	148.2									
Labour_October_FL	832	≥	mh				32.1	101.3									
Labour_October_TL	832	≥	mh				96.3	622.4									
Labour_November_FL	832	≥	mh				22.2	81.5									
Labour_November_TL	832	≥	mh				103.7	348.3									
Labour_December_FL	832	≥	mh				29.6	4.9									
Labour_December_TL	832	≥	mh				74.1	14.8									
Coffee_balance	0	≥	kg	-5529					1								
Banana_balance	0	≥	kg		-8104					1	1						
Maize_balance	0	≥	kg			-5928						1	1				
Beans_balance	0	≥	kg				-2964							1	1		
Sukumawiki_balance	0	≥	kg					-								1	1

								19760				
Min_Energy_req	-4305600	≥	kcal						-1220	-3690	-3470	-500
Min_Protein_req	-80640	≥	g						-13	-73	-214	-33
Min_VitaminA_req	-1296000	≥	µg						-560	0	0	-7690
Min_Thiamin_req	-1728	≥	mg						-0.5	-1.4	-7.1	-1.1
Min_Riboflavin_req	-1872	≥	mg						-0.5	-0.5	-2.1	-1.3
Min_Niacin_req	-23040	≥	mg						-6.9	-10	-11.7	-10
Min_VitaminB6_req	-1872	≥	mg						-2.9	-1.9	-4.7	-2.71
Min_Folate_req	-1296000	≥	µg						-220	-300	-5250	-290
Min_VitaminC_req	-129600	≥	mg						-184	0	-63	-1200
				ha	ha	ha	ha	ha	kg	kg	kg	kg

Note:

Co -coffee, Ba -banana, Ma -maize, Be -beans, Suk –sukumawiki

Co-S= coffee sell, Ba-C= banana consumption, Ba-S=banana sell, Ma-C=maize consumption, Ma-S=maize sell, Be-C=beans consumption, Be-S=beans sell, Suk-C=sukumawiki consumption, Suk-s=sukumawiki sell.

Table 7.5: Continuation of the matrix

	Cap		Unit	Labour hiring activities											
Constraints				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	GM		$	-1.17	-1.17	-0.27	-0.32	-0.32	-0.27	-0.27	-1.17	-1.17	-0.32	-0.32	-0.27
Area	0.61	≥	Ha												
Maximum_area_sukumawiki	0.01	≥	Ha												
Labour_January_FL	832	≥	mh												
Labour_January_TL	832	≥	mh	-1											
Labour_February_FL	832	≥	mh												
Labour_February_TL	832	≥	mh		-1										
Labour_March_FL	832	≥	mh												
Labour_March_TL	832	≥	mh			-1									
Labour_April_FL	832	≥	mh												
Labour_April_TL	832	≥	mh				-1								
Labour_May_FL	832	≥	mh												
Labour_May_TL	832	≥	mh					-1							
Labour_June_FL	832	≥	mh												
Labour_June_TL	832	≥	mh						-1						
Labour_July_FL	832	≥	mh												
Labour_July_TL	832	≥	mh							-1					
Labour_August_FL	832	≥	mh												
Labour_August_TL	832	≥	mh								-1				
Labour_September_FL	832	≥	mh												
Labour_September_TL	832	≥	mh									-1			
Labour_October_FL	832	≥	mh												
Labour_October_TL	832	≥	mh										-1		
Labour_November_FL	832	≥	mh												
Labour_November_TL	832	≥	mh											-1	
Labour_December_FL	832	≥	mh												
Labour_December_TL	832	≥	mh												-1

Production activities

The production activities included in the model were, staple crops (banana, maize, beans, sukumawiki) and coffee, which is particularly a cash crop. Not all the crops identified in the survey were included in the model. Some crops were grown in small quantities and allocated smaller plots of land and these were not included. These crops also did not have the cash and household sustenance reasons for increasing their production. The farm household therefore faces a decision problem of how much of the available land should be allocated to each of the crops considering its objectives and available resources, in relation to the labour effort required to produce the crops. Farm households also do consider food preparation in their objective of meeting their food and nutrition needs. However, food preparation requires time and may be shaped by culture. Other activities include labour hiring activities, crop product consumption and selling activities. For perennial crops like bananas and coffee, which have a growing period of 1 and 3 years respectively, the coefficients for particular cropping activities were divided by the number of seasons of growth. Crop choices are made along contribution to household nutrition. For example, vegetables were included.

Constraints imposed on the model

Farm households usually seek to achieve several objectives through their crop production activities. However, the extent of these production activities is normally constrained. The constraints in the model included; area constraints, monthly labour constraints, which was comprised of family labour and total labour required for production activities, crop balance constraints and minimum household nutrient requirements constraints. The resource constraints are discussed below in detail.

Area constraint

This constraint deals with the farm's maximum land area used for crop production. That is, the sum of all crop areas equals the total available land area of the farm. Therefore, the total area for the different crops cannot exceed the total available farm area.

Upper boundaries for crop area

This constraint maintains the crop area within maximum bounds in relation to total land use. Maximum area under particular crops (sukumawiki) during the season were set such that the minimal nutrient level of the household is met. The actual area of the crop under the current cropping pattern (Osama et al., 2017) was taken as the maximum cultivatable area (upper limit) for the crop.

Labour constraint

The amount of household working labour is estimated as the upper limit of labour constraints. Household labour supply is assumed equal in each of the months. The labour requirement for a particular crop per hectare were obtained from the households through focus group discussions. The number of man-hours per month is estimated by multiplying the mean number of farm labour of the selected household (expressed as adult equivalent units) by the number of days per month, less four days considered for religious activities and an average number of eight working hours per day.

Labour demand by farm households in the Mount Elgon varies each month of the cropping season. It implies that labour is probably a limiting factor at particular times of the season, especially during planting, weeding and harvesting periods. The model considered the annual labour demands of the different crops. Farm households without doubt desire to minimize their production costs completely and therefore household members usually provide the farm labour, although hired labour is also employed particularly during the peak periods. In addition, various cropping activities are performed in different months and have different wage rates, so the wage rate also varies on a monthly basis. Therefore, a feasible cropping plan should make sure that adequate labour is available in each of the months.

Assuming a household with 4 labour units, each having a capacity of 26 man-hours a month, then the total household labour supply per month equals 832 man-hours. However, this supply of labour is both for production as well as leisure activities. Labour use therefore cannot exceed the total supply of labour both from family and hired. The requirement for leisure activities on the other hand is incorporated into the model as one of the household objectives. Labour requirements for the different production activities are presented in Table 7.6. The labour requirements were elicited for each of the cropping tasks and the people who perform the particular tasks. The labour requirements entails time required for production tasks such as nursery bed preparation, land clearing, 1st and 2nd ploughing, digging holes, planting, 1st and 2nd

weeding, manure application, spraying, fertilizer application, mulching, digging trenches and harvesting.

Table 7. 6: Monthly labour requirement per hectare (man-hours) for different crops in a season

	Months (hrs/month)								
Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Coffee	81.6	45.7	37.1	0	24.7	14.8	0	0	123.5
Banana	92.6	92.7	148.2	111.2	0	0	76.6	0	9.9
Maize	118.6	74.1	74.1	185.3	163	0	0	123.5	0
Beans	185.3	74.1	96.3	103.7	0	74.1	0	0	0
Banana + Beans	92.6	167.3	96.3	121	0	29.6	0	0	4.94
Maize + Beans	118.6	74.1	123.5	234.7	197.6	29.6	0	98.8	0
Sukuma wiki	170.4	148.2	622.4	348.3	14.8	0	0	0	0

Source: Author's own compilation based on FGD data

Crop balance constraint

A crop can be consumed by the household or sold to earn cash income. The crop balance is measured as the yield of the different crops harvested during the cropping season. Therefore the crop balances are specified with the assumption that the production of individual crops minus consumption and sales ought to be greater than zero or equal to zero. Cash income is measured, in the model, by splitting the production and selling activities using balance rows. Implying that, production utilized for consumption purposes is then not sold. Selling activities are incorporated in the model to provide for revenue from sales of farm output.

Minimum food nutrient requirements constraint

The nutrient consumption behaviour of the farm household is included in the model by putting in lower bound constraints on the consumption of the required food nutrients. Both macronutrient and micronutrient adequacy have been included in the model to evaluate the nutritive value of household diets. The nutrition requirements include energy, protein, and seven micronutrients, comprised of vitamin A, C, thiamine, riboflavin, niacin, B_6, and folate. The nutrients were selected because of their significance for human diet. Therefore, in the model, the recommended daily nutrient intake regarded as sufficient for a healthy person was considered, as greater than or equal constraint for minimum. So, the nutrient constraints introduced in the model ensured that the family achieved the nutrient recommendations over a year. Each of the individual nutrients for example protein, plays a particular role, and so, they are independent of one another. Therefore, a given nutrient, for example protein cannot substitute for another nutrient like vitamin A . This is attained, based on the amount of nutrients that is available for the household to consume, thereby enabling the estimation of the nutritional adequacy of food that is available. The requirements were estimated by multiplying the total number of household members in the selected farm by the average length of a year and the minimum requirements of each nutrient per adult equivalent per day. It was calculated based on the nutrient content of raw crops using the food composition table for Eastern Uganda. The food composition table represents the composition of foods consumed in Eastern Uganda. In addition, it includes nutrients mainly taken into account in dealing with inadequacies in food and nutrient intake (Hotz et al., 2012). Therefore, since nutrition requirements should be met in a given feasible solution, selling activities can then discard off the “surplus” production after the minimum requirements of nutrients have been met.

Limitations of the model

Although the model provides a clear analytical understanding of the various cropping options available to a farm household, one limitation of the model was the availability of reliable data, therefore assumptions had to be made so as to off-set the data insufficiency. Another limitation of the model is that it was specified for a one-year period. It has defined resources and activities, of which in reality, farming systems are usually dynamic over a season. It is a single year model, which does not include within-year adjustments. For example, crop prices are assumed constant all over the year, and therefore price adjustments within the year are not considered. However, the inclusion of crop management changes within the year would otherwise make the model rather complex and may not clearly be insightful. The model in its present state provides clear insights into farm household production decisions.

Therefore, the model results should be seen as an analytical tool for assessing the economic and social implications of adjusting different crops within the farm, and creating trade-offs amongst households’ preferences.

7.3.1 Mathematical model formulation

This section presents the equations of the programming model, and they are listed below using the GAMS notation. The equations are comprised of the three objective functions, equations of the constraints and the bounds on the constraints.

Objective functions of the model

Objective 1: Maximization of household farm income

Household income was measured as the total income from crop sales, that is, total gross margin (tgm).

$$\text{Max } tgm = \sum_{act=1}^{5} gm(act) * x(act) \tag{7.9}$$

Where;

$gm(act)$ – Gross margin for each crop activity

$x(act)$ − Level for each activity

Objective 2: Maximization of household nutrition

$$\text{Max } nutrition = \sum_{nutr\_cons=1}^{9} \sum_{act=1}^{4} coef(nutr\_cons, act) * x(act) \tag{7.10}$$

Where;

$nutr\_cons$ − nutritional constraints for 9 nutrients

act − 4 crop activities

$coef(nutr\_cons, act)$ – Coefficients for the nutritional constraints for the activities

Objective 3: Maximization of household leisure

$$\text{Max } leisure = \sum_{FL\_cons=1}^{12} rhs(FL\_cons) - \sum_{crops=1}^{5} coef\ (FL\_cons,\ crops) * \ x\ (crops) \tag{7.11}$$

Where;

$FL\_ cons$ – Family labour constraints for 12 months in a year

$coef(FL\_cons, crop) * x(crops) -$ Coefficients for family labour for the crops

$x(crops) -$ Levels for the crops

Equations of the constraints

Equation for constraints

$$\sum_{act} coef(cons, act) * x(act) \leq rhs\_eff(cons) \tag{7.12}$$

Where

$coef\ (cons, act) -$ represents the coefficients of the constraints for the activities

$rhs\_eff(cons) -$ represents the capacities for the constraints

Nutrition constraint

$$\sum_{i=1}^{n} C_i N_{k,i} \geq rhs(nutr\_cons) * 365 \tag{7.13}$$

Where;

$k -$ is the nutrient, for example protein

$C_i -$ is the crop output (kg/ha)

$N_{k,i} -$ is the content of nutrient k in crop output i (g/mg/ µg per kg)

$rhs(nutr\_cons) -$ is the capacities for the nutrition requirements

Equation (7.14) sets an upper bound on the area (ha) that must be allocated to sukumawiki production. In that event, sufficient sukumawiki must be produced to meet the household's nutritional requirements.

$$Maximum\_area\_sukumawiki \geq 0.01 \tag{7.14}$$

Equation (7.15) represents the change in different fixed values of family labour, used to generate the efficient set

$$rhs(FL\_cons) = rhs(FL\_cons) * \theta \tag{7.15}$$

Equations employed in Compromise programming

$$\boldsymbol{l1} = \boldsymbol{weight\_tgm} * \boldsymbol{tgm} + \boldsymbol{weight\_nut} * \boldsymbol{nutrition} + \boldsymbol{weight\_leis} * \boldsymbol{var\_leisure} \quad (\mathbf{7.16})$$

$Where;$

$$tgm = ((\max\_tgm - tgm\_level) \,/\, (\max\_tgm - \min\_tgm)) \quad (7.17)$$

$$nutrition = ((\max\_nut - nut\_level) \,/\, (\max\_nut - \min\_nut)) \quad (7.18)$$

$$var\_leisure = ((\max\_leis - leis\_level) \,/\, (\max\_leis - \min\_leis)) \quad (7.19)$$

Table 7. 7: Variables in the model

Abbreviation	Description	Unit
tgm	Total gross margin	dollars
var_leisure	Leisure time	hour
nutrition	Nutritional level	kcal, g, µg, mg
x (act)	Activity levels: crop production activities, consumption and selling activities, labour hiring activities	ha for cultivation, dollar for selling and labour hiring
l1	L1 distance	No unit

Source: Author's compilation

Note: Variables refer to endogenous variables (decision variables) in modelling, and indicate the values that are chosen within the model to optimize an objective function.

Table 7. 8: Parameters employed in the model

Abbreviation	**Description**	**Unit**
min_tgm	Minimum total gross margin	dollar
min_nutr_level	Minimum nutrition level	percent
max_nutr_level	Maximum nutrition level	percent
coef (cons, act)	Coefficients for constraints and activities	dollar, ha, hour, kg, kcal, g, µg, mg,
gm (act)	Crop gross margin per hectare	dollars per ha
rhs (cons)	capacities of constraints	dollar, ha, hour, kg, kcal, g, µg, mg,
rhs_eff (cons)	capacities for nutrition constraints	kcal, g, µg, mg,
tot_leisure	Total leisure time	hour
tot_nutr_level	Total nutrition level	percent
tgm_p	Total gross margin when leisure time is optimized	dollar
tgm_n	Total gross margin when nutrition is optimized	dollar
total_leisure	Total leisure when nutrition is opimized	hour
Parameters employed in the compromise process		
max (obj)	Maximum level for the objectives	Dollar, percent, hours
min (obj)	Minimum level for the objectives	Dollar, percent, hours
weight (obj)	Objective function weights	No unit
Objectivel1 (obj)	Actual level of objective in minimizing l1	Dollar, percent, hours

Source: Author’s compilation

Note: Parameters (exogenous values) refer to constants in the model.

Table 7. 9: Sets employed in the model

Abbreviation	**Description**
act 'activities' /Coffee, Banana, Maize, Beans, Coffee_sell, Banana_consume, Hiring_Labour_January, Hiring_Labour_December/	Five crop production activities: coffee, banana, maize, beans, sukumawiki Nine consumption and selling activities: selling coffee, consuming banana, selling banana, consuming maize, selling maize, consuming beans, selling beans, consuming sukumawiki, selling sukumawiki Twelve labour hiring activities: 12 months in a year
cons 'constraints' /Area, Maximum_area_sukumawiki, Labour_January_FL, Labour_January_TL, Coffee_balance, Banana_balance, Maize_balance, Beans_balance, Sukumawiki_balance, Minimum_Energy_requirement, Minimum_VitaminC_requirement/	One constraint: total farm area for crop production One constraint: maximum area allocated to sukumawiki production Twelve constraints: family labour availability in a year Twelve constraints: total (family and hired) labour available in a year Five crop balances: coffee balance, banana balance, maize balance, beans balance, sukumawiki balance Nine constraints: minimum nutritional requirements for energy, protein, vitamin A, thiamine, riboflavin, niacin, vitamin B6, folate, vitamin C
nutr_cons (cons) /Minimum_Energy_requirement, Minimum_VitaminC_requirement/	Nine constraints: minimum nutritional requirements
crops (act) /coffee, banana, maize, beans, sukumawiki/	Five crop production activities: coffee, banana, maize, beans, sukumawiki
FL_cons (cons) /Labour_January_FL, Labour_February_FL, Labour_December_FL/	Twelve constraints: family labour availability in a year

Source: Author's compilation

Note: Sets describe the indices for the parameters and variables in the model

7.4: Empirical findings

This section presents the results of the individual objective optimization obtained from the multi-objective programming, as well as the compromise solutions provided by the model. Further, it illustrates the conflict between the three objectives in the empirical problem. The model was analysed using the General Algebriac Modelling System (GAMS) software.

7.4.1 The pay-off matrix for the objectives under sole cropping for a resource-poor farm household

The pay-off matrix for the three objectives was obtained through linear programming to identify the optimal values for each of the objective functions. A minimum income of $80.8 for a resource-poor farm household in a year was set in the model and this was estimated based on the average farm income of a smallholder farm in Uganda in relation to the size of land farmed by the household (Anderson et al., 2016). Further, a maximum of 120% increment in nutrition was also fixed in the model. Table 7:10 shows the pay-off matrix for the objectives optimized. The values in the first row, imply that the maximum cash income solution ($386), matches with an increment of 109% in nutrition and leisure time of 9854 hours in a year.

Table 7.10 also shows the conflict that exists between household nutrition, income and leisure. For example, it is evident from the table that cash income conflicts with nutrition and leisure. That is, when nutrition and leisure are optimized, cash income achieves its worst value or anti-ideal solution. This indicates that increased income would always lead to less leisure time as well as reduced nutritional quality of household members. It is also worthwhile to note that the desire to maximize income may lead households to allocate larger plots to cash crops such as coffee and allocate smaller plots to vegetables, thus reducing the consumption of nutritional foods due to their unavailability.

The achievement of daily nutrients through the consumption of different foods, that is, nutritional adequacy, was used to measure household nutrition. The mean adequacy ratio was the indicator used and it expresses the household's nutrient intake as a percentage. For each of the nutrients, a nutrient adequacy ratio was estimated as the percentage of the nutrient achieving its recommended intake. Thereafter, the mean adequacy ratio was calculated from the individual adequacy ratios. It is measured as a percentage because different food nutrients are included in the assessment of the nutritional adequacy of the household. Furthermore, the various nutrients are measured in different units, that is, kilocalories, grams, micrograms and milligrams. Therefore, to assess the overall nutritional quality of the household, a percentage achievement of nutrients is employed.

On the other hand, a mean adequacy ratio of 100 percent does not guarantee that a household's needs are fulfilled, since the mean adequacy ratio is based on estimates of recommended nutrient intakes for which a person would have a probability of 97.5 percent to meet his/her nutrient needs (Becquey et al., 2010). However, a mean adequacy ratio greater than 100 percent could possibly be attributed to the quantity or kind of food consumed. Furthermore, the World Health Organization (WHO) defines the Recommended Nutrient Intake (RNI) levels and the Upper Limit (UL) levels (Pasic et al., 2012). The RNI value is the daily level considered as sufficient to meet the nutrient requirements of a healthy person, while the UL is the highest daily intake level of a nutrient that would cause no risk of harmful health effects to an individual. Admittedly, possible risks of harmful health outcomes may increase as nutrient intake rises above the UL level (Pasic et al., 2012). Accordingly, the minimum nutrient requirement levels were used in this study.

Table 7. 10: Pay-off matrix for the three objective functions optimized

	Maximise cash income ($)	Maximise nutrition (%)	Maximise leisure (hrs)
Maximise cash income ($)	<u>386</u>	*109*	9854
Maximise nutrition (%)	*80.8*	<u>116</u>	*9850*
Maximise leisure (hrs)	*80.8*	111	<u>9895</u>

Note: Optimal solutions for each objective function are underlined, worst values for the objectives are in italics.

Source: Author's compilation based on model results

The underlined values, that is, the values in the major diagonal of the matrix, represent the optimal solution for all the objectives. It represents a point where all the objectives are optimized. In other words, an "ideal cropping plan" of a farm is achieved at this point. An ideal cropping plan represents a plan where the farm household achieves the optimum values for all its objectives. Therefore, the ideal cropping pattern would generate $386 of gross margin, a nutritional achievement in nutrition of 116% while at the same time enjoying 9895 hours of leisure time. However, because of the conflict that exists among the objectives, attaining a cropping plan with optimal solutions for all the three objectives was infeasible. Nonetheless, a household may choose a point of maximum farm income, maximum nutritional achievement, maximum leisure time or a compromising solution between the identified solutions.

This assessment of trade-offs among the three objectives implies that if the household solely concentrates on increasing income as its objective, then the household has to forego a number of leisure hours and also consume less of foods with more nutrients. Maximizing leisure hours by the household, that is, achieving household needs with the minimum work effort would imply forfeiting about $305. Likewise, maximizing household nutrition would mean foregoing an income of $305. This may not be a wise decision because farm households also desire to have a considerable amount of income to be able to meet other household needs such as school fees, housing and other market purchased goods like clothing and salt. Due to these trade-offs among the objectives, the need to find a compromise solution is of utmost importance.

Table 7.11 shows that if the household's objective is to maximize cash income from crop production, then the household needs to allocate the largest portion of land to coffee production (0.30 ha). This is due to the fact that coffee is the main cash crop in the Mt. Elgon, and so more production of coffee would result in higher income for the household. On the other hand, if the household's objective is to maximize nutrition, banana production would take the largest portion of farmland while maize would not be included in the production mix. From the results, the consumption of more banana (0.52 ha) would provide more nutrients and increase the nutritional quality of the household. Moreover, banana is a perennial crop and so it provides a steady food supply throughout the year.

Table 7. 11: Optimization results for the different objectives in a sole cropping system

	Objective function		
	Maximise cash income	Maximise nutrition	Maximise leisure
Maximise cash income ($)	**386**	109	9854
Maximise nutrition (%)	80.8	**116**	9850
Maximise leisure (hrs)	80.8	111	**9895**
Crop			
Coffee	0.30	0.07	0.08
Banana	0.25	0.52	0.22
Maize	0.03	-	0.05
Beans	0.03	0.01	0.03
Sukumawiki	0.01	0.01	0.01

Source: Author’s compilation based on model results

When the objective of the household is to maximize leisure, the largest share of area in the crop mix solution is allocated to banana production. The increase in the area under banana could be a result of banana being a less labour demanding crop and so, less time will be allocated to its production and more time spent on leisure activities. The results provide insights into the changes in crop plans because of changes in household priorities. For example, crops like coffee are cultivated less when the household seeks to maximize nutrition and leisure but its area under production increases when cash income is the household’s priority, as a single objective. These results suggest that households will have diverse crop plans due to different behaviour in relation to their priorities.

7.4.2 Trade-offs between the objectives under sole cropping

Figure 7.7 shows the pareto-optimal set or compromise solutions for the cropping plan in a three dimensional objective space under a sole cropping system. The pareto-optimal sets or efficient set of solutions are generated using a constraint approach (Romero and Rehman, 2003). The efficient sets are generated by maximizing cash income and parametrically varying the bounds on household labour. It illustrates a set of trade-off solutions whereby no solution is better off than another in all the three objectives, that is, all the objectives are considered necessary. The same Figure 7.7 also represents the ideal point (located at the extreme right) in relation to the compromise solutions. The values for the ideal point are the best solutions for each of the objectives.

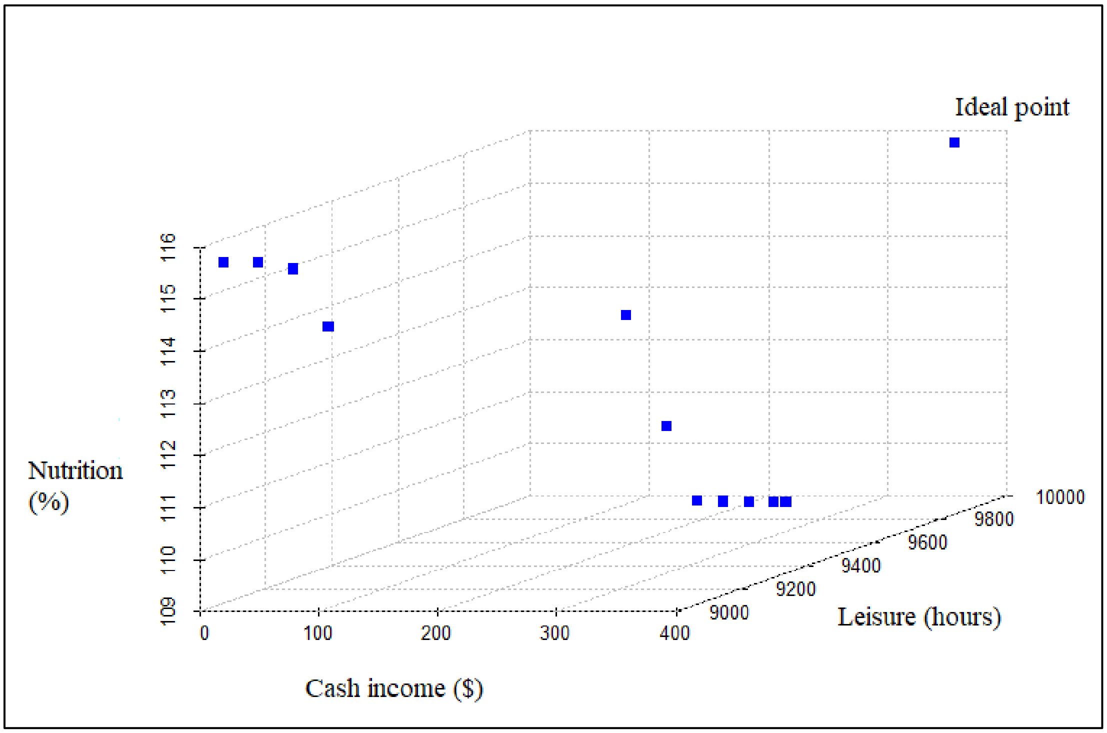


Figure 7. 7: Alternative pareto-optimal sets from the model

Source: Author's own illustration based on model results

From the pareto-optimal sets above**,** different farm arrangements are made, given the available household resources and constraints. These sets represent the income, nutritional achievements and leisure hours for the efficient solutions. This pareto-based optimization assists households in exploring possible choices available. Consequently, households are able to examine the trade-offs existing between various cropping decisions and their outcomes.

Figure 7.8 gives an example of the trade-offs among the objectives. It shows the trade-off that exists between household income and nutrition. The trade-off can clearly be noticed from the figure and it is probable that cropping patterns chosen during optimization attributed to this trade-off. The farm configurations from the model suggest that the household may decrease its time allocation to production activities, and as a result, increase its leisure time. Consequently, the household will have to spend more to hire casual labour for production activities and in the end earn less income. Therefore, from the figure, as households invest more of their time in leisure activities, their income reduces, while their nutritional quality increases.

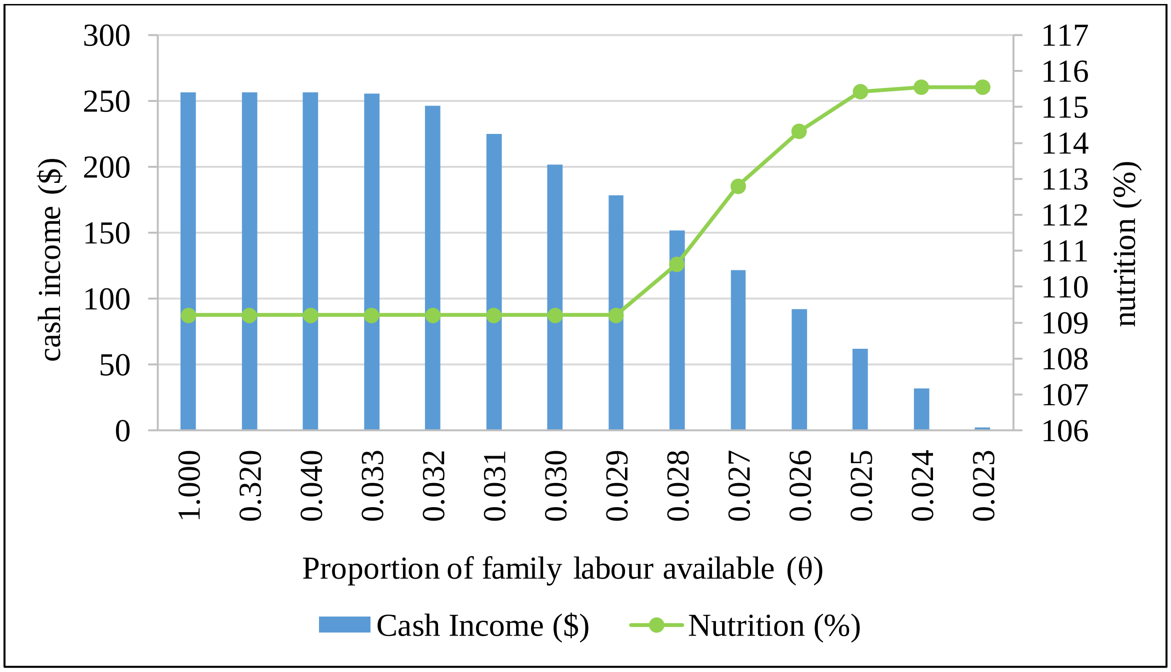


Figure 7. 8: Trade-off between cash income and nutrition

Source: Author's own illustration based on model results

Figure 7.8 shows different scenarios when time allocated to production activities by family members varies by a given value (θ). The value θ represents the proportion of household labour available for crop production activities. It represents the percentage of family labour available. Therefore, for each value of family labour available, a set of alternative farm configurations representing different objective values, are generated by the model. These different objective values represent the efficient set, along with their different cropping patterns.

From Figure 7.8, the constant level of income up to a certain point plausibly implies abundant family labour and therefore any reduction in the time allocated to crop production activities by family members will have no impact on farm income as well as the nutrition status of the household. After a certain point however, if family labour time reduces further, farm income begins to decline while the nutritional quality of the household improves. The farm configuration generated by the model when the objective cash income is maximized, while the other objectives were the restraints, selected crops that made it possible for the household to achieve its nutritional needs, for example by increasing the area allocated to food crops that contribute to household nutrition. This may be explained by the fact that when family labour becomes scarce, households can no longer produce cash crops or they may reduce the areas allocated to such crops and mainly concentrate on the production of food crops for household sustenance. This evidence is illustrated by the decline in cash income and an increase in nutrition. This observation provides an understanding on the linkages that exist between agricultural production and nutrition. Also, as cash income from crop sales declines, households have the option of working off-farm and hire labour to compensate their work on-farm.

Figure 7.9 presents the different arrangements of crop areas when different proportions of family labour is available. The model results show that in all the cropping patterns, bananas have the largest crop areas when family labour varies, followed by coffee. Typically, a poor resource endowed farm household in the Mt. Elgon would own 0.61 ha of farmland and would be able to cultivate 0.4 ha of maize, 0.14 ha of banana, 0.05 ha of coffee and 0.02 ha of beans.

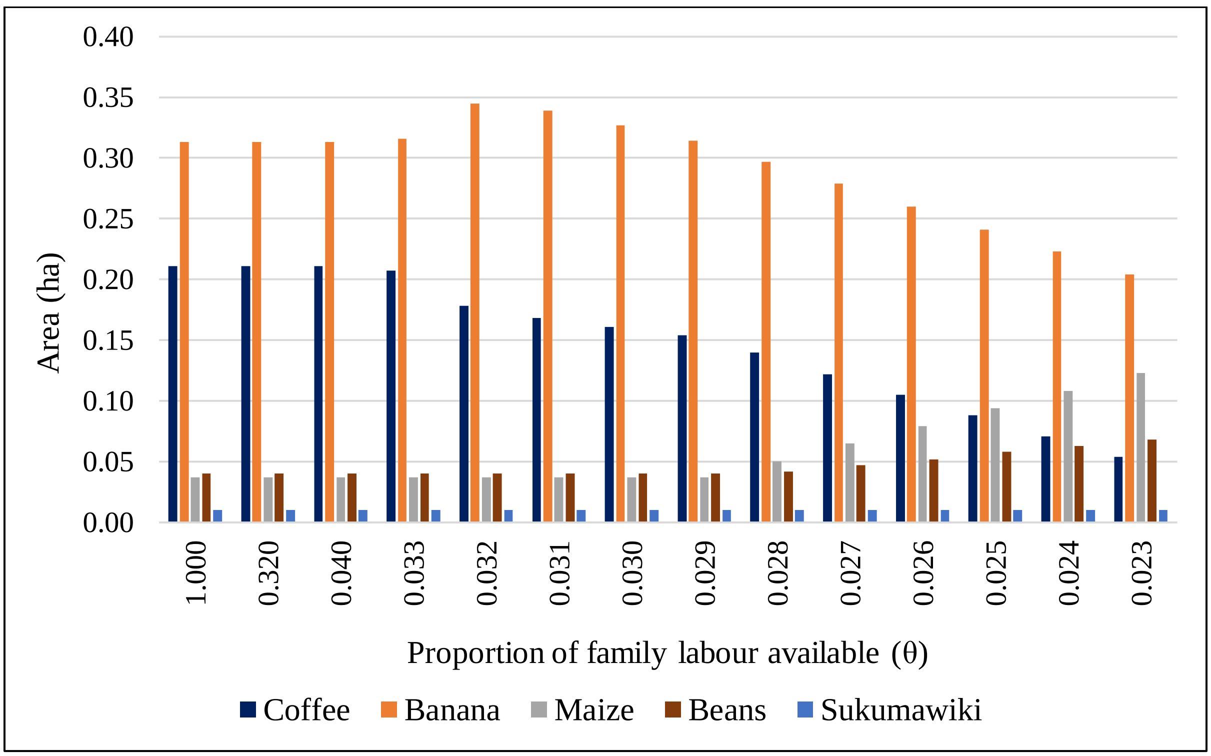


Figure 7. 9: Crop areas in the alternative farm configurations generated by the model

Source: Author's own illustration based on model results

Figure 7.9 shows that households could modifying their cropping patterns, in order to achieve their various objectives. This can be done for example, by adjustments in crop area such as the inclusion of vegetables like sukumawiki in the cropping system. Therefore, if a household needs to increase its vitamin intake, then there is a need to dedicate a portion of farmland to the production of vegetables. This change will cause adjustments in areas dedicated to other crops. For example, if a household decides to choose the first alternative in Figure 7.9, then the area allocated to sukumawiki will be 0.01 ha, while that of maize reduces to 0.04 ha. This farm configuration will generate an income of $257 for the household and an increment of nutrition quality by 109%.

7.4.3 Results of the model with crop mixtures in the model

The study area is faced with the burden of increasing population densities and consequently, declining farm sizes. Therefore, one strategy to increase production is to utilize the small parcels of land through mixed cropping practices. Accordingly, with the aim of achieving the “best” cropping pattern, that satisfies the various objectives for the three different farm types, mixed cropping options were introduced into the model by including the production of maize-beans intercrop and banana-beans intercrop. The practice of crop mixtures is oriented towards better utilization of labour and land resources. The farm types included; (1) resource-poor endowed farm, (2) medium-resource endowed farm, and (3) high-resource endowed farm. The medium-resource and high-resource endowed farm types had different scenarios, for example, the medium-resource farm type had an additional food crop, which is cassava, whereas the high-resource farm type had an additional cash crop, that is, sunflower included in the model. The representative poor, medium and high-resource farm households were endowed with 0.61, 0.81 and 1.42 hectares of cropping area respectively.

Table 7.12 shows the pay-off matrix of the objectives with its associated cropping pattern for the three farm types. A minimum income of $113.5 for a medium-resource farm household in a year was set in the model, whereas a minimum income of $243.2 was set for the high-resource farm household. The minimum income was estimated based on the average farm income of a smallholder farm in Uganda in relation to the size of land farmed by the household (Anderson et al., 2016).

Table 7.12 shows that if the cropping pattern is improved through the inclusion of crop mixtures, for a poor-resource endowed farm type, an ideal farm plan would result in $ 420 worth of farm income, an increment in nutrition of 120 percent and 9899 hours of leisure time, compared to the model with sole crops as previously presented. However, such an ideal farm plan where the household attains the optimal values for all the objectives is also not possible because of the conflicting objectives. It should be noted, however, that the results of the pay-off matrix with crop mixtures yields better results than the results with pure stand crops. For example, if the household's goal is to maximize nutrition, then, the household has to allocate most of its farmland to the production of a mixture of maize and beans while avoiding the production of sole cropped maize, beans and bananas.

Table 7.12 also shows the pay-off matrix for a medium-resource endowed farm household, as well as for a high-resource endowed farm household. For a medium-resource endowed farm household, the ideal cropping pattern would generate $755 of cash income from crop production, nutrition achievement of 120% and leisure time of 11140 hours. For example, this implies that if the household's sole objective is to maximise cash income, then the household has to give up 115 hours of leisure time. In the same way, if the household were to focus only on its nutrition as a single objective, then it would sacrifice around about $641. However, an ideal cropping plan, whereby all the optimal values for the objectives are met is not feasible due to the conflict amongst the objectives.

On the other hand, for a high-resource endowed farm household, the ideal cropping plan would yield $1819 of income, nutrition achievement of 120% and leisure time of 13616 hours. Similarly, the household would for instance give up, nearly $1575, If the household's only objective is maximizing nutrition. In a similar vein, this ideal cropping plan is infeasible since the household's would want a compromise between multiple objectives.

From Table 7.12, if the sole objective of a medium-resource endowed farm household is to maximise cash income from its production activities, the household can allocate the largest share of its cropping area to the production of coffee (0.56 ha), which is the main income generating crop. If the household were to maximize leisure as its sole objective, the area under coffee would reduce to 0.1 ha, while cassava would take the largest portion of crop area (0.26). This is because cassava is a less labour intensive crop and so the household wants to spend less effort in production activities. On the contrary, if the household's objective is to maximise nutrition, the household would have to allocate the largest portion of land to the production of a mixture of maize and beans (0.54 ha) and also allocate part of the cropland to the production of sukumawiki (0.03).

The household not only would have to reduce the area under coffee, but also exclude cassava from its cropping plan because cassava provides lower nutritional value. For a high-resource endowed farm household, the largest crop area would be allocated to the production of coffee (1.21) (Table 7.12), if the household decides to only maximize cash income. Similar to the other farm types, the household would allocate the largest crop area to produce a mixture of maize and beans and also allocate a portion of land to produce sukumawiki, if the household's only objective is to maximize nutrition. If the household concentrates on maximizing leisure, the household would need to include bananas in its cropping plan (0.08), since it requires relatively less effort.

Table 7. 12: Optimization results for the different objectives with crop mixtures included in the model

	Objective function								
	Poor-resource farm household			Medium-resource farm household			High-resource farm household		
	Maximise cash income ($)	Maximise nutrition (%)	Maximise leisure (hrs)	Maximise cash income ($)	Maximise nutrition (%)	Maximise leisure (hrs)	Maximise cash income ($)	Maximise nutrition (%)	Maximise leisure (hrs)
Maximise cash income ($)	420	116	9847	755	118	11025	1819	116	13409
Maximise nutrition (%)	*80.8*	120	*9779*	*113.5*	120	*10961*	*243.2*	120	*13258*
Maximise leisure (hrs)	*80.8*	*111*	9899	*113.5*	*110*	11140	*243.2*	*113*	13616
Crop									
Coffee	0.32	0.16	0.08	0.56	0.24	0.103	1.21	0.43	0.20
Banana	0.23	-	0.22	-	-	-	-	-	0.08
Maize	-	-	0.05	-	-	0.051	-	-	0.12
Beans	-	-	-	-	-	-	-	-	-
Sukumawiki	0.01	0.01	0.01	0.03	0.03	0.03	0.05	0.05	0.05
Maize + Beans	0.06	0.44	0.02	0.216	0.544	0.018	1.156	0.94	0.02
Banana + Beans	-	-	-	-	-	-	-	-	-
Cassava				-	-	0.26			
Sunflower							-	-	-

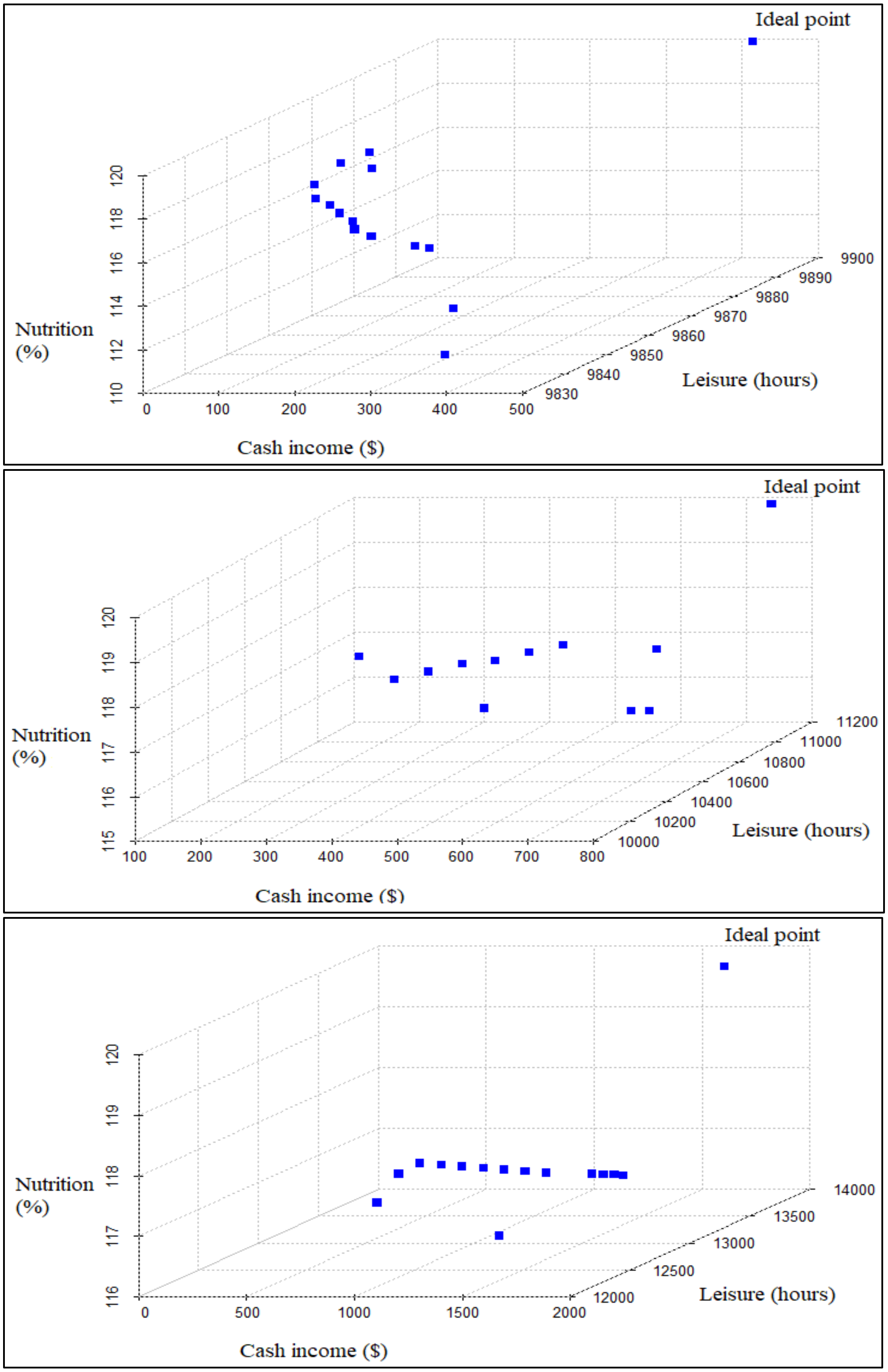
Note: Optimal solutions for each objective function are underlined, worst values for the objectives are in italics

Source: Author's own compilation based on model results

Figure 7.10 shows the pareto-optimal solutions as well as the ideal point for the three objectives in a three dimensional objective space, for the three farm types. To generate the efficient set of solutions (pareto-optimal solutions), a constrained optimization was carried out (Romero and Rehman., 2003). The various efficient sets are generated by maximizing the objective cash income and parametrically varying the bounds on family labour.

As an extension, we made a sensitivity analysis. The different farm types were endowed with various labour availability, for example the representative resource-poor farm household had available labour of 4 adult equivalent units, while the medium-resource and high-resource farm households had labour availability of 4.5 and 5.5 adult equivalent units respectively. Therefore, a high-resource farm household for example, with 5.5 labour units is assumed to have a capacity of 26 man-hours a month for each unit, which then gives a total of 1144 man-hours in a month. The results show that the model is capable of capturing different production strategies of households with different labour availability. The efficient solutions portray different combinations of cash income, nutritional achievement and leisure time. The solution sets provide a set of choices from which the household can a make a choice.

The resource-poor farm household is represented in Figure 7.10 A, medium-resource farm household in Figure 7.10 B, while the high-resource farm household is shown in Figure 7.10 C. The solutions in the figure, indicate trade-offs between the objectives. These alternative farm arrangements represent a solution space from which possible crop plans can be selected. The figure also provides a better visualization and analysis the trade-offs amongst the objectives.



A

B

C

Figure 7. 10: Alternative pareto-optimal sets from the model for the three farm types

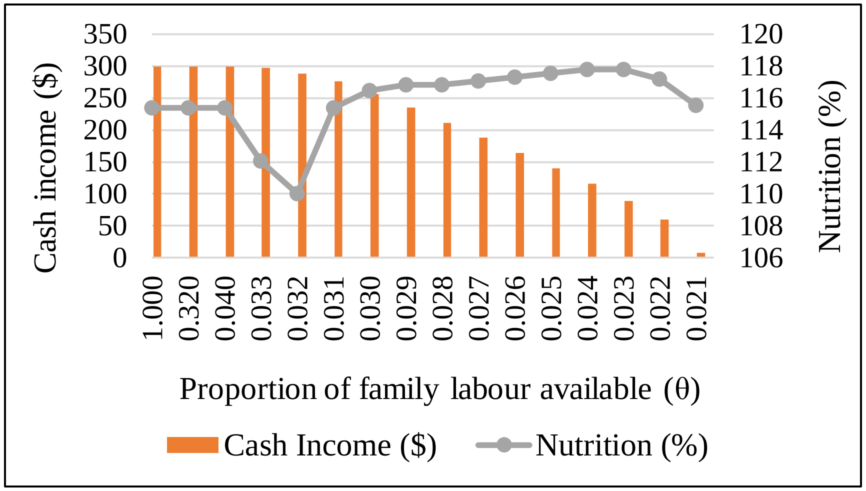
Source: Own illustration based on model results

Figure 7.11 shows the pareto-optimal solutions, plotted again as trade-off curves now, between household income and nutrition for the three farm types. The figure demonstrates the changes in the household objectives when the number of hours that family members spend in production activities decreases. For instance, for the resource-poor farm household, when the hours spent in production activities reduces, farm income also keeps declining. This may mean that the household can no longer engage in the production of cash crops due to shortage of labour.

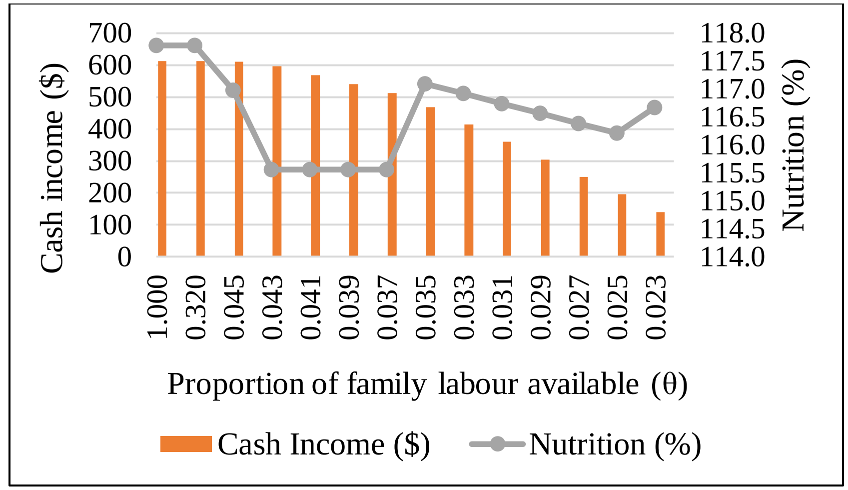
Furthermore, Figure 7.11 illustrates a gradual increase in household nutrition from a certain point as few family members are engaged in production activities. The increase in nutritional achievement can be described by the nutritional attributes of the cropping patterns chosen during the optimization of the model. For example, the model reduces the area allocated to coffee, which is the main cash crop, a reason for the decreasing cash income.In addition, for the resource-poor farm household, the model increases the area allocated to the mixture of maize and beans, as well as bananas and beans. The model therefore, substitutes part of the area assigned to the income-generating crop with the area allocated to crops cultivated for household consumption. Hence, reflecting the trade-off between the allocation of crop area to crops that generate cash income and crops that are consumed within the household. Crops consumed by the household in the end help to meet household nutritional needs and thus, improve their nutritional quality.

For the case of the medium-resource endowed farm household, as family labour input reduces, cash income reduces and there is a decline in nutrition. The decline in nutritional achievement is as a result of the cropping patterns chosen by the model. The household allocates more land to the production of bananas, and no land is allocated to produce maize and beans mixture. However, when the area under the banana and beans mixture increases, the nutritional achievement also increases. Likewise, when the model allocates a portion of land to produce a mixture of maize and beans, nutrition also increases. This is due to model specifications.

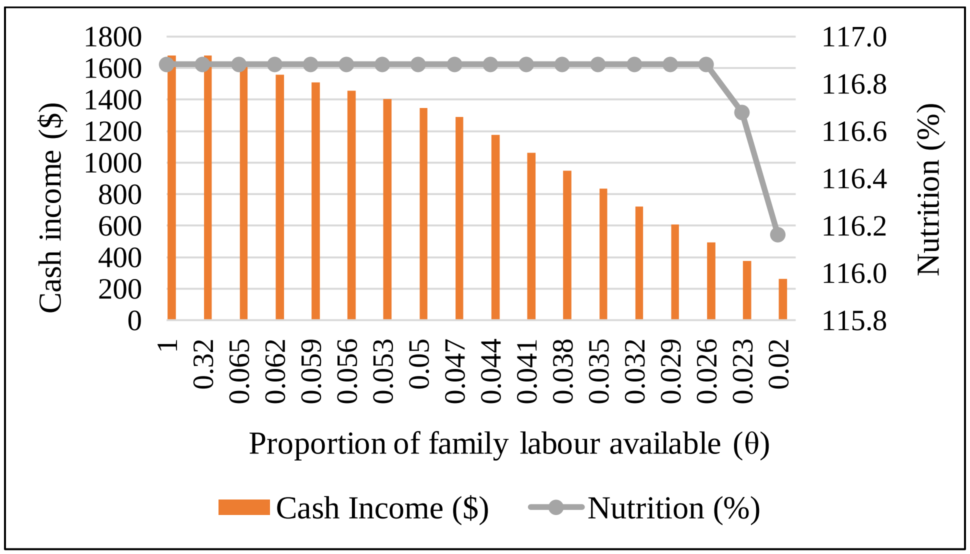
For the high-resource endowed farm households, when household labour input in production activities reduces, household cash income also declines, however, there is no decline in the nutrition of the household, until a given point when family labour considerably reduces. At this point, the model allocates a smaller area to the production of maize and beans mixture, which most likely contributes to household dietary needs. At the same time, the model allocates a larger part of the land to the production of sunflower, which can be explained by its minimal labour input.



Poor-resource endowed farm household



Medium-resource endowed farm household



High-resource endowed farm household

Figure 7. 11: Trade-offs between cash income and nutrition for the different farm types

The results from the figures indicate that income incrementally reduces as labour force in terms of hours is pulled out of households. A decline in the number of hours family members work on-farm may occur as a result illness of a family member, or as a result of older children going off to school. A study carried out by Anang (2017), in northern Ghana found that education actually drew away farm labour from the household, and this eventually reduced farm productivity. In accordance with Chayanov's theory, that production decisions are made based on the family labour available (Ellis, 1993), these results indicate that household labour is crucial in meeting the family's production and consumption needs.

However, concerning the leisure model for all the households, although labour is withdrawn from production activities, nutrition increases, implying that household nutritional requirements can still be meet if the household decides to hire in labour. In other cases, the household may decide to allocate the available labour to produce more of the crops that increase nutrition for example beans and maize. On a similar note, a study by Ntakyo et al., (2019) analyzed the impact of market production on farm household food consumption in Uganda. Their results showed that market production negatively affects the consumption of calories within the household. Despite the increase in income from the sale of market crops, the authors found that most of the income is actually used on non-food items like paying school fees.

In their study, Poole et al., (2020) demonstrate the need to include cereals like maize in the diet because it is an important source of carbohydrates providing energy especially for the farm households. These households need to consume energy giving foods for strenuous activities for example during the cropping season. The authors also suggest that the consumption of these foods by the farm families can be increased through own-production and improved household incomes.

7.4.4 Identification of the "best" solution for the different farm types

To identify the satisficing cropping plan for each of the farm types, in the given context of modelling, the L_p metrics is applied. The family of L_p metrics suggests closeness of the satisficing solution and the ideal solution. The 'best' solution is one whereby the distance from the set of pareto-optimal solutions and the ideal solution is minimized. The procedure employed is minimizing the normalized deviation from the ideal solution (Lounis and Cohn, 1995). As already mentioned, the L_1 metric is minimized by assigning weights to the different objectives. For the L_p metric where $p = 1$, the L_1 metric measures the longest distance geometrically and therefore it was minimized.

The L_1 metric was applied in the decision-making process to select the satisficing solution from the feasible set. It was applied to a set of efficient solutions so as to select the best solution. The solution with the lowest value for the L_1 metric is the one closest to the ideal point, and therefore, it is chosen as the "best" compromise solution (Beula and Prasad, 2012). Also, different best-compromise solutions may be generated if the weights attached to the different objectives changes.

Table 7.13 shows the set of pareto-optimal solutions in the objective space for a resource-poor farm household. The distances from the ideal solution are presented in the column L_1. Since the L_1 metric minimizes the longest distance from the ideal solution, therefore the alternative with the minimum value for the L_1 metric represents the satisficing solution. For each of the alternative pareto-optimal solutions, the L_1 metric was measured. The objective function values and the decision variable values summarized in Table 7.13 form the grounds for the decision makers to choose the best cropping plan given the resources present in the farm. From the table, the alternative solutions differ with regards to the objective function values.

From the results in Table 7.13, alternative pareto-optimal solution 5 has the minimum value for the L_1 metric. This implies that from all the alternatives, alternative solution 5 would be the best satisfying solution with the minimum deviation from the ideal solution. The solution corresponds to the objective function values of 235 dollars of cash income, 1.17 percent of nutrition increment and 9838 hours of leisure time. This solution is also the closest to the ideal point, and so, it provides the best values for farm planning. The corresponding decision variables are; coffee (0.18 ha), bananas (0.24 ha), sukumawiki (0.01 ha), and bananas + beans (0.17 ha).

From the same table, the alternative solutions from the minimum L_1 metric generate the following order (with the best solution ranked first), considering five solutions closest to the ideal point; (1) solution 5, (2) solution 4, (3) solution 7, (4) solution 6, and (5) solution 8. The trade-offs between the three objectives can also be assessed from Table 7.13. For example, if the farm household is still undecided between solution 5 and 7, the household may prefer solution 5 if it examines that an increase of 47 dollars of farm income is more important than an increment of 0.3 percent of nutritional quality and an increase in leisure time of 5 hours. Along the same lines, the household will prefer solution 7 to solution 6 if the household considers that forfeiting 23 dollars of cash income and an hour of leisure time can be balanced by an increase of 0.3 percent of nutrition quality.

Table 7. 13: **Efficient solutions and cropping patterns for the objectives for a resource-poor endowed farm household**

Solution no.	Objective function values			L_1	Decision variables						
	Cash income	Nutrition	Leisure		Coffee	Banana	Maize	Beans	Sukumawiki	Maize + Beans	Bananas + Beans
	($)	(%)	(hours)		(ha)						
1	300	115.4	9844	0.461	0.24	0.31			0.01	0.06	
2	298	112.1	9850	0.681	0.23	0.32	0.02		0.01	0.03	
3	276	115.4	9845	0.480	0.20	0.32			0.01	0.01	0.08
4	257	116.5	9838	0.428	0.19	0.27			0.01		0.14
5	235	116.8	9838	0.426	0.18	0.24			0.01		0.17
6	211	116.8	9842	0.442	0.17	0.23			0.01	0.01	0.16
7	188	117.1	9843	0.439	0.16	0.22			0.01	0.02	0.16
8	164	117.3	9845	0.444	0.15	0.20			0.01	0.04	0.15
9	140	117.5	9846	0.449	0.13	0.19			0.01	0.05	0.14
10	116	117.8	9850	0.445	0.12	0.18	0.02		0.01	0.05	0.14
11	89	117.8	9861	0.457	0.09	0.16	0.07		0.01	0.02	0.13

Source: Author’s computations based on model results

Table 7.14 summarizes the results of the solutions and compromise plan for a medium-resource endowed farm household. The different solutions also vary largely with reference to the objective function values. For instance, alternatives 1 and 2 are characterized by high cash income and high nutritional achievement, with lower leisure time. On the other hand alternatives 10 and 11 are characterized by low cash incomes with higher leisure time. In accordance with results of compromise programming, the best satisficing set of solution is offered by alternative 2 (Table 7.14). According to this cropping plan, land is allocated in this way; coffee (0.47 ha), banana (0.13 ha), sukumawiki (0.03 ha), maize and beans mixture (0.18 ha).

The allocation of land in this cropping plan provides a cash income of $611, nutritional achievement of 117 percent and leisure time of 11028 hours. In case, the decision maker is not contented with the leisure hours from alternative 2, and would like to participate more in leisure activities, then alternatives 3 or 4 could be chosen preferably. If the decision maker decides to choose for instance alternative 3, then the leisure time will increase by 13 hours (from 11028 to 11041 hours). This would mean that the crop area allocated to the income-generating crop like coffee has to decrease and the area allocated to bananas increases, since banana is a less-labour intensive crop. As a result, the household will enjoy more leisure time.

On the other hand, the representative alternative solutions in Table 7.14 indicate that sole cropped maize and beans, and cassava are excluded from the vectors of the pareto-optimal solutions. This presumably indicates that sole cropped maize and beans is unable to compete with the same crops grown in mixtures, in satisfying the household's various objectives. For the case of cassava, not being a part of the vectors for the efficient solutions, this possibly suggests that cassava is low in the household's dietary needs, and cannot contribute to the household's income because of its low value. Therefore the household should cultivate a mixture of maize and beans, sukumawiki and bananas in order to maximize household nutrition.

Table 7. 14: **Efficient solutions and cropping patterns for the objectives for a medium-resource endowed farm household**

Solution no	Objective function values			L_1	Decision variables							
	Cash income	Nutrition	Leisure		Coffee	Banana	Maize	Beans	Sukumawiki	Maize + Beans	Bananas + Beans	Cassava
	($)	(%)	(hours)						(ha)			
1	613	117.8	10075	0.851	0.49				0.03	0.29		
2	611	117.0	11028	0.315	0.47	0.13			0.03	0.18		
3	596	115.6	11041	0.399	0.44	0.22			0.03	0.07	0.05	
4	568	115.6	11042	0.410	0.41	0.23			0.03		0.14	
5	468	117.1	11028	0.371	0.24	0.29			0.03		0.25	
6	413	116.9	11039	0.400	0.23	0.27			0.03		0.24	
7	359	116.7	11050	0.429	0.22	0.25			0.03		0.22	
8	305	116.6	11061	0.452	0.20	0.22			0.03		0.21	
9	251	116.4	11072	0.481	0.19	0.2			0.03		0.2	
10	196	116.2	11083	0.511	0.17	0.18			0.03		0.19	
11	141	116.7	11087	0.502	0.14	0.15			0.03	0.03	0.18	

Source: Author's computations based on model results

The results from Table 7.15 show the compromise set of cropping plans for the high-resource endowed farm household. The values of the different objectives for the various alternatives are summarized in the table. The minimum L_1 criterion, is utilized in the decision making process to select the satisficing solution from amongst the alternative solutions. Using this criterion, it can be observed that alternative number 2 could be selected as the satisficing solution. The corresponding objective function values for this alternative are; (1) cash income – $1558, (2) nutrition – 116.9 percent and (3) leisure – 13244 hours.

From this identified satisficing solution, the model allocates land to the following crops; coffee (0.33 ha), banana (0.04 ha), sukumawiki (0.05 ha), maize + beans (0.31 ha) and sunflower (0.69 ha). From this solution, the household is in a position to obtain its income and a considerable amount of leisure time by allocating a larger portion of its land to the production of sunflower. This may probably be attributed to the fact that sunflower, as an income-generating crop is less-labour intensive compared to coffee, which is also an income generating crop. Additionally, the allocation of larger areas to selected crops like sunflower and coffee, could suggest that these crops tend to generate a larger cash income to the household compared to other crops and also provide more more leisure time, because they are less-labour intensive.

Table 7. 15: **Efficient solutions and cropping patterns for the objectives for a high-resource endowed farm household**

Solution no	Objective function values			L_1	Decision variables							
	Cash income	Nutrition	Leisure		Coffee	Banana	Maize	Beans	Sukumawiki	Maize + Beans	Bananas + Beans	Sunflower
	($)	(%)	(hours)		(ha)							
1	1605	116.9	12123	0.767	0.48				0.05	0.23		0.66
2	1558	116.9	13244	0.431	0.33	0.04			0.05	0.31		0.69
3	1507	116.9	13258	0.436	0.23	0.23			0.05	0.23		0.68
4	1454	116.9	13262	0.444	0.13	0.37			0.05	0.23		0.64
5	1401	116.9	13266	0.452	0.03	0.51			0.05	0.23		0.6
6	1175	116.9	13289	0.485	0.00	0.31			0.05	0.05	0.44	0.42
7	1061	116.9	13318	0.496	0.01	0.28			0.05	0.05	0.42	0.44
8	947	116.9	13348	0.507	0.01	0.25			0.05	0.04	0.39	0.41
9	834	116.9	13377	0.519	0.01	0.22			0.05	0.04	0.37	0.38
10	720	116.9	13406	0.530	0.01	0.19			0.05	0.03	0.34	0.34
11	606	116.9	13435	0.541	0.01	0.16			0.05	0.02	0.32	0.31
12	493	116.9	13464	0.552	0.01	0.13			0.05	0.02	0.29	0.28
13	378	116.7	13493	0.581	0.01	0.11			0.05	0.01	0.26	0.25
14	261	116.2	13522	0.637	0.01	0.08			0.05	0.01	0.24	0.21

Source: Author’s computations based on model results

7.5. Concluding remarks

This chapter has focused on the development of a multi-objective programming model to represent farm households' production decision-making in the Mt. Elgon region. The choice of the mathematical programming model used, that is, compromise programming, suited the farm household problem depicted, which is, allocating scarce resources to meet household nutrient requirements, cash and leisure needs. The model also suitably integrated the necessary characteristics of the farm such as the constrained farm setting, needed to realize the household's objectives. The chapter also investigated farm household objectives and their preferences for the multiple objectives, which was then used in a multiple objective decision making model. The elicitation of household objectives was done using a pair-wise ranking matrix, which was used to rank the objectives according to their level of "importance".

The major production activities incorporated in the model included; production activities, which entailed the cultivation of coffee, banana, maize, beans, sukuma wiki (kale), maize mixture with beans and a mixture of bananas with beans. Selling activities included in the model involved marketing of "surplus" farm produce, decided upon as the left-over output after production and consumption decisions have been made; labour use activities, which involved monthly labour hiring. The mathematical programming model portrays one cropping year, with production activities starting in January. Results from the model also indicated that farm households are in a better position to derive a higher overall utility from all their objectives, through the inclusion of mixtures in their cropping systems as compared to cultivating mono-crops.

The results of this chapter indicate that different trade-offs occur amongst various household objectives on the three farm types modelled. Furthermore, the results demonstrate how the linkages between farm household components could influence household nutrition and labour demands. The compromise-programming model used in this chapter identified the satisficing solution, that is, the objective values and cropping pattern nearest to the ideal point. These multiple programming models also help to depict the farm household's utility function. Therefore, farm households can make better decisions or their decisions can be predicted better. The application of compromise programming places emphasis on the dynamic relationships existing between crop production activities, constraints and household objectives. However, there is scope for the model to take into account any possible changes in crop prices occurring during the seasons.

CHAPTER 8

8 CONCLUSIONS AND POLICY IMPLICATIONS

This last Chapter presents the summaries of the preceding chapters. In accordance with the findings, it also presents some suggestions for recommendations. Three main topics were investigated in this dissertation and these summaries highlight the labour allocation patterns towards production activities, typology of smallholder farms, as well as the optimization of cropping patterns in smallholder farms.

8.1 Labour allocation patterns in crop production activities

In this first topic, the study assessed how farm labour is allocated towards the various crop production activities. In addition, variability in labour allocation decisions between crops grown for subsistence and commercial purposes was also assessed. The study also looked at how different household types, that is, male headed and female-headed households, allocated their farm labour.

From the assessments, the study identified the different cropping tasks and thereafter, categories of the tasks were formed according to the effort needed to perform the task. This was based on the households' perceptions. Four distinct categories were identified, that is light, moderate, hard and very hard tasks. Additionally, lighter tasks were found to be performed by women. Overall, there was gender specificity of cropping tasks. The labour requirements for the different crops were further estimated. This was based on the numerous cropping tasks for each individual crop. This computation helped to determine which crops farm households allocated more time. Results also indicated that female-headed households spent relatively more time in carrying out the same tasks compared to male-headed households. Variations in labour input were also observed for the same crop cultivated for different purposes in different plots. For example, households invested more time in maize and beans plots meant for cash income as compared to plots with the same crop meant for home consumption.

Generally, variations in labour allocation in production activities depends on the choice of crops of the households as well as the purpose of a particular crop. Although certain crops especially those meant for the market required relatively more labour input in terms of time, farmers argued that in order for them to attain higher yields and consequently more income, they needed to invest more effort. For instance, in applying fertilizers due to the nature of their soils, which they perceived to be of poor soil fertility. The study also aids in examining the linkage between household nutrition and the labour allocation to production activities. This is important because nutritional status and production are closely linked.

8.2 Typology of smallholder farms

The study investigated the diversity of smallholder farms based on their structural and functional characteristics. These characteristics were examined to give an insight into the various constraints faced by the different kinds of smallholder farms. The structural characteristics were specifically related to the resource endowments of the household whereas the functional characteristics were associated with the production and livelihood strategies of the households. Furthermore, the relation between production diversity of farms and their socio-economic characteristics was also explored.

Findings from the study revealed that the highest variability amongst the farms was due to the land resource owned by the farms. This included the amount of land that they had access to and also the portion that was cultivated. The low resource endowed farm type however, had less access to arable land and this in turn led to low production diversity among this group of farms. As a result, their farm income was also low. On the other hand, the high resource endowed farms possessed and cultivated large farmlands, and earned the highest income from farm products. Generally, the high resource endowed farms had more productive assets for instance land and labour compared to farm households in other farm types. Unlike the high resource endowed farms, low production diversity and crop sales were characteristic of the low resource endowed farms.

This classification is important because it helps to understand the current cropping practices employed by the farms. In addition, it gives insights into the aspects, which influence the land and crop management strategies employed by the households, since they face various challenges. This suggests that, to increase productivity in rural production systems, there is need to understand the diversity in these farm systems. Also, identifying the farm types forms a basis for selecting typical farms from which mathematical programming models could possibly be constructed (Kobrich et al., 2003)(see Chapter seven). This leads to a better comprehension of production systems within the study area and consequently to crop management practices that have an impact on household decision-making. Even so, typifying farms is essential if farm models that depict the decision-making behavior of households is set up.

8.3 Optimization of cropping patterns

Evidence from this study indicates that the behaviour of smallholder farms in the Mt. Elgon region regarding their allocation of resources to production activities cannot be represented by a single objective of maximizing farm profit. More so, when assumptions in behaviour are made, there is variation in crop production plans. As such, the model results indicate the potential of applying a compromise-programming model to a multi-objective problem under constrained circumstances. The model made it possible to identify the trade-offs that exist between the allocation of farm resources and the objectives of the different types of resource endowed farm households. Results from the model depict the optimum cropping plans that are able to meet the different household objectives. In the study, cropping plans that promoted better nutrition included the cultivation of crop mixtures, i.e, maize and beans, which besides improving nutrition, also improves farm productivity. Altieri and Nichols (2012) point out that mixed cropping practices can enhance crop yields up to a range of 60 percent. Furthermore, cropping patterns identified by the model, that reduced the labour burden of households included those that allocated larger areas to the production of bananas or included a mixture of bananas and beans. In addition, for the resource-poor and medium-resource farm household to generate cash income, the model allocated a larger crop area to the production of coffee while for the high-resource farm household, the model allocated the largest crop are to sunflower production

The results also reveal that the cropping plans developed through the mathematical programming model in the study would contribute greatly to the nutrition of the farm households compared to the existing cropping patterns, which do not include vegetables like sukumawiki. Findings from this study also showed that there exists a competition between the allocation of labour resources towards the production of crops utilized for different purposes. This involves for example whether the household should allocate family labour to the production of crops meant for household nutrition or to the production of an income-generating crop. These decisions will finally have an impact on the performance of the farm in relation to crop choices and likewise the household objectives.

Although the low resource endowed farm households have less access to productive resources such as land, the model still provides possibilities for the households to find optimal crop mixtures that would help them to achieve minimal nutrition requirements and be able to generate a given amount of cash income, in addition to enjoying a certain level of leisure time. Thus, the inclusion of vegetables in a small portion of the currently cultivated crops can be adequate to increase the nutritional intake of the household.

With the use of the model, it is also possible to assign different weights to the various objectives and be able to generate a set of compromise cropping plans. This eventually provides the decision-maker with further liberty to select an optimum-cropping plan depending on the weights assigned to the objectives. Availing the decision-maker with various crop plan choices provides a somewhat realistic cropping plan as opposed to optimum crop plans attained through single objective optimization.

The mathematical model played an important role in incorporating both the economic, social and nutritional parameters so as to assist in ascertaining how resources such as land and labour should be put to use in order to meet the various household objectives and also determine the trade-offs between the objectives. In addition, the compromise-programming model applied was able to incorporate all the household objectives into a composite objective function with the aid of weights attached to the different objectives.

The use of compromise programming in this study is due to the fact that farm planning revolves around multiple objectives either for individual farms or policy makers and so compromise programming as a decision making tool helps in solving such decision-making processes with multiple objectives. It also provides the decision maker with information for a greater comprehension of the decision-making problem (Romero et al., 1987). Agricultural systems often involve trade-offs during the decision-making process, and therefore the use of compromise programming permits an understanding of the linkages that exist within the different aspects of farming systems. The approach highlights the relationships that exist among farm household objectives, activities, farm constraints, as well as management practices employed in the farm. Also, it explores the relationship between the farm objectives identified by the households. It follows that multiple criteria decision making models (MCDM) can be used as pragmatic depictions of actual problems of farm planning.

8.4 Policy implications

Uganda's agricultural sector is dominated by mostly smallholder farms who produce on small pieces of land with low input use. This affects the productivity of these farms, since the households have to make decisions related to production activities. This study aimed at gaining an understanding of farm household decisions regarding their cropping practices. These decisions in the end, have an impact on the overall welfare of the household in relation to their nutrition and nutritional status, economic and social wellbeing. However, farm household decision-making behaviour depends on a number of factors, which may or may not be under the control of the household. Factors that the household has no control over include, for example, the agro-ecological environment.

This study focuses mainly on those factors that the household can influence, such as crop choice and crop management decisions, as well as the structure of the farm and the household composition. These decisions once taken rationally will improve household food and nutrition, income and social status. Typification of the farms also showed that different household categories have different farm structures and constraints and so have different factors that influence their cropping decisions. Results from this study therefore form a basis for further improvements in smallholder farming systems in terms of recommendations. Identifying the various constraints of the different farm types provided pathways that can be targeted for further improvements in smallholder farm livelihoods. Such pathways could include targeting certain sustainable intensification strategies of agricultural production to particular farm types based on their constraints. Likewise, innovation strategies can be formulated for the different farm types based on the amount of their resource endowment.

As identified by the study, heterogeneity of farms exists, which implies that farms have different possibilities for implementing cropping practices or technologies and therefore policies focused on extension services should focus on particular farm types like the three farm types identified in this study. In addition, the farm types face different challenges and possess distinct resources. So development or support programs that aim at fostering agricultural development in the Mt. Elgon region as well as in other parts of Uganda through improvements in productivity ought to consider these challenges and opportunities available to the different farm types. Understanding the strategic decisions made by different farm types in addition to their crop and crop management choices has been identified as of relevance for an efficient formulation of policies (Weltin et al., 2017).

One way of enhancing productivity is to target interventions to the appropriate farm types. For example, the poor resource endowed farms could benefit from interventions that increase their access to productive resources such as land as well as access to market opportunities. This is so because these farms had less access to farmland and hardly sold their crop produce. This implies that the size of land cultivated by these households could not enable them to produce both for home consumption and for the market. Moreover, it is possible that some of the households had less access to the market. Interventions that encourage mixed cropping practices can also be geared to this farm type. For example, intercrops of bananas and other annual crops, since bananas provide ground cover that helps to reduce soil erosion (Jassogne et al., 2012).

On the other hand, the medium resource endowed farms could be directed towards interventions that improve their access to credit as well as strategies that diversify their income, such as non-farm income activities. Likewise, Wegener et al., (2009) note that income support to farms through government agricultural programs, reduces the household’s engagement in off-farm income activities. The high resource endowed farms who had access to larger farmlands and had relatively higher income from crop produce could benefit from interventions that focus on improved agricultural technologies such as improved seeds and chemical inputs. These farms could also benefit from extension advice inclined towards marketing strategies.

While most of the farm households in the study area use external inputs such as chemical inputs, their use rates are still low and so such challenges can be addressed during policy formulation, which aim to enhance agricultural productivity through technology promotion. This in the end will lead to different farm types contributing to increasing nutrition security besides eradicating poverty. In light of the above, the Mt. Elgon region is faced with a burden of increasing population densities and declining farm sizes and so an increase in food production can only be realized through increase in crop yields per unit area. Therefore, farms that are not carrying out mixed cropping practices should adopt the practice so as to better utilize the available land and realize increases in production. In addition, such farms could incorporate vegetables to their cropping systems, for example incorporating vegetables to maize-based cropping systems, to increase nutrition security.

It follows that, the identified farm types may also guide government extension programs that are inclined towards advisory services and agricultural inputs. Furthermore, most of the farms in all the three farm types cultivate perennial crops, which include coffee and bananas. Therefore, agroforestry practices that help to alleviate the impacts of climate change in the region could be encouraged. Additionally these practices also increase the production of coffee especially through improving the quantity and quality of coffee beans. Admittedly, Jassogne et al., (2012) in their study on the perceptions of intercropping coffee and bananas in the East African highlands of Uganda noted that the price of coffee beans received by the farmers depended on its quality.

Shade trees such as cordia, are best managed as a crop within a mixed farming system and work well within the coffee-banana farming system that is predominant in the East African Highlands including the mountain Elgon. Agroforestry systems promote multi-functional trees planted together with perennial as well as annual crops, allowing families to produce and manage staple crops and trees on the same plot of land. These trees assist with soil retention, serve as animal forage and also a source of biomass which enhances the nutrient and moisture content of the soils, restoring soil fertility, wind breaking and improving agricultural productivity. Farmers' landholdings in the highly populated mountain area are often too small for them to carry out dense tree planting that would eventually eliminate their ability to produce certain staple crops.

Even though the model results do not provide information directed towards improvements in nutrition education, the findings however, suggest that strategies that assist the different resource endowed farm households to cultivate crop combinations from different food groups will help meet the nutritional needs of households. Consequently, nutrition policies aiming at nutrition interventions should support nutritious food choices at the farm level for different farm types. In the same way, research and development should focus on improving crop varieties, which have the potential to increase nutrition as well as income for rural smallholders. In order to promote future inclusion of vegetable crops into the cropping plans through research and development, typical farms where such crops are not presently incorporated can be used to develop the cropping strategies. Also, the national advisory bodies that aim to commercialize agriculture in the Elgon region and Uganda in general should focus efforts towards farms that have larger pieces of land like the high-resource endowed farms. Such farms are in a better position to produce “surplus” output for the market. Moreover smallholder commercialization increases the production of staple crops through the purchase of more land and thus, increasing yields (Wiggins and Keats, 2013).

The application of multiple criteria decision making models aids decision-making in farm planning problems by providing insights into the problem. Therefore, analyzing farm household behaviour using realistic models such as compromise programming ought to be considered by policy makers. This helps to assess the impact of alternative crops as well as the potential for adjustments of other crops on farm household livelihood and agricultural policies. Additionally, the model may also be used to assess the impact of interventions intended to improve smallholder livelihoods with similar circumstances. With the aim of smoothing decision-making not only at the farm but also at research and policy levels, knowledge pertaining to crop planning decisions need to be generated and specified.

ZUSAMMENFASSUNG

Die Studie zielt darauf ab, ein besseres Verständnis der Beweggründe landwirtschaftlicher Haushalte in der Region Mount Elgon im Osten Ugandas bei Ihrer Wahl der Anbauprodukte und der Bewirtschaftungspraktiken auf Grundlage der Verfügbarkeit von Arbeitskräften zu entwickeln, um die Ziele zu maximieren. Es wird davon ausgegangen, dass die landwirtschaftlichen Haushalte in der Region Entscheidungen über die Produktion von Feldfrüchten treffen, wie z.B. die Zuteilung von Arbeitskräften, Land und Landbewirtschaftungspraktiken, um ihre Wohlfahrt zu maximieren. Diese Entscheidungen werden auf Grundlage des menschlichen, physischen, finanziellen und natürlichen Kapitals getroffen, das dem Haushalt jedes Jahr zur Verfügung steht. Da die Entscheidungen zu Beginn eines jeden Jahres getroffen werden, variieren (1) die Entscheidungen darüber, welche Feldfrüchte angebaut werden, (2) wie die Arbeitskräfte zugeteilt werden und (3) welche Landbewirtschaftungspraktiken angewendet werden (Nkonya et al., 2008).

Diese Studie konzentriert sich auf die Entscheidungen zur Allokation von landwirtschaftlichen Ressourcen, die Kleinbauernhaushalte in der Mount Elgon Region in Uganda treffen müssen, um die verschiedenen Ziele des Haushalts zu erreichen. Diese Haushaltsziele beziehen sich auf die Ernährung des Haushalts, das Bareinkommen und die Freizeit der Haushaltsmitglieder. Diese Entscheidungen werden in der Regel unter eingeschränkter landwirtschaftlicher Ressourcen getroffen, zu denen Land und Zeit gehören. Daher müssen landwirtschaftliche Haushalte oft entscheiden, wie und wo sie ihre Ressourcen in Abhängigkeit von ihrem Produktionsziel einsetzen. Diese Studie untersuchte den Arbeitsaufwand der landwirtschaftlichen Haushalte in der Pflanzenproduktion sowie die Vielfalt, die in den landwirtschaftlichen Systemen in Bezug auf die Produktionsressourcen existiert. Darüber hinaus wurden optimale Anbaumuster in den kleinbäuerlichen Anbausystemen identifiziert. Im Einzelnen waren die Ziele der Studie (1) die Bestimmung der Rationalität der Arbeitsallokation zu den gewählten Feldfrüchten durch die landwirtschaftlichen Haushalte, (2) die Klassifizierung der kleinbäuerlichen Betriebe im Hinblick auf ihre Ressourcen für die Feldfruchtproduktion, sowie (3) die Erstellung von linearen Programmierungs- und Kompromissprogrammierungsmodellen zur Schätzung des optimalen Anbaumusters und der benötigten Ressourcen, um die Ziele der landwirtschaftlichen Haushalte zu erreichen.

Die Studie wurde im östlichen Teil Ugandas durchgeführt, speziell im Bezirk Kapchorwa, der nördlich der Mount Elgon Region liegt. Die Region befindet sich in der agro-ökologischen Zone des Elgon-Hochlandes. Da es sich um eine bergige Region handelt, hat der Distrikt drei Höhenlagen, d.h. niedrige, mittlere und hohe Höhenlagen. Die Studie konzentrierte sich jedoch nur auf die mittleren und unteren Höhenlagen, da diese in Bezug auf das landwirtschaftliche System recht ähnlich sind. Bei der Untersuchung handelte es sich um eine Querschnittsstudie, bei der sowohl quantitative als auch qualitative Methoden der Datenerhebung zum Einsatz kamen. Es wurde eine repräsentative Stichprobe von 120 Haushalten befragt, davon 65 Haushalte in der niedrigen und 55 Haushalte in der mittleren Höhenlage.

Während der Studie wurden verschiedene Techniken der Datenerhebung eingesetzt. Dazu gehörten Interviews mit Schlüsselinformanten, Fokusgruppendiskussionen, Haushalts-/Feldbeobachtungen und Haushaltsbefragungen. Schlüsselinformanten-Interviews wurden durchgeführt, um Informationen über das landwirtschaftliche System, agro-ökologische Details und die Märkte in der Region zu sammeln. Zu den Schlüsselinformanten gehörten die Produktionsverantwortlichen des Distrikts und die lokalen Führer. Die Fokusgruppendiskussionen (FGDs) beinhalteten Aktivitäten wie die partizipative Systemanalyse und die Erstellung von Saisonkalendern. Darüber hinaus wurde eine Checkliste verwendet, um die erforderlichen Informationen zu sammeln. Die Fokusgruppendiskussionen wurden durchgeführt, um Daten über die angebauten Feldfrüchte, die Kombinationen von Feldfrüchten, den Arbeitsaufwand für verschiedene Feldfrüchtein Bezug auf die Aktivitäten im Feldbau, in Bezug auf die Zeit, die für die Durchführung einer Aktivität aufgewendet wird, die Arbeitskosten und die Aktivitäten nach der Produktion zu sammeln. Ein halbstrukturierter Fragebogen wurde verwendet, um die Daten auf Haushaltsebene zu sammeln. Die Befragten waren Haushaltsvorstände oder Ehegatten. Auf Haushaltsebene wurden Informationen zu allgemeinen Haushaltsmerkmalen wie Geschlecht, Alter, Haushaltszusammensetzung, Bildungsniveau, landwirtschaftliche und tierische Produktion, Nachernteaktivitäten, Aktivitäten zur Nahrungszubereitung und andere einkommensschaffende Aktivitäten gesammelt.

In der Studie wurden verschiedene Softwareprogramme wie SPSS, STATA, R und GAMS verwendet, um die Daten zu analysieren. Deskriptive Statistiken wie Prozentsätze, Mittelwerte, Standardabweichungen und t-Tests wurden mit den Computerpaketen SPSS und STATA erstellt, um auf Unterschiede zwischen den Bauernhaushalten in den beiden Höhenlagen zu testen. Um die Vielfalt, die innerhalb des landwirtschaftlichen Systems existiert, zu verstehen, wurde eine Farmtypologie erstellt. Diese wurde mit Hilfe der Hauptkomponentenanalyse (PCA) und der Clusteranalyse (CA) entwickelt, die mit der Software R durchgeführt wurden. Um die Mittelwerte der Variablen in jedem der Betriebstypen zu vergleichen, wurde außerdem eine Einweg-ANOVA (Gleichheit der Gruppenmittelwerte) durchgeführt. Ein Mehrzielprogrammierungsmodell mit der GAMS-Software wurde dann verwendet, um die optimalen Anbaumuster der kleinbäuerlichen Haushalte für die verschiedenen Betriebstypen zu analysieren.

Die deskriptiven Ergebnisse zeigen einen statistisch signifikanten Unterschied in der Gesamtmenge des bewirtschafteten Landes, der für den Anbau von Feldfrüchten genutzten Fläche, dem Viehbestand, der Anzahl der bewirtschafteten Felder und der Art der angebauten Feldfrüchte bei Haushalten in den niedrigen und mittleren Höhenlagen der Berglandschaft. Zum Beispiel betrug die durchschnittliche Landfläche, die von Haushalten in den niedrigen Höhenlagen genutzt wurde, einen Hektar, verglichen mit 0,8 Hektar, die von Haushalten in den mittleren Höhenlagen genutzt wurden. Darüber hinaus zeigen die Ergebnisse, dass der Arbeitsaufwand in der Pflanzenproduktion von der Wahl der Pflanzen durch die Haushalte abhängt. Auch die in die Produktion investierte Zeit hängt vom Haushaltstyp (männlich oder weiblich geführt) und der Verfügbarkeit von Arbeitskräften im Haushalt ab.

Basierend auf den Ergebnissen der Betriebstypologie wurden drei Betriebstypen identifiziert. Zu diesen Farmtypen gehörten: (1) ressourcenarme Farmhaushalte, die weniger Zugang zu Ackerland hatten und nicht viel von ihren Ernteprodukten verkauften, (2) mittelmäßig ausgestattete Farmhaushalte, die eine durchschnittliche Landgröße hatten und deren Ernteverkäufe ebenfalls durchschnittlich waren, und schließlich (3) ressourcenstarke Farmhaushalte, die Zugang zu größeren Anbauflächen hatten und deren Verkäufe aus der eigenen Ernteproduktion im Vergleich zu den anderen Farmtypen am höchsten waren. Die Ergebnisse zeigen, dass die Mehrheit der Haushalte, die in die Kategorie der ressourcenarmen Bauernhöfe fielen, in der mittleren Höhenlage angesiedelt war, während die meisten Haushalte des Typs mittlerer und hoher Ressourcenausstattung in der niedrigen Höhenlage angesiedelt waren. Diese unterschiedlichen Betriebstypen wiesen auch darauf hin, dass ihre

Arbeitsallokationsmuster aufgrund ihrer unterschiedlichen Produktionsstrategien variierten. Auf Basis der oben indentifizierten Betriebstypen wurde ein repräsentativer Bauernhaushalt ausgewählt. Die Klassifizierung der landwirtschaftlichen Haushalte in ähnliche Gruppen diente dazu, eine repräsentative Betriebsbedingung für die Konstruktion eines repräsentativen Betriebsmodells zu identifizieren.

Die Ergebnisse des Kompromissmodells zeigten, dass es einen Wettbewerb zwischen der Allokation von Arbeitsressourcen in Richtung der Produktion von Feldfrüchten gibt, die entweder für den Konsum des Haushalts oder für die Generierung von Bargeldeinkommen genutzt werden. Dabei geht es zum Beispiel darum, ob der Haushalt die Arbeitskraft der Familie für die Produktion von Feldfrüchten, die für die Ernährung des Haushalts bestimmt sind, oder für die Produktion einer einkommensschaffenden Feldfrucht einsetzen sollte. Zusätzlich zeigten die Ergebnisse, dass Anbaupläne, die eine bessere Ernährung fördern, den Anbau von Mischkulturen, d.h. Mais und Bohnen, beinhalten, was nicht nur die Ernährung, sondern auch die Produktivität des Betriebs verbessert. Darüber hinaus identifizierte das Modell Anbaumuster, die die Arbeitsbelastung der Haushalte reduzierten, darunter solche, die größere Flächen für die Produktion von Bananen vorsahen oder eine Mischung aus Bananen und Bohnen enthielten. Außerdem wies das Modell den Haushalten mit wenig und mittleren Ressourcen zur Erzielung von Bargeldeinkommen eine größere Anbaufläche für die Produktion von Kaffee zu, während das Modell für die Haushalte mit hohen Ressourcen die größte Anbaufläche für die Produktion von Sonnenblumen zuwies. Die Ergebnisse des Modells zeigten optimale Anbaupläne, die in der Lage sind, die verschiedenen Haushaltsziele zu erfüllen.

Obwohl die ressourcenarmen landwirtschaftlichen Haushalte weniger Zugang zu produktiven Ressourcen wie Land haben, bietet das Modell dennoch Möglichkeiten für die Haushalte optimale Anbaumischungen zu finden, die ihnen helfen würden, einen minimalen Nährstoffbedarf zu erreichen und eine bestimmte Menge an Bareinkommen zu generieren, zusätzlich zu der Möglichkeit ein gewisses Maß an Freizeit zu genießen. So kann die Einbeziehung von Gemüse in einem kleinen Teil der derzeit angebauten Kulturen ausreichen, um die Nährstoffzufuhr des Haushalts zu erhöhen.

Produktionsentscheidungen werden von mehreren Faktoren beeinflusst, darunter interne und externe Faktoren. Diese Studie konzentriert sich hauptsächlich auf die Faktoren, die der Haushalt beeinflussen kann, wie z.B. die Wahl der Feldfrüchte und die Entscheidungen über das Erntemanagement, sowie die Struktur des Betriebs und die Zusammensetzung des Haushalts. Diese Entscheidungen, wenn sie vernünftig getroffen werden, verbessern die Ernährung des Haushalts, das Einkommen und den sozialen Status. Die Klassifizierung der Betriebe zeigte auch, dass verschiedene Haushaltskategorien unterschiedliche Betriebsstrukturen und -zwänge haben und somit unterschiedliche Faktoren, die ihre Anbauentscheidungen beeinflussen. Die Ergebnisse dieser Studie bilden daher die Grundlage für weitere Verbesserungen der kleinbäuerlichen Anbausysteme in Form von Empfehlungen. Die Identifizierung der verschiedenen Einschränkungen der unterschiedlichen Betriebstypen hat Wege aufgezeigt, die für weitere Verbesserungen der kleinbäuerlichen Lebensgrundlagen genutzt werden können. Solche Wege könnten beinhalten, dass bestimmte nachhaltige Intensivierungsstrategien der landwirtschaftlichen Produktion auf bestimmte Betriebstypen auf Grundlage ihrer Einschränkungen ausgerichtet werden. Ebenso können Innovationsstrategien für die verschiedenen Betriebstypen basierend auf der Höhe ihrer Ressourcenausstattung formuliert werden.

Wie in der Studie festgestellt wurde, gibt es eine Heterogenität der landwirtschaftlichen Betriebe, was bedeutet, dass die Betriebe unterschiedliche Möglichkeiten haben, Anbaupraktiken oder Technologien zu implementieren. Daher sollte sich die Politik, die sich auf Beratungsdienste spezialisiert, auf bestimmte Betriebstypen konzentrieren, wie die drei in dieser Studie identifizierten Betriebstypen. Darüber hinaus stehen die Betriebstypen vor unterschiedlichen Herausforderungen und verfügen über unterschiedliche Ressourcen. Entwicklungs- oder Unterstützungsprogramme, die darauf abzielen, die landwirtschaftliche Entwicklung in der Mt.-Elgon-Region sowie in anderen Teilen Ugandas durch Produktivitätssteigerungen zu fördern, sollten daher diese Herausforderungen und Möglichkeiten, die den verschiedenen Betriebstypen zur Verfügung stehen, berücksichtigen. Eine Möglichkeit zur Produktivitätssteigerung besteht darin, die Interventionen auf die entsprechenden Betriebstypen auszurichten.

Auch wenn die Modellergebnisse keine Informationen liefern, die auf eine Verbesserung der Ernährungsbildung abzielen, deuten die Ergebnisse jedoch darauf hin, dass Strategien, die unterschiedlich ressourcenstarke landwirtschaftliche Haushalte dabei unterstützen, Anbaukombinationen aus verschiedenen Nahrungsmittelgruppen anzubauen, dazu beitragen, die

Ernährungsbedürfnisse der Haushalte zu erfüllen. Folglich sollte eine Ernährungspolitik, die auf Ernährungsinterventionen abzielt, eine nahrhafte Lebensmittelauswahl auf der Ebene der verschiedenen landwirtschaftlichen Betriebe unterstützen. Ebenso sollten sich Forschung und Entwicklung auf die Verbesserung von Pflanzensorten konzentrieren, die das Potenzial haben, sowohl die Ernährung als auch das Einkommen ländlicher Kleinbauern zu verbessern.

Schließlich sollte die Analyse des Verhaltens der landwirtschaftlichen Haushalte mit Hilfe von Modellen wie der Kompromissprogrammierung von den politischen Entscheidungsträgern in Betracht gezogen werden, da sie helfen, die Auswirkungen alternativer Nutzpflanzen sowie das Potenzial für Anpassungen anderer Nutzpflanzen auf den Lebensunterhalt der landwirtschaftlichen Haushalte und die Agrarpolitik zu beurteilen. Das Modell kann auch verwendet werden, um die Auswirkungen von Interventionen zu bewerten, die die Lebensbedingungen von Kleinbauern unter ähnlichen Umständen verbessern sollen.

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APPENDICES

Appendix 1: Focus Group Discussion Checklist 1

Participants: Both male and female farmers carrying out general cropping activities and those with exceptional activities. Purposively selected based on information obtained from key informants.

Number of participants: Eight-Ten persons per focus group

How the data will be collected: Voice recorder will be used for the discussions

Number of focus groups: Two focus groups per altitude zone, one for cropping and livestock, non-farm activities and another for labour requirements.

Purpose of focus groups: Purposively to gather both qualitative and quantitative data on mean labour needs of farm households, also as an input in questionnaire design.

Agricultural production
1. Which crops do you grow? *Comment: please probe, by asking “anything else?” DO NOT NAME EXAMPLES!* - Please name all the crops including food and cash crops - Which ones are the food crops, cash crops, both food and cash crops? *Comment: use cards with different colours to identify the food, cash, both food and cash crops* - Can you rank the crops mentioned from more important to less important *Comment: rank using numbers “with 1 being the most important”* - In which seasons do you grow these crops?
2. Can you give the reasons why you grow these crops in particular?
3. Which crops do you usually grow together in the same plot of land? *Comment: please probe, by asking “any other crops mixed together”*
4. Can you give reasons why you usually grow these crops together?
5. What cropping tasks are carried out for the crops? - What is the first task? *Comment: please probe, by asking “do you do any tasks before that?”* - Which task follows after that?
6. During which months of the year are these tasks carried out? *Comment: write down months on a flip chart and assign tasks to months* *Comment: continue mentioning all the tasks they mentioned in the question before* - You mentioned land preparation… in which month do you perform this task?
7. Which months do you consider the busiest months?
8. Can you give reasons why you consider these months as the busiest months?
Livestock activities
9. Do you carry out activities related to livestock?

- What are those activities? - During which months are these activities carried out?
Non-farm activities
10. Do you carry out any non-farm activities? - What are those activities? *Comment: please probe for more, by asking "what else do you do when not in the farm?"*
11. In which months do you perform these activities?
Labour requirement
12. Which household members perform the cropping tasks mentioned? *Comment: list the tasks on a flip chart and assign different card colours for men and women*
13. Can you give reasons why certain tasks are performed by men only, women only, or both men and women?
14. How many household members are needed to finish each task? - Among the household members performing the task, how many are men, women, boys and girls? - How many hours per day does each task normally last? - How many days does each task usually last in a cropping season?
15. Do you take breaks when performing the tasks? - After how much time do you normally take a break when performing each task?
16. Do you use hired labour? - Which cropping tasks do you normally use hired labour? - Why do you normally use hired labour for the tasks you have mentioned?
17. How do you usually pay hired labour? *Comment: please probe by asking, "any other modes of payment"* - How much on average do you normally pay hired labour per cropping task?
18. Do you carry out cropping tasks as a group? - Which tasks do you normally perform as a group? - Why are these tasks carried out in a group?
19. Can you classify the tasks as light, moderate, hard and very hard tasks? *Comment: tasks to be assigned different signs +,++,+++and ++++ indicating light, moderate, hard and very hard tasks respectively.*
20. Can you give reasons why these tasks are regarded as light, moderate, hard and very hard tasks?

Appendix 2: Focus Group Discussion Checklist 2

Purpose of focus groups: To gather both qualitative and quantitative data on labour needs of farm households to generate parameters for the model and as an input in questionnaire design regarding cropping activities.

Participants: Both male and female farmers carrying out general cropping activities and those with exceptional cropping activities. They will be purposively selected based on information obtained from key informants.

Number of participants: Eight-Ten persons per focus group

How the data will be collected: A voice recorder will be used for recording the discussions. A written consent will be obtained from the participants for the recording to be done.

Crop production activities
1. Which crops do you grow? - *Comment: Please name all the crops including food and cash crops*
2. What cropping activities are carried out for the crops? - *Comment: please probe, by asking "do you do any tasks before that?* - Which activity follows after that?
3. How much time is taken to perform the above mentioned activities?
Post harvest activities
4. Which post harvest activities do you carry out on the crops you grow? - Mention all the activities done until its ready for food or selling
5. Who performs the above mentioned activities?
6. How much time is taken to perform the above mentioned activities?
Decision making
7. Who makes decisions on the kinds of crops grown by the household? - Cash crops - Food crops - Both cash and food crops
8. Who makes decisions on the amount of area used for growing the crops in the household? - Cash crops - Food crops - Both cash and food crops
9. Who makes decisions on the quantity of crops sold by household? - Cash crops - Food crops - Both cash and food crops
10. Who makes decisions on the food to be prepared and eaten in the household?
Drivers of decision making
11.What do you think drives/influences/determines the decisions on the crops cultivated by the household? - *Comment: Please mention all drivers, both drivers within and outside the household*
12. What do you think drives/influences/determines the kind of food cooked and eaten in the household? - *Comment: Please mention all drivers, both drivers within and outside the household*
13. What do you think drives/influences/determines the crops sold by the household? - *Comment: Please mention all drivers, both drivers within and outside the household*
14. What do you think drives/influences/determines the quantity of crops sold by the household? - *Comment: Please mention all drivers, both drivers within and outside the household*

15. What do you think drives/influences/determines the time allocated to each of the cropping activities mentioned above? - *Comment: Please mention all drivers, both drivers within and outside the household*
Payment for farm labor
16. Is the price paid for farm labor the same for every household?
17. If yes, does it depend on the cropping activity performed by the hired labor?
18. How much does it cost for the different cropping activities if payment varies between the activities? - *Comment: please list all the activities and assign the cost (cash)*
19. Are there payments for farm labor made in-kind? 20. If yes, what kind of things are always given as payment in-kind?
21. For which tasks is payment in-kind always made? - *Comment: please mention all the activities for which payment in-kind is made*
22. How many hours would the activities (for which payment in-kind is made) normally last?
23. How hard would the activity be (for which payment in-kind is made)? *Comment: use + for light activities, ++ for moderate, +++ for hard, ++++ very hard*
Slope and soil fertility
24. Does the slope of the land affect the kind of crop grown in this area?
25. If yes, mention the crops that require flat land in order to perform well
26. Mention the crops that require fertile land in order to perform well
27. Mention the crops which are not selective on the kind of soil *Comment: Crops which can be grown on any soils and still grow well*

Appendix 3: Focus Group Discussion Checklist 3

Crop production objectives
1. What are your objectives of crop production? - *Let them mention all their objectives for crop production that they would seek to achieve*
2. Rank the objectives of crop production mentioned - *Let them rank their crop production objectives according to the importance attached to them*
3. Why did you decide to give the objectives the different ranks? - *Ask what influenced them to give the objectives the different ranks* - *Ask why an objective was preferable over another*
4. What are some of the reasons that hinder the achievement of your household objectives? - *Ask which challenges they face in attaining each of the objectives mentioned*

Appendix 4: Household Observation Checklist

Household observation
1. What crops did you grow last season? - *Let them mention all the crops they grew*
2. How did you decide to grow the crops you mentioned? - *Let them explain the process of deciding to grow the crops*
3. Why did you decide to grow those crops in particular? - *Ask what influenced them to grow those crops*
4. Why did you decide to grow those crops on that particular size of land? - *Ask which crop has/took the largest area up to the one with the smallest area* - *And then ask why they decided to allocated such area to the individual crops*
5. Why did you decide to grow the crops on that particular plot of land?

Appendix 5: Questionnaire for the Households

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

IPPAE INTERNATIONAL PHD PROGRAM

Introduction:

Hello Sir/Madam,

My name is………… and I am a research assistant being supervised by Christine Arwata Alum, who is a PhD student at the JLU Giessen, Germany. She is carrying out a research on agricultural activities. The research aims to find out how farmers choose the crops they grow and also looks at how they allocate their labour resources to crop production activities.

I would like to kindly ask you some questions concerning the crops you grow and the different cropping activities you perform and how you allocate labour to these activities.

[Ask if the farmer is willing to take part in the interview]

[If yes, continue with the interview. If not, find out why and then you may leave]

RATIONALITY IN RESOURCE ALLOCATION BY SMALLHOLDER FARMERS AND IMPLICATIONS ON PRODUCTIVITY IN MT ELGON REGION, UGANDA

Identification information

A001: Date of interview: _____/ _____ / 2018	**A002: Name of Respondent:**
A003: Sex of respondent: 1. Male 2. Female	**A004: Age of respondent:**

A005: Is the respondent the farm owner? 1. Yes 2. No	
A006: Sub-county:	**A007: Location on Mountain landscape (Zone):**
A008: Village:	**A009: Enumerator's name:**

1: HOUSEHOLD DEMOGRAPHICS

1.0	What is your marital status?	1. Single 2. Married 3. Widowed 4. Divorced/Separated	
1.1	Are you the head of the household?	1. Yes 2. No	
1.2	If no, what is your relationship to the household head?	1. Husband 2. Wife 3. Father 4. Mother 5. Brother/Sister 6. Other (specify)	
1.3	What is the sex of the household head?	1. Male 2. Female	
1.4	What is the education level of the household head?	1. Primary 2. Secondary 3. Tertiary institution 4. University 5. Other (specify)	
1.5	How many people live in this household?	1. 0-5 years	
		2. 6-15 years	
		3. 16-49 years	
		4. Above 50 years	
1.6	How many males live in this household in these age categories?	1. 0-5 years	
		2. 6-15 years	
		3. 16-49 years	

		4. Above 50 years	
1.7	How many females live in this household in these age categories?	1. 0-5 years	
		2. 6-15 years	
		3. 16-49 years	
		4. Above 50 years	

2: CROP PRODUCTION AND MARKETING

2.0	How much land does your household own in total?	……………….(Acres)
2.1	How much land does your household have access to (including rented, shared and borrowed)?	……………….(Acres)
2.2a	How much land is farmed by the household for crops?	……………….(Acres)
2.2b	How much land is farmed by the household for livestock?	………………(Acres)
2.2c	How much land is farmed by the household for other purposes e.g trees and apiary?	………………(Acres)
2.3	Have you hired land in the last 2 years?	1. Yes 2. No
2.4	If yes, how much land did you hire last year (2018)?	……………….(Acres)
2.5	If yes, how much land did you hire in 2019?	…………..……(Acres)
2.6	Is it possible to hire as much land as you want?	1. Yes 2. No
2.7	If no, what is the reason for not hiring more land?	1. There is scarcity of land 2. Do not have enough labor to cultivate it all 3. Land tenure systems are prohibiting 4. No money to hire more 5. Other (specify)
2.8	Do you sometimes fail to cultivate all of your available land?	1. Yes 2. No
2.9	If yes, what is the reason for not cultivating all available land?	1. Lack of labor 2. Lack of inputs 3. I have more land than I need 4. I rest the land by fallowing 5. Other (specify)

2.10	What are the main crops grown by this household?	1. Coffee 2. Sunflower 3. Bananas 4. Beans 5. Maize 6. Irish potatoes 7. Sweet potatoes 8. Cassava 9. Groundnuts 10. Field peas 11. Millet 12. Sorghum 13. Sukuma wiki 14. Tomatoes 15. Cabbages 16. Onions 17. Yams 18. Egg plants 19. Coco yams 20. Pumpkin 21. Other (specify)	Crop 1: Crop 2: Crop 3: Crop 4: Crop 5: Crop 6: Crop 7: Crop 8:
2.11	What is the main reason for growing Crop 1	1. Ready market 2. Less labor requirement 3. Drought tolerant 4. Food security 5. Cash income 6. Preferred food crop 7. Seeds easily available for planting 8. Other (specify)	Reason 1: Reason 2: Reason 3: Reason 4:
2.12	What is the main reason for growing Crop 2	1. Ready market 2. Less labor requirement 3. Drought tolerant 4. Food security 5. Cash income 6. Preferred food crop 7. Seeds easily available for	Reason 1: Reason 2: Reason 3: Reason 4:

		planting 8. Other (specify)	
2.13	What is the main reason for growing Crop 3	1. Ready market 2. Less labor requirement 3. Drought tolerant 4. Food security 5. Cash income 6. Preferred food crop 7. Seeds easily available for planting 8. Other (specify)	Reason 1: Reason 2: Reason 3: Reason 4:
2.14	What is the main reason for growing Crop 4	1. Ready market 2. Less labor requirement 3. Drought tolerant 4. Food security 5. Cash income 6. Preferred food crop 7. Seeds easily available for planting 8. Other (specify)	Reason 1: Reason 2: Reason 3: Reason 4:
2.15	What is the main reason for growing Crop 5	1. Ready market 2. Less labor requirement 3. Drought tolerant 4. Food security 5. Cash income 6. Preferred food crop 7. Seeds easily available for planting 8. Other (specify)	Reason 1: Reason 2: Reason 3: Reason 4:
2.16	What is the main reason for growing Crop 6	1. Ready market 2. Less labor requirement 3. Drought tolerant 4. Food security 5. Cash income 6. Preferred food crop 7. Seeds easily available for planting 8. Other (specify)	Reason 1: Reason 2: Reason 3: Reason 4:

2.17	What is the main reason for growing Crop 7	1. Ready market 2. Less labor requirement 3. Drought tolerant 4. Food security 5. Cash income 6. Preferred food crop 7. Seeds easily available for planting 8. Other (specify)	Reason 1: Reason 2: Reason 3: Reason 4:
2.18	What is the main reason for growing Crop 8	1. Ready market 2. Less labor requirement 3. Drought tolerant 4. Food security 5. Cash income 6. Preferred food crop 7. Seeds easily available for planting 8. Other (specify)	Reason 1: Reason 2: Reason 3: Reason 4:
2.19	Which crops does this household mainly grow in mixtures?	1. Banana + Coffee 2. Banana + Cassava 3. Banana + Beans 4. Maize + Beans 5. Maize + Pumpkin 6. Maize + Sweet potatoes 7. Sorghum + Millet 8. Maize + Beans +Pumpkin 9. Banana + Coffee + Beans 10. Other (specify)	Mixture 1: Mixture 2: Mixture 3: Mixture 4: Mixture 5:

2.20	What are the main reasons for growing the above crops in mixture 1?	1. Pest and disease control 2. Improve soil fertility 3. Increased production 4. Risk reduction 5. Scarcity of land 6. Other (specify)	Reason 1: Reason 2: Reason 3: Reason 4:
2.21	What are the main reasons for growing the above crops in mixture 2?	1. Pest and disease control 2. Improve soil fertility 3. Increased production 4. Risk reduction 5. Scarcity of land 6. Other (specify)	Reason 1: Reason 2: Reason 3: Reason 4:
2.22	What are the main reasons for growing the above crops in mixture 3?	1. Pest and disease control 2. Improve soil fertility 3. Increased production 4. Risk reduction 5. Scarcity of land 6. Other (specify)	Reason 1: Reason 2: Reason 3: Reason 4:
2.23	What are the main reasons for growing the above crops in mixture 4?	1. Pest and disease control 2. Improve soil fertility 3. Increased production 4. Risk reduction 5. Scarcity of land 6. Other (specify)	Reason 1: Reason 2: Reason 3: Reason 4:
2.24	What are the main reasons for growing the above crops in mixture 5?	1. Pest and disease control 2. Improve soil fertility 3. Increased production 4. Risk reduction 5. Scarcity of land 6. Other (specify)	Reason 1: Reason 2: Reason 3: Reason 4:
2.25	Which crops does this household grow as pure stands/monoculture?	1. Irish potatoes 2. Cabbages 3. Tomatoes 4. Onions	Crop 1: Crop 2: Crop 3: Crop 4: Crop 5:

		5. Sweet potatoes 6. Field peas 7. Sukuma wiki 8. Coco yams 9. Yams 10. Groundnuts 11. Other (specify)	
2.26	What is the reason for growing Crop 1 as a pure stand/monoculture?	1. More yields 2. Easy management 3. Labor intensive 4. Availability of land 5. Other (specify)	Reason 1: Reason 2: Reason 3: Reason 4:
2.27	What is the reason for growing Crop 2 as a pure stand/monoculture?	1. More yields 2. Easy management 3. Labor intensive 4. Availability of land 5. Other (specify)	Reason 1: Reason 2: Reason 3: Reason 4:
2.28	What is the reason for growing Crop 3 as a pure stand/monoculture?	1. More yields 2. Easy management 3. Labor intensive 4. Availability of land 5. Other (specify)	Reason 1: Reason 2: Reason 3: Reason 4:
2.29	What is the reason for growing Crop 4 as a pure stand/monoculture?	1. More yields 2. Easy management 3. Labor intensive 4. Availability of land 5. Other (specify)	Reason 1: Reason 2: Reason 3: Reason 4:
2.30	What is the reason for growing Crop 5 as a pure stand/monoculture?	1. More yields 2. Easy management 3. Labor intensive 4. Availability of land 5. Other (specify)	Reason 1: Reason 2: Reason 3: Reason 4:
2.31	How many fields does your household have?		
	Field 1		

2.32	What is the size (acres) of field 1?		
2.33	What is the distance of field 1 from your household?	1. Around household 2. 30 min 3. 1 hour 4. More than 1 hour 5. Other (specify)	
2.34	How many plots does field 1 have?		
2.35	Which crops were planted in plot 1_field 1(2nd season 2018)?		
2.36	What was the size (acres) of plot 1_field 1?		
2.37	If the plot was intercropped, estimate the percent of land devoted to each of the crops?	1. Crop 1:	
		2. Crop 2:	
		3. Crop 3:	
2.38	Which of these cropping activities were carried out in plot 1_field 1?	1. Fertilizer application 2. Manure application 3. Constructing terraces/stone/grass bunds 4. Digging trenches 5. Mulching 6. Spraying 7. Heaping 8. Other (specify)	
2.39	How much Kgs of the crops that you planted in plot 1_field 1 did you harvest this season?		
2.40	How much Kgs of the crops that you planted in plot 1_field 1 did you sell this season?		
2.41	Where did you sell the crops you harvested from plot 1_field 1?	1. At the farm gate 2. At the neighbors 3. Nearby market 4. Urban market	

2.42	How far is the market from your household?	1. Less than 1 km 2. 1 km 3. 2 km 4. More than 2 km	
2.43	Did you hire labor to work in plot 1_field 1?	1. Yes 2. No	
2.44	If yes, for which cropping activities did you hire labor?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.45	How many hired labor did you hire for the cropping activities above?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.46	How many family members were involved in crop production in this plot?		
2.47	How many family members involved were in the following categories?	1. Men: 2. Women: 3. Children:	
2.48	Which crops were planted in plot 2_field 1(2nd season 2018)?		
2.49	What was the size (acres) of plot 2_field 1		
2.50	If the plot was intercropped, estimate the percent of land devoted to each of the crops?	1. Crop 1:	
		2. Crop 2:	
		3. Crop 3:	

2.51	Which of these cropping activities were carried out in plot 2_field 1?	1. Fertilizer application 2. Manure application 3. Constructing terraces/stone/grass bunds 4. Digging trenches 5. Mulching 6. Spraying 7. Heaping 8. Other (specify)	
2.52	How much Kgs of the crops that you planted in plot 2_field 1 did you harvest this season?		
2.453	How much Kgs of the crops that you planted in plot 2_field 1 did you sell this season?		
2.54	Where did you sell the crops you harvested from plot 2_field 1?	1. At the farm gate 2. At the neighbors 3. Nearby market 4. Urban market	
2.55	How far is the market from your household?	1. Less than 1 km 2. 1 km 3. 2 km 4. More than 2 km	
2.56	Did you hire labor to work in plot 2_field 1?	1. Yes 2. No	
2.57	If yes, for which cropping activities did you hire labor?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.58	How many hired labor did you hire for the cropping activities above?	1. Activity 1: 2. Activity 2: 3. Activity 3:	

		4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.59	How many family members were involved in crop production in this plot?		
2.60	How many family members involved were in the following categories?	1. Men: 2. Women: 3. Children:	
2.61	Which crops were planted in plot 3_field 1(2nd season)?		
2.62	What was the size (acres) of plot 3_field 1?		
2.63	If the plot was intercropped, estimate the percent of land devoted to each of the crops?	1. Crop 1:	
		2. Crop 2:	
		3. Crop 3:	
2.64	Which of these cropping activities were carried out in plot 3_field 1?	1. Fertilizer application 2. Manure application 3. Constructing terraces/stone/grass bunds 4. Digging trenches 5. Mulching 6. Spraying 7. Heaping 8. Other (specify)	
2.65	How much Kgs of the crops that you planted in plot 3_field 1 did you harvest this season?		
2.66	How much Kgs of the crops that you planted in plot 3_field 1 did you sell this season?		
2.67	Where did you sell the crops you	1. At the farm gate	

	harvested from plot 3_field 1?	2. At the neighbors 3. Nearby market 4. Urban market	
2.68	How far is the market from your household?	1. Less than 1 km 2. 1 km 3. 2 km 4. More than 2 km	
2.69	Did you hire labor to work in plot 3_field 1?	1. Yes 2. No	
2.70	If yes, for which cropping activities did you hire labor?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.71	How many hired labor did you hire for the cropping activities above?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.72	How many family members were involved in crop production in this plot?		
2.73	How many family members involved were in the following categories?	1. Men: 2. Women: 3. Children:	
2.74	Which crops were planted in plot 4_field 1(2nd season 2018)?		
2.75	What was the size (acres) of plot 4_field 1?		
2.76	If the plot was intercropped, estimate the percent of land	1. Crop 1:	

	devoted to each of the crops?	2. Crop 2: 3. Crop 3:	
2.77	Which of these cropping activities were carried out in plot 4_field 1?	1. Fertilizer application 2. Manure application 3. Constructing terraces/stone/grass bunds 4. Digging trenches 5. Mulching 6. Spraying 7. Heaping 8. Other (specify)	
2.78	How much Kgs of the crops that you planted in plot 4_field 1 did you harvest this season?		
2.79	How much Kgs of the crops that you planted in plot 4_field 1 did you sell this season?		
2.80	Where did you sell the crops you harvested from plot 4_field 1?	1. At the farm gate 2. At the neighbors 3. Nearby market 4. Urban market	
2.81	How far is the market from your household?	1. Less than 1 km 2. 1 km 3. 2 km 4. More than 2 km	
2.82	Did you hire labor to work in plot 4_field 1?	1. Yes 2. No	
2.83	If yes, for which cropping activities did you hire labor?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	

2.84	How many hired labor did you hire for the cropping activities above?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.85	How many family members were involved in crop production in this plot?		
2.86	How many family members involved were in the following categories?	1. Men: 2. Women: 3. Children:	
	Field 2		
2.87	What is the size (acres) of field 2?		
2.88	What is the distance of field 2 from your household?	1. Around household 2. 30 min 3. 1 hour 4. More than 1 hour 5. Other (specify)	
2.89	How many plots does field 2 have?		
2.90	Which crops were planted in plot 1_field 2 (2nd season 2018)?		
2.91	What was the size (acres) of plot 1_field 2		
2.92	If the plot was intercropped, estimate the percent of land devoted to each of the crops?	1. Crop 1:	
		2. Crop 2:	
		3. Crop 3:	
2.93	Which of these cropping activities were carried out in plot 1_field 2?	1. Fertilizer application 2. Manure application 3. Constructing terraces/stone/grass bunds 4. Digging trenches	

		5. Mulching 6. Spraying 7. Heaping 8. Other (specify)	
2.94	How much Kgs of the crops that you planted in plot 1_field 2 did you harvest this season?		
2.95	How much Kgs of the crops that you planted in plot 1_field 2 did you sell this season?		
2.96	Where did you sell the crops you harvested from plot 1_field 2?	1. At the farm gate 2. At the neighbors 3. Nearby market 4. Urban market	
2.97	How far is the market from your household?	1. Less than 1 km 2. 1 km 3. 2 km 4. More than 2 km	
2.98	Did you hire labor to work in plot 1_field 2?	1. Yes 2. No	
2.99	If yes, for which cropping activities did you hire labor?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.100	How many hired labor did you hire for the cropping activities above?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	

2.101	How many family members were involved in crop production in this plot?		
2.102	How many family members involved were in the following categories?	1. Men: 2. Women: 3. Children:	
2.103	Which crops were planted in plot 2_field 2 (2nd season 2018)?		
2.104	What was the size (acres) of plot 2_field 2?		
2.105	If the plot was intercropped, estimate the percent of land devoted to each of the crops?	1. Crop 1:	
		2. Crop 2:	
		3. Crop 3:	
2.106	Which of these cropping activities were carried out in plot 2_field 2?	1. Fertilizer application 2. Manure application 3. Constructing terraces/stone/grass bunds 4. Digging trenches 5. Mulching 6. Spraying 7. Heaping 8. Other (specify)	
2.107	How much Kgs of the crops that you planted in plot 2_field 2 did you harvest this season?		
2.108	How much Kgs of the crops that you planted in plot 2_field 2 did you sell this season?		
2.109	Where did you sell the crops you harvested from plot 2_field 2?	1. At the farm gate 2. At the neighbors 3. Nearby market 4. Urban market	
2.110	How far is the market from your household?	1. Less than 1 km 2. 1 km 3. 2 km 4. More than 2 km	

2.111	Did you hire labor to work in plot 2_field 2?	1. Yes 2. No	
2.112	If yes, for which cropping activities did you hire labor?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.113	How many hired labor did you hire for the cropping activities above?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.114	How many family members were involved in crop production in this plot?		
2.115	How many family members involved were in the following categories?	1. Men: 2. Women: 3. Children:	
2.116	Which crops were planted in plot 3_field 2 (2^{nd} season 2018)?		
2.117	What was the size (acres) of plot 3_field 2?		
2.118	If the plot was intercropped, estimate the percent of land devoted to each of the crops?	1. Crop 1:	
		2. Crop 2:	
		3. Crop 3:	
2.119	Which of these cropping activities were carried out in plot 3_field 2?	1. Fertilizer application 2. Manure application	

		3. Constructing terraces/stone/grass bunds 4. Digging trenches 5. Mulching 6. Spraying 7. Heaping 8. Other (specify)	
2.120	How much Kgs of the crops that you planted in plot 3_field 2 did you harvest this season?		
2.121	How much Kgs of the crops that you planted in plot 3_field 2 did you sell this season?		
2.122	Where did you sell the crops you harvested from plot 3_field 2?	1. At the farm gate 2. At the neighbors 3. Nearby market 4. Urban market	
2.123	How far is the market from your household?	1. Less than 1 km 2. 1 km 3. 2 km 4. More than 2 km	
2.124	Did you hire labor to work in plot 3_field 2?	1. Yes 2. No	
2.125	If yes, for which cropping activities did you hire labor?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.126	How many hired labor did you hire for the cropping activities above?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5:	

		6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.127	How many family members were involved in crop production in this plot?		
2.128	How many family members involved were in the following categories?	1. Men: 2. Women: 3. Children:	
2.129	Which crops were planted in plot 4_field 2 (2nd season 2018)?		
2.130	What was the size (acres) of plot 4_field 2		
2.131	If the plot was intercropped, estimate the percent of land devoted to each of the crops?	1. Crop 1:	
		2. Crop 2:	
		3. Crop 3:	
2.132	Which of these cropping activities were carried out in plot 4_field 2?	1. Fertilizer application 2. Manure application 3. Constructing terraces/stone/grass bunds 4. Digging trenches 5. Mulching 6. Spraying 7. Heaping 8. Other (specify)	
2.133	How much Kgs of the crops that you planted in plot 4_field 2 did you harvest this season?		
2.134	How much Kgs of the crops that you planted in plot 4_field 2 did you sell this season?		
2.135	Where did you sell the crops you harvested from plot 4_field 2?	1. At the farm gate 2. At the neighbors 3. Nearby market 4. Urban market	
2.136	How far is the market from your household?	1. Less than 1 km 2. 1 km	

		3. 2 km 4. More than 2 km	
2.137	Did you hire labor to work in plot 4_field 2?	1. Yes 2. No	
2.138	If yes, for which cropping activities did you hire labor?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.139	How many hired labour did you hire for the cropping activities above?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.140	How many family members were involved in crop production in this plot?		
2.141	How many family members involved were in the following categories?	1. Men: 2. Women: 3. Children:	
	Field 3		
2.142	What is the size (acres) of field 3?		
2.143	What is the distance of field 3 from your household?	1. Around household 2. 30 min 3. 1 hour 4. More than 1 hour 5. Other (specify)	
2.144	How many plots does field 3 have?		

2.145	Which crops were planted in plot 1_field 3 (2nd season 2018)?		
2.146	What was the size (acres) of plot 1_field 3?		
2.147	If the plot was intercropped, estimate the percent of land devoted to each of the crops?	1. Crop 1:	
		2. Crop 2:	
		3. Crop 3:	
2.148	Which of these cropping activities were carried out in plot 1_field 3?	1. Fertilizer application 2. Manure application 3. Constructing terraces/stone/grass bunds 4. Digging trenches 5. Mulching 6. Spraying 7. Heaping 8. Other (specify)	
2.149	How much Kgs of the crops that you planted in plot 1_field 3 did you harvest this season?		
2.150	How much Kgs of the crops that you planted in plot 1_field 3 did you sell this season?		
2.151	Where did you sell the crops you harvested from plot 1_field 3?	1. At the farm gate 2. At the neighbors 3. Nearby market 4. Urban market	
2.152	How far is the market from your household?	1. Less than 1 km 2. 1 km 3. 2 km 4. More than 2 km	
2.153	Did you hire labor to work in plot 1_field 3?	1. Yes 2. No	
2.154	If yes, for which cropping activities did you hire labor?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4:	

		5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.155	How many hired labor did you hire for the cropping activities above?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.156	How many family members were involved in crop production in this plot?		
2.157	How many family members involved were in the following categories?	1. Men: 2. Women: 3. Children:	
2.158	Which crops were planted in plot 2_field 3 (2nd season 2018)?		
2.159	What was the size (acres) of plot 2_field 3?		
2.160	If the plot was intercropped, estimate the percent of land devoted to each of the crops?	1. Crop 1:	
		2. Crop 2:	
		3. Crop 3:	
2.161	Which of these cropping activities were carried out in plot 2_field 3?	1. Fertilizer application 2. Manure application 3. Constructing terraces/stone/grass bunds 4. Digging trenches 5. Mulching 6. Spraying 7. Heaping 8. Other (specify)	
2.162	How much Kgs of the crops that you planted in plot 2_field 3 did you harvest this season?		

2.163	How much Kgs of the crops that you planted in plot 2_field 3 did you sell this season?		
2.164	Where did you sell the crops you harvested from plot 2_field 3?	1. At the farm gate 2. At the neighbors 3. Nearby market 4. Urban market	
2.165	How far is the market from your household?	1. Less than 1 km 2. 1 km 3. 2 km 4. More than 2 km	
2.166	Did you hire labor to work in plot 2_field 3?	1. Yes 2. No	
2.167	If yes, for which cropping activities did you hire labor?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.168	How many hired labor did you hire for the cropping activities above?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.169	How many family members were involved in crop production in this plot?		
2.170	How many family members involved were in the following categories?	1. Men: 2. Women: 3. Children:	
2.171	Which crops were planted in plot		

	3_field 3 (2nd season 2018)?		
2.172	What was the size (acres) of plot 3_field 3?		
2.173	If the plot was intercropped, estimate the percent of land devoted to each of the crops?	1. Crop 1	
		2. Crop 2:	
		3. Crop 3:	
2.174	Which of these cropping activities were carried out in plot 3_field 3?	1. Fertilizer application 2. Manure application 3. Constructing terraces/stone/grass bunds 4. Digging trenches 5. Mulching 6. Spraying 7. Heaping 8. Other (specify)	
2.175	How much Kgs of the crops that you planted in plot 3_field 3 did you harvest this season?		
2.176	How much Kgs of the crops that you planted in plot 3_field 3 did you sell this season?		
2.177	Where did you sell the crops you harvested from plot 3_field 3?	1. At the farm gate 2. At the neighbors 3. Nearby market 4. Urban market	
2.178	How far is the market from your household?	1. Less than 1 km 2. 1 km 3. 2 km 4. More than 2 km	
2.179	Did you hire labor to work in plot 3_field 3?	1. Yes 2. No	
2.180	If yes, for which cropping activities did you hire labor?	1. Activity 1: 2. Activity 2: 3. Activity 3:	

		4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.181	How many hired labor did you hire for the cropping activities above?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.182	How many family members were involved in crop production in this plot?		
2.183	How many family members involved were in the following categories?	1. Men: 2. Women: 3. Children:	
2.184	Which crops were planted in plot 4_field 3 (2nd season 2018)?		
2.185	What was the size (acres) of plot 4_field 3?		
2.186	If the plot was intercropped, estimate the percent of land devoted to each of the crops?	1. Crop 1:	
		2. Crop 2:	
		3. Crop 3:	
2.187	Which of these cropping activities were carried out in plot 4_field 3?	1. Fertilizer application 2. Manure application 3. Constructing terraces/stone/grass bunds 4. Digging trenches 5. Mulching 6. Spraying 7. Heaping 8. Other (specify)	
2.188	How much Kgs of the crops that you planted in plot 4_field 3 did		

	you harvest this season?		
2.189	How much Kgs of the crops that you planted in plot 4_field 3 did you sell this season?		
2.190	Where did you sell the crops you harvested from plot 4_field 3?	1. At the farm gate 2. At the neighbors 3. Nearby market 4. Urban market	
2.191	How far is the market from your household?	1. Less than 1 km 2. 1 km 3. 2 km 4. More than 2 km	
2.192	Did you hire labor to work in plot 4_field 3?	1. Yes 2. No	
2.193	If yes, for which cropping activities did you hire labor?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.194	How many hired labor did you hire for the cropping activities above?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.195	How many family members were involved in crop production in this plot?		
2.196	How many family members involved were in the following categories?	1. Men: 2. Women: 3. Children:	

	Field 4		
2.197	What is the size (acres) of field 4?		
2.198	What is the distance of field 4 from your household?	1. Around household 2. 30 min 3. 1 hour 4. More than 1 hour 5. Other (specify)	
2.199	How many plots does field 4 have?		
2.200	Which crops were planted in plot 1_field 4 (2nd season 2018)?		
2.201	What was the size (acres) of plot 1_field 4?		
2.202	If the plot was intercropped, estimate the percent of land devoted to each of the crops?	1. Crop 1	
		2. Crop 2:	
		3. Crop 3:	
2.203	Which of these cropping activities were carried out in plot 1_field 4?	1. Fertilizer application 2. Manure application 3. Constructing terraces/stone/grass bunds 4. Digging trenches 5. Mulching 6. Spraying 7. Heaping 8. Other (specify)	
2.204	How much Kgs of the crops that you planted in plot 1_field 4 did you harvest this season?		
2.205	How much Kgs of the crops that you planted in plot 1_field 4 did you sell this season?		
2.206	Where did you sell the crops you harvested from plot 1_field 4?	1. At the farm gate 2. At the neighbors 3. Nearby market 4. Urban market	
2.207	How far is the market from your	1. Less than 1 km	

	household?	2. 1 km 3. 2 km 4. More than 2 km	
2.208	Did you hire labor to work in plot 1_field 4?	1. Yes 2. No	
2.209	If yes, for which cropping activities did you hire labor?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.210	How many hired labor did you hire for the cropping activities above?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.211	How many family members were involved in crop production in this plot?		
2.212	How many family members involved were in the following categories?	1. Men: 2. Women: 3. Children:	
2.213	Which crops were planted in plot 2_field 4 (2nd season 2018)?		
2.214	What was the size (acres) of plot 2_field 4?		
2.215	If the plot was intercropped, estimate the percent of land devoted to each of the crops?	1. Crop 1:	
		2. Crop 2:	
		3. Crop 3:	
2.216	Which of these cropping activities were carried out in plot	1. Fertilizer application	

	3_field 4?	2. Manure application 3. Constructing terraces/stone/grass bunds 4. Digging trenches 5. Mulching 6. Spraying 7. Heaping 8. Other (specify)	
2.217	How much Kgs of the crops that you planted in plot 2_field 4 did you harvest this season?		
2.218	How much Kgs of the crops that you planted in plot 2_field 4 did you sell this season?		
2.219	Where did you sell the crops you harvested from plot 2_field 4?	1. At the farm gate 2. At the neighbors 3. Nearby market 4. Urban market	
2.220	How far is the market from your household?	1. Less than 1 km 2. 1 km 3. 2 km 4. More than 2 km	
2.221	Did you hire labor to work in plot 2_field 4?		
2.222	If yes, for which cropping activities did you hire labor?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.223	How many hired labor did you hire for the cropping activities above?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4:	

		5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.224	How many family members were involved in crop production in this plot?		
2.225	How many family members involved were in the following categories?	1. Men: 2. Women: 3. Children:	
2.226	Which crops were planted in plot 3_field 4 (2nd season 2018)?		
2.227	What was the size (acres) of plot 3_field 4?		
2.228	If the plot was intercropped, estimate the percent of land devoted to each of the crops?	1. Crop 1:	
		2. Crop 2:	
		3. Crop 3:	
2.229	Which of these cropping activities were carried out in plot 3_field 4?	1. Fertilizer application 2. Manure application 3. Constructing terraces/stone/grass bunds 4. Digging trenches 5. Mulching 6. Spraying 7. Heaping 8. Other (specify)	
2.300	How much Kgs of the crops that you planted in plot 3_field 4 did you harvest this season?		
2.301	How much Kgs of the crops that you planted in plot 3_field 4 did you sell this season?		
2.302	Where did you sell the crops you harvested from plot 3_field 4?	1. At the farm gate 2. At the neighbors 3. Nearby market 4. Urban market	
2.303	How far is the market from your household?	1. Less than 1 km	

		2. 1 km 3. 2 km 4. More than 2 km	
2.304	Did you hire labor to work in plot 3_field 4?	1. Yes 2. No	
2.305	If yes, for which cropping activities did you hire labor?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.306	How many hired labor did you hire for the cropping activities above?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.307	How many family members were involved in crop production in this plot?		
2.308	How many family members involved were in the following categories?	1. Men: 2. Women: 3. Children:	
2.309	Which crops were planted in plot 4_field 4 (2nd season 2018)?		
2.310	What was the size (acres) of plot 4_field 4?		
2.311	If the plot was intercropped, estimate the percent of land devoted to each of the crops?	1. Crop 1:	
		2. Crop 2:	
		3. Crop 3:	
2.312	Which of these cropping activities were carried out in plot	1. Fertilizer application	

	4_field 4?	2. Manure application 3. Constructing terraces/stone/grass bunds 4. Digging trenches 5. Mulching 6. Spraying 7. Heaping 8. Other (specify)	
2.313	How much Kgs of the crops that you planted in plot 4_field 4 did you harvest this season?		
2.314	How much Kgs of the crops that you planted in plot 4_field 4 did you sell this season?		
2.315	Where did you sell the crops you harvested from plot 4_field 4?	1. At the farm gate 2. At the neighbors 3. Nearby market 4. Urban market	
2.316	How far is the market from your household?	1. Less than 1 km 2. 1 km 3. 2 km 4. More than 2 km	
2.317	Did you hire labor to work in plot 4_field 4?	1. Yes 2. No	
2.318	If yes, for which cropping activities did you hire labor?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4: 5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.319	How many hired labor did you hire for the cropping activities above?	1. Activity 1: 2. Activity 2: 3. Activity 3: 4. Activity 4:	

		5. Activity 5: 6. Activity 6: 7. Activity 7: 8. Activity 8:	
2.320	How many family members were involved in crop production in this plot?		
2.321	How many family members involved were in the following categories?	1. Men: 2. Women: 3. Children:	
2.322	On which fields do you always plant crops mainly grown for household consumption?	1. Fields near home 2. Fields far away 3. Other (specify)	
2.323	On which fields do you always plant crops grown for sale?	1. Fields near home 2. Fields far away 3. Other (specify)	
2.324	Do you feel tired walking to the fields located far away from home?	1. Yes 2. No	
2.325	If yes, how tired do you feel after walking to a field located far away from home?	1. Slightly tired 2. Tired 3. Very tired 4. Extremely tired	
2.326	Are all your fields located in the same altitude belt?	1. Yes 2. No	
2.327	If no, why do you have fields in different altitudes?	1. Availability of land 2. Fertile soils 3. Temperature 4. Slope 5. Other (specify)	
2.328	In which altitudes are your other fields located?	1. Lower 2. Mid 3. Upper	
2.329	Which crops did you grow in fields located in a different altitude belt?		

2.330	On which plots do you always apply manure?	1. All plots 2. Plots with cash crops 3. Plots with food crops 4. Vegetable/Kitchen gardens 5. Other (specify)	
2.331	On which plots do you always apply fertilizer?	1. All plots 2. Plots with cash crops 3. Plots with food crops 4. Vegetable/Kitchen gardens 5. Other (specify)	
2.332	On which plots do you always apply mulch?	1. All plots 2. Plots with cash crops 3. Plots with food crops 4. Vegetable/Kitchen gardens 5. Other (specify)	
2.333	Is it always the same plot for the same crop or you keep rotating different crops in different plots?	1. Same plot for same crop 2. Keep rotating	
2.334	Did you hire out/ sell your labor for any farm work in the last 2 seasons?	1. Yes 2. No	
2.335	If yes, how much did you earn from selling your labor last season (Ushs)?		

3: HOUSEHOLD ASSETS AND INCOME AT PRESENT DATE

3.1	How many of the following livestock does your household currently own?	1. Oxen	
		2. Bulls	
		3. Cows	
		4. Heifers	
		5. Calves	
		6. Donkey (Both males and females)	
		7. Goats (Both males and females)	
		8. Sheep (Both males and females)	
		9. Pigs (Both males and females)	
		10. Chicken (Both males and females)	
		11. Other (specify)	
3.2	Do you earn any income outside farm work?	1. Yes 2. No	
3.3	If yes, which activities do you earn from outside farm work?	1. Produce trading 2. Wage labor 3. Retail shop 4. Other (specify)	Activity 1: Activity 2: Activity 3:
3.4	How much did you earn from activity 1 last year?	Activity 1_Amount	
3.5	How much did you earn from activity 2 last year?	Activity 2_Amount	
3.6	How much did you earn from activity 3 last year?	Activity 3_Amount	

Thank you very much for participating in this interview.
Would you like to ask any questions or any comments? If yes, (write down)
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……………………………………………………………………………………………………

Thank you.

I declare: this dissertation submitted is a work of my own, written without any illegitimate help by any third party and only with materials indicated in the dissertation. I have indicated in the text where I have used texts from already published sources, either word for word or in substance, and where I have made statements based on oral information given to me. At any time during the investigations carried out by me and described in the dissertation, I followed the principles of good scientific practice as defined in the "Statutes of the Justus Liebig University Giessen for the Safeguarding of Good Scientific Practice".