OPTIMAL RESOURCE ALLOCATION IN COWPEA PRODUCTION SYSTEMS IN EASTERN UGANDA

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Declaration

I Nakakawa Frances, hereby declare to the best of my knowledge and understanding that the originality of the findings in this thesis is my work, and has never been presented in Makerere University or any other university for the award of a degree. This thesis has been submitted with permission from University supervisors

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Dedication

I dedicate this thesis to Patrick.

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Abstract

This study focused on examining the allocation of farm resources by farmers engaged in cowpea production and developing optimal farm plans for cowpea production systems in Eastern Uganda. Earlier studies revealed that cowpea yields are below potential due to factors such as pests and diseases, low soil fertility and low plant populations. To manage these problems, Integrated Pest Management (IPM) technologies, were developed and demonstrated on-farm to the farmers. It was further indicated that the IPM technologies were more profitable than farmers' traditional methods. Since a farmer's major objective is to maximise output, resource poor farmers produce competing crop enterprises constrained by land, labour, capital, technology and diseases among others for income and their daily food requirements. In this study, effort was made to find out if cowpea farmers in Eastern Uganda were optimally allocating their resources in the production of the five major crop enterprises including cowpeas. Using face-to-face interviews, data were collected using a structured pre-tested questionnaire and analysed using descriptive statistics, enterprise budgeting and linear programming.

The optimisation results clearly show that farmers were not allocating their resources optimally and thus were not maximising returns from crop production. It was shown that a farmer could improve annual gross margins when the existing crop enterprise mixes are re-planned to a tune of 171.20% (IPM farmer) or 286.07% (non-IPM farmer). This implies that farmers in Eastern Uganda were operating way below their optimal values. Results further show that reductions in cowpea prices and increases in capital reduced the overall gross margins by percentages of less than 13%, implying that an optimising farmer is safe to operate under these challenges. It was, therefore, recommended that farmers in

the area take up the resource use plans to optimally allocate their resources and improve their bargaining power for better prices and/or participate in markets with higher prices in order to improve their returns.

CHAPTER ONE

INTRODUCTION

1.1 Importance of legumes

Legumes are an essential component of all agricultural systems due to their wealth in quality proteins to feed humans and animals as well as their contribution to soil fertility. Legume seed is second only to cereals as a source of human and animal food (Kaur *et al.*, 2004). Nutritionally, grain legumes are 2-3 times richer in protein than cereal grains (Bahl *et al.*, 1980) with many having protein contents between 20-40% (Onwukaio and Okala, 2003). An increase in grain legume supply in malnourished areas represents a less difficult, less expensive and more energy efficient prospect thus boosting the supply of animal protein. The main plant protein sources are grain legumes which include cowpea, beans, groundnuts, soybean and pigeon peas (Emaju, 2000).

Cowpea (*Vigna ungiculata* L. Walp) is a grain legume of considerable importance in arid and semi-arid tropics. It is an integral part of traditional cropping systems throughout Africa (Jackai and Adalla, 1997) and commonly grown in savannah regions of the tropics and sub tropics (Obuo *et al.*, 1997). The crop is one of the common protein providing food crops in Uganda grown in nearly all parts of the country especially the Eastern and Northern regions (Sabiti *et al.*, 1994). Recently, there has also been increased cultivation of the crop during the longer rainy season (March to June), largely in response to the high market demand for the crop (Kongai, 2005).

The largest quantity of the Cowpeas produced in Uganda are utilised domestically as food, seed and in manufacturing processes (Table 1.1). Cowpea production in Uganda has been fluctuating in the last few years. From 1995, it increased for the next two years, fell in 1998 and rose for the next two years and that has been the trend.

Table 1.1: Domestic supply and utilization of cowpeas in Uganda, 1994-2004 ('00tonnes)

Variable	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Production	170	200	190	190	200	150	160	140	150	150
Import	64	66	14	43	17	26	53	116	142	24
Export	159	64	6	76	47	18	22	0	93	5
Feed and seed	12	12	11	12	10	11	11	10	10	10
Other net uses	23	27	20	23	22	12	21	26	32	13

Source: www.faostat.org

Like in many developing countries, cowpeas are grown in Uganda primarily for domestic consumption with limited quantities left for export. It is important to note that average quantities exported over the years have been decreasing as those imported increase. The observed trends could probably be attributed to factors like dry spells, declining soil fertility, pests and diseases of the crop, among others.

1.2 Importance and production of cowpeas

Cowpea grain contains about 23.4% protein, 1.3% fat, 3.9% fibre, 56.8% carbohydrate and 3.6% ash (Purseglove, 1974). Both grain and leaves are consumed making it important where many people cannot afford foods such as meat and fish. Many cultivars are early maturing, an attribute that is very important for the drought prone areas. After the cowpea pods have been harvested, the rest of the plant can be used as animal feed.

The value of cowpea depends on many factors. It lies in its high vegetable protein content, ability to tolerate drought (Dadson, *et al.*, 2005) and to fix atmospheric nitrogen in the soil (Bationo *et al.*, 2000) efficiently to a tune of 30-70kg ha^{-1} (Sabiti, 1994). Thus, it is becoming an integral part of the crop rotation programme for subsistence communities where use of fertilizer is hardly practiced. It also establishes rapidly thereby reducing soil erosion and soil temperature, and also lowers weed pressure (Zuofa *et al.*, 1992) which allows it to grow on and improve poor soils. Further more, cowpea is shade-tolerant and, therefore compatible as an intercrop with many cereals and root crops.

In many parts of the world, the leaves and grains are sold for cash and stalks fed to livestock (Singh and Jackai, 1985). The crop is increasingly becoming a source of income especially in rural areas of Uganda (Sabiti, 1994; Kongai, 2005). Although farmers in Eastern Uganda grow the crop on large scale with an aim of selling it for cash income (Emaju *et al.*, 2002), the proportion of cowpeas marketed is often through unofficial channels (Kongai, 2005). In Eastern and Northern parts of the country, the crop is of critical importance as its leaves provide vegetable sauce to off-set early season famine.

Despite the importances, in Uganda, average cowpea yields are low ranging between 100-700 Kg ha^{-1} (Adipala *et al.*, 1999; FAO, 1998; FAOSTAT, 2006) compared to potential 2500 Kg ha^{-1} (Rusoke and Rubaihayo, 1994). This is due to predations of pests which contribute 24-69% yield loss (Karungi *et al.*, 2000) and diseases which contribute yield losses of up to 70% (Edema and Adipala, 1996). Low soil fertility, low plant populations

(Obuo *et al.*, 1997), and the occurrence of drought, particularly terminal droughts (IITA, 1993) also contribute towards losses.

To respond to cowpea production problems, Cowpea Improvement project at Makerere University and Integrated Pest Management Collaborative Research Support Program (IPM CRSP) developed Integrated Pest Management (IPM) technologies to increase its yield benefits. These technologies included the integrated use of appropriate spacing, early planting, plant density, minimum pesticide or seed dressing, planting time and use of improved varieties (Nampala, 1998; Karungi *et al.*, 1999). Most of the work by the IPM CRSP was carried out through trials, on-farm. In order to make the technologies known to the farmers, Farmer Field Schools with outreach activities to enhance adoption were established in Kumi and pallisa districts. Further more, a farmer led extension system was built in order to achieve the impact

Farmers in Eastern Uganda particularly Kumi and Pallisa districts are currently applying different levels of cowpea IPM technologies. Follow up studies done in Easten Uganda on the disseminated technologies have revealed that, besides reducing the incidence of pests and diseases, the technologies have lead to increased yields and profits. According to Karungi *et al.* (2000), the technologies are farmer friendly and cost effective. The technologies aimed at reducing the costs of using pesticides by using alternative but less costly cultural methods like early planting. A study by Ekiyar *et al.* (2003) on assessing the economics of cowpea and groundnut IPM technologies used by farmers in Eastern Uganda indicated that the IPM technologies were gave more profits than farmers'

traditional methods. It was observed that the overall mean yield from IPM technologies was 30% higher than that from traditional technologies. The study also indicated that increasing the use of labour and capital would increase the benefits of using IPM technology implying that labour, land and capital inputs were still limiting factors. The study further revealed that a cowpea farmer applying IPM technologies could realize marginal rates of return ranging between 173% and 700%. This is far above the accepted marginal rate of return of 100% (as a guiding benchmark given by CIMMYT, 1988).

1.3 Problem statement

Despite IPM technologies being profitable, they do involve a higher cost of production incurred by the farmer. This partly explains why some farmers, despite their knowledge about the benefits of using IPM technologies, were not enthusiastic to give up the traditional technologies (Mugisha *et al.*, 2006). Besides, the most important crop in the study area is not only cowpeas but also groundnuts, maize, cassava, finger millet, sorghum, rice and sweet potatoes (Mugisha, 2002). Since a farmer's major objective is to maximise output, resource poor farmers produce these competing crop enterprises with limited land, labour, and capital among others for income and daily food requirements (Low, 1997).

Owing to the limited resources available at farm level, producers are faced with the task of allocating their resources among the different crop enterprises using different production technologies in order to maximise farm incomes while at the same time satisfying their household food needs.

Resource allocation is influenced by resource scarcity as well as risk factors such as increases in input costs, fluctuations in output prices and reduction in yields. In such a situation, it is not known whether allocating more farm resources (and to what level) to the production of cowpeas using the recommended or most profitable IPM technologies is rational enough to compensate for the reduced production levels of the other competing crop enterprises. Likewise, if a farmer decided to continue using traditional methods of production, there are no farm plans (layout showing how much of each farm resource at the farmer's disposal should be allocated to which enterprise) available to guide farmers on how the farm resources could be optimally combined.

Studies by Karungi *et al.* (1999) have emphasized development and demonstration of IPM technologies for cowpeas on farm. Subsequent studies such as by Ekiyar *et al.* (2003) emphasised the profitability of these technologies. However, resource base and resource use in the production of these crops has received little attention yet these affect the benefits of these technologies to a great extent. This study, therefore, aimed at filling this information gap and making optimal farm plans for cowpea farmers who use different production technologies.

1.4 Objectives of the study

This study focused on examining the allocation of farm resources by farmers engaged in cowpea production, and developing optimal farm plans for cowpea production systems in Eastern Uganda. The specific objectives were;

1. To compare production costs and returns from cowpea with competing crop

enterprises such as maize, sorghum, and groundnuts.

2. To determine the levels at which cowpea farmers can combine available farm resources to maximise farm gross margins.
3. To determine the extent to which changes in capital costs and output prices, are likely to impact on the derived optimum resource allocation plans. That is, to carry out a sensitivity analysis to test the robustness of the LP model.

1.5 Hypotheses

The study was guided by the following hypotheses;

1. Cowpeas generate significantly greater returns to farmers than other crop enterprises in the study area.
2. Reallocation of farm resources within farmers' enterprise mix gives significantly higher farm gross margins than in the current situation.
3. Emerging economic challenges such as changes in input costs and output prices do not significantly affect gross margins of a resource-optimising farmer.

1.6 Significance of the study

The government's strategy is to ensure that enterprise selection is guided by sound economic analysis. This study is therefore, beneficial to various stakeholders including scientists, farmers, extension workers and policy makers. The results give a clear understanding of farmers' resource base and how the scarce resources can be put into better economic use. Farmers will benefit from improved returns by adopting the

recommended resource use farm plans. It will also contribute towards the existing research for scientists to refer to. NAADS, through enterprise development and promotions programme, supports farmers to produce enterprises that are profitable, meet market demand and to be able to exploit available or potential market opportunities. If used by the advisory service providers, they will be in a better position to advice farmers as regards optimal use of resources available to them. This study will be helpful to the policy makers especially at sub-county level in the area while formulating objectives and activities to improve farmers' incomes. It will guide them on which enterprises to support while giving priorities to the more profitable ones.

1.7 Scope of study

The study was based on survey data collected from the districts of Kumi and Pallisa in Eastern Uganda. It was carried out during the period of 2004-2006 for the two production seasons in 2005. Relevant secondary data was collected from the respective district agricultural officials. The thesis is organised into five chapters. Chapter one, covers the introduction, chapter two contains literature relating to the subject matter and chapter three covers methodology used to achieve the objectives of the study. Chapter four highlights the results and their discussions. Lastly, chapter five documents the conclusions derived from the study and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Optimisation in agricultural production

In economic sense, production is defined as the process in which inputs or resources are transformed into goods and services usually referred to as outputs. Agricultural production involves inputs of natural resources, labour and capital being converted into food and other commodities. Decision makers in farm households are presumed to be concerned with maximization of some measure of an achievement such as profit or utility. Farmers usually aim at achieving maximum returns in terms of yield and profits. It seems reasonable to assume that a farmer has some idea of the amount of average output to expect from a given production process. Of course he or she cannot predict the output he is to obtain with certainty but knows what to expect on average from a given combination of inputs and bases his decisions on this knowledge. However, the farm production process is constrained by the limited resource. As such, they are faced with the task of allocating the available resources or combining the enterprises in a manner that will lead them to their goals. This calls for optimisation. The theory of production economics is concerned with optimization of the objectives or goals and optimization implies efficiency (Baumol, 1977).

Optimisation therefore, involves the choice of variables that will give the extreme in the economic sense. According to Castle *et al.* (1987) and Derbertin (1989), an input limited in supply should be allocated among all of its alternative uses such that the marginal value

products for the last units allocated to each use are equal in all alternative uses.

Farm resource allocation is influenced by many factors which include technology support and input availability (Simon, 1998). It was further asserted that crop enterprises with available, traditionally understandable technology and easily accessible inputs are easily adopted even without profit consideration.

2.2 Measurement of optimal resource allocation

Optimal resource combination is defined as one which given the physical, technical and resource conditions, shows the activities to be undertaken (Nagaraja *et al.*, 2002). The authors further stated that optimal resource combinations show the extent to which each resource is used in each activity so that net farm returns are maximised or production costs are minimised. Firms are considered to take a given technology, output and input prices as given and decide the resource amounts that maximise profits.

There are different methodologies used in determining optimum resource levels which include econometric and mathematical ones. The econometric methodologies involve the use of marginal analysis. For instance, Abdulai and Huffman (1998) used a stochastic translog frontier while examining profit efficiency of rice farmers in Northern Ghana. The researchers found out that farmers were inefficiently allocating their inputs at an average level of 24.7%. Mathematic ones include the linear and non-linear programming methodologies. Linear programming has an assumption that all the functions are linear while the same assumption is not applied for non linear programming. In a study to determine optimal application for controlling boll weevil on cotton, Talpaz *et al.* (1978)

used the non-linear dynamic optimisation model and the optimal policy for a single producer recommended three chemical applications. One of the greatest challenges in non-linear programming is that some problems exhibit "local optimal" that is, spurious solutions that merely satisfy requirements on the derivatives of the functions. As such, the intended optimal solution is not reached. In some studies, a combination of econometric and Linear Programming analyses has been used with the former providing coefficients that are fed into the Linear Programming model (G-egziabher, 1995). For instance, enterprise budgeting can be used to provide coefficients for the LP model (Castle *et al.*, 1987). However, enterprise budgeting possesses a weakness of arbitrariness in choosing the quantities produced hence, there is a need for careful selection of the parameters. According to Derbetin, (1989), irrespective of the analytical technique used, optimal production is said to be attained when the marginal value product equals marginal factor cost for each input used under conditions of perfect competition in output and factor markets.

In a study on Agriculture, poverty and freedom in developing countries, Clayton (1989) reported that much as marginal analysis studies of a farmer's rationality have significantly affected academic thought and influenced American aid strategy, these studies have little practical impact on agricultural development policies. In an earlier study by Upton (1979) it was suggested that when the task involves considering many enterprises and resources to choose from, the use of linear programming is the best systematic mathematical procedure for determining the optimal use of limited resources. Linear programming deals with optimisation (Kaplan, 1982), which involves making plans or decisions such

that the best outcome is obtained. It involves maximisation and minimisation of linear functions subject to linear constraints (Derbertin, 1989).

2.3 Application of Linear programming in agriculture.

Linear programming (LP) is a problem-solving approach that has been developed for situations involving maximising or minimising a linear function subject to linear constraints that limit the degree to which the objective can be pursued (Anderson *et al.*, 1994). In its simplest form, LP is a method of determining a profit maximising combination of farm enterprises that is feasible with respect to a set of fixed farm constraints (Hazell and Norton, 1986).

Linear Programming enables the farm to produce a number of products, which jointly use the production facilities. Unlike any other method linear programming can deal with hundreds of decision variables and within this huge space identify and set the values of the variables that are critical in the problem. The method is also appropriate when determining input combinations that are limited and is used to design models based on resource availability and use (Harsh *et al.*, 1981).

The tool has been widely used in determining efficiency in resource allocation among alternative enterprises and testing farmer recommended packages (Ngambeki *et al.*, 1992; Ithinji *et al.*, 2000). According to Scott and Gregory (1995), linear programming can help governments to find the optimum settlement size for a family. It can be used to indicate

effects of changes in prices, costs, labour supply of technical improvement and hence averting risks.

According to The linear programming model involves the following assumptions (Chinneck, 2001). There exists a linear relationship among the different variables. This implies proportionality between inputs and products and that the prices of inputs and coefficients are given, constant and known with certainty, hence the single value expectations assumption. That is, gross margin and resource requirement per unit of activity are assumed to be constant regardless of the level of the activity.

Continuity assumption requires that the variables are real-valued, meaning that they can take on fractional values. In other words, resources can be used and activities produced in quantities that are fractional units. Additivity assumption prohibits cross-product terms which might represent interaction effects between activities. Activities are additive in the sense that when two or more are used, their total product is the sum of their individual products. Finally, LP has a non-negativity condition which assumes that the solution should not require negative quantities. A given period is assumed for programming and it is a short time for convenience and accuracy of results.

The non-parametric nature of linear programming is a problem makes it impossible for one to carry out t-test or z-test. Besides, the assumptions of the optimisation are assumed to be very restrictive (Upton, 1979). For instance, it assumes that the objective function and constraint inequalities are linear in nature. The assumption that however many units

of an activity are included in the plan, unit costs and returns are constant is some times inappropriate. Like in any other mathematical programming, is the assumption that the input data are perfectly accurate (Johnson, 1990). One assumes that the objective function coefficient, right hand sides of the constraint are all correct. In the real world, these values are seldom known with accuracy. Given the simple nature of this study, it was believed that the results would not be significantly compromised despite the above weaknesses of linear programming.

2.4 Agricultural empirical studies done using linear programming

Economists have found linear programming worthwhile in solving optimisation problems including military, industrial and agricultural fields (Derbatin, 1989). In farm management, it has been used in; planning production functions which maximise profits (Kasenge *et al.*, 2001), minimise production costs (Gowa, 2000), finding the least cost feed mixes that meet stated nutritional standards (Busingye, 2004) and planning the best mix of finance-equity and loan preference (Jagwe, 1999). Parks and Hansen (1978) used LP to analyse water utilisation and reallocation and their results suggested that optimum allocation would result in progressive income redistribution among farmers although aggregate income gains among farmers would not exceed 5%. Magino (2005) used linear programming in his study of evaluating the profitability of sorghum-legume intercropping systems in Eastern Uganda and reported that a farmer would increase his returns by over 200% if he followed the recommended resource use plan which recommended increase in all resources from the current levels.

In another study by Afzal *et al.* (1992) of optimising the alternative use of different quality waters in Pakistan, linear programming model was used and different quality waters by alternative irrigation rather than blending were recommended to farmers. The model recommended size of land to put under each crop and how much ground water to abstract and apply to each crop in each time period. Busingye (2004) used the same model to determine the optimal use of feed resources for zero grazing dairy enterprises in Wakiso district. The researcher recommended that cost effective feeding could be achieved through increased and more efficient use of locally available crop residues that gave a diet which is sufficient and adequate in nutrition.

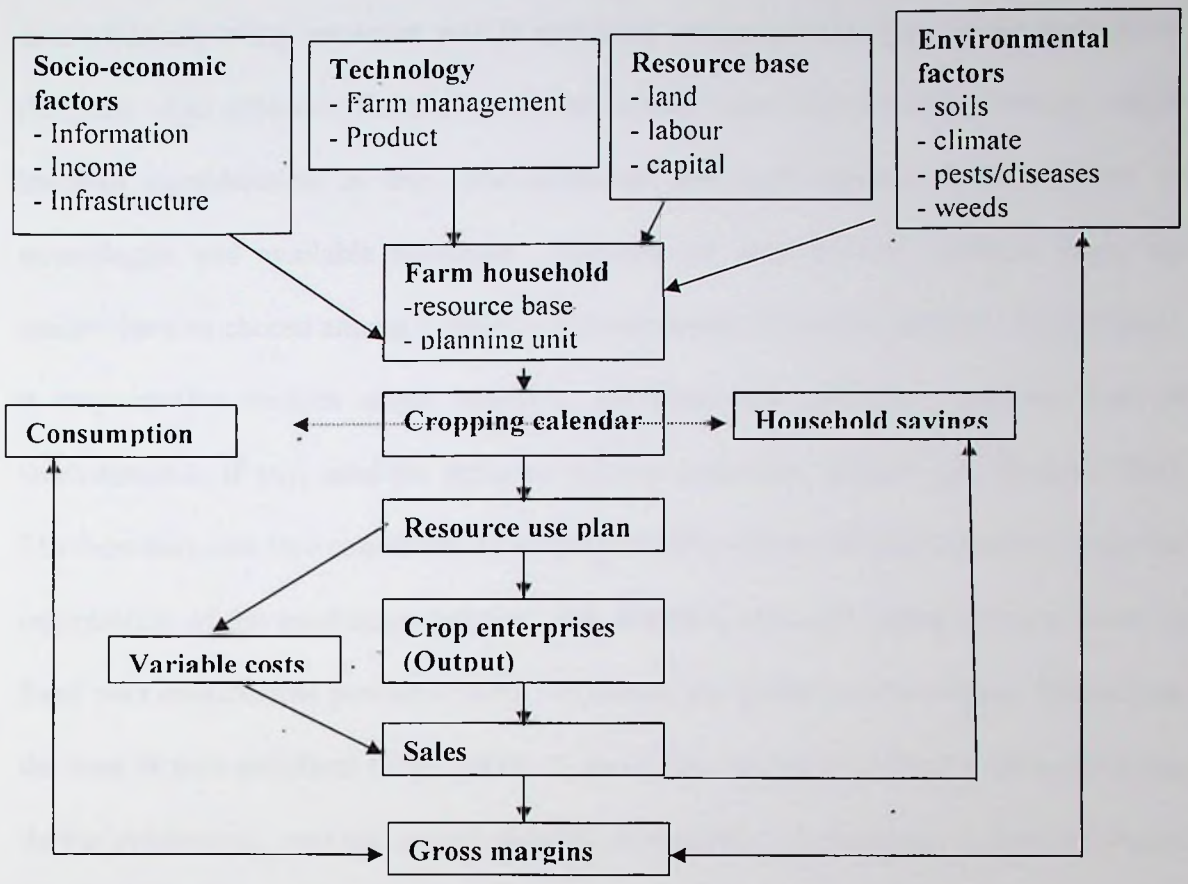
Nagaraja *et al.* (2002) used the linear programming model to study optimal dairy farming system for stable income of small farms in India. The dairy farming system comprised of crop+dairy+forestry+sericulture followed by crop+dairy+sericulture. The researchers concluded that appropriate combination of enterprises with dairy not only increased net farm incomes by over 100% but also utilised available resources efficiently. They further reported that the farming system approach provides an opportunity for effective recycling of the products and by-products of any of the components as inputs in the other components linked in the system. A study by Pali (2003) which aimed at evaluating resource use efficiency and profitability of soil fertility management technologies used the same model. It was reported that an optimising farmer would get over Ush. 400,000 from incorporations of 100% *Mucuna pruriens* and 0.9tha^{-1} T*ithonia diversifolia* with inorganic nitrogen application at the rate of 30kg ha^{-1}.

Some researchers assert that improvement of agricultural production can only be realised by adopting modern technologies. For instance, Sahota (1968) and Ngambeki *et al.* (1992) argue that agricultural development can only be achieved by breaking through the traditional farming methods and introducing modern technology. However, Heady (1964) found out that reallocating the existing resources with no technology improvement could increase farm production. Ali and Flinn (1989) also indicated that better use of existing technology resulted into significant improvement in returns. Similarly, Bagamba (1994) observed that re-planning the existing farm enterprises in the banana based cropping systems in Central Uganda would increase return to land and management resources by 40.2% and 46.1% respectively, without change in technology. The same researcher also argued that returns to these resources would be much higher with greater impact on farmers' gross margin if improved crop technology were used. This implies that reorganizing the existing farm enterprises and at the same time employing improved farm technologies gives higher farm returns than adopting one of them.

2.4 Conceptual framework for optimal resource use in cowpea growing systems

Households are taken as unified units of production (Mudhara *et al.*, 2002) and therefore, considered the planning and resource base units (fig. 2.1). In small-scale agriculture, the farming system is embedded in the household economy, which integrates both production and consumption, and it shaped by the multiple goals that are operative in the system (Norman *et. al*, 1982).

Figure 2. 1 Frame work for decision making on resource allocation



Source: Ellis, 2000

The process of decision making begins with the farmer (farm household) as an individual decision maker. He or she is concerned with questions such as how much labour to devote to the cultivation of each crop; whether or not to purchase inputs and which quantities and how much land to allocate to each crop. It thus centres on the idea that farmers can vary the levels and kinds of farm inputs and outputs. In practice, farm families have many different goals; long term income stability, family food security, achievement of certain consumption preferences, fulfilment of community obligations, provision for the future and welfare of the dependants (Upton, 1979; Castle *et al.*, 1987).

For this study, it was assumed that the main objective pursued by the farmer in the study area while allocating resources was to maximise returns for the farm family throughout the year. The objective function to be maximised takes into account planning which involves consideration of the socio-economic and environmental factors, levels of technologies and available resources. Farmers not only produce different crops but usually have to choose among a variety of technologies of producing them. For instance, it may involve choices about varieties, fertilizers and pesticides, and the type of mechanisation, if any, used for different cultural operations (Hazell and Norton, 1986). The farm may also face constraints of varying severity which limit the capacity to vary the organisation of the production process. For instance, land size which in many cases is fixed over considerable periods of time. However, for farmers in the tropics, this may be the least of their problems (Ellis, 2000). Labour may not be available for seasonal peaks during production; working capital may be unavailable or expensive; purchased inputs may be variable in availability, quality and price.

Because of seasonality of most of the farming activities, supplies of resources may be much more critical at some times of the year than at others. As such, with the cropping calendar of the area and level of savings from the previous seasons in mind, a resource use plan for the different crop enterprises is formulated. Depending on the levels of input use, technology and productivity, sales and variable costs can be calculated while assuming constant favourable environmental and socio-economic factors.

The process starts again with gross margin affecting the level of savings and resource base. High gross margins will increase savings which will in turn improve households' acquisition of resources and therefore broaden resource base. Therefore, in order to maximize gross margins, it is vital to formulate efficient resource use plans.

With respect to this myriad of possible goals and constraint, the basic theory of farm production involves some important simplifications (Ellis, 2000). For this study, the consumption side of the farm household was ignored, only a single goal of profit maximisation was explored and only a single decision maker, the farmer was permitted. Distribution of decision making roles and opinions amongst members of the farm household was certainly not allowed in this study. Lastly, non-farm activities of the household members were ignored.

CHAPTER THREE

METHODOLOGY

3.1 The study area

The study was carried out in Pallisa and Kumi districts. This is where IPM CRSP established the demonstration sites to carry out on-farm trials and thus chances of getting a sound number of farmers applying IPM or traditional technologies were expected to be high. Agriculture is the major economic activity in the study districts. The main food crops grown are cowpeas, finger millet, groundnuts, sweet potatoes, cassava, sorghum, rice, maize, soybean, bananas and sunflower. Coffee and cotton are the major cash crops. Cattle, goats and sheep are the animals kept in the districts, though the cattle population in Kumi was greatly reduced as a result of the insurgency and cattle rustling (Mugisha, 2002).

Kumi district covers a total area of 2,820.68 sq.km, of which only 14.4% is covered by open water bodies and swamps or wetlands. Pallisa is mainly a plateau, traversed by numerous swamps and springs and covers 1956 sq. km with only 20% covered with water. Kumi has a total population of 389,665 persons and Pallisa district has a population of 522,248 persons. Since over 85% of the population in the study area is engaged in agriculture, this gives a clear picture of the agriculture labour structure.

3.2 Sampling and sample size

Both purposive and random sampling procedures were used to select study sites as well as respondents. Three sub-counties with IPM CRSP demonstration sites were purposively selected from each of the two districts to get a representative sample of farmers practicing either IPM technologies or traditional ones. These included Iki-Iki, Pallisa and Apopobong in Pallisa district, and Kumi, Bukedea and Malera in Kumi district. With the help of extension workers, lists of cowpea farmers in the selected sub-counties were formulated. In each of the sub-counties, two cowpea-farmer categories (those using IPM technologies and those using traditional production methods) were purposively generated from the list.

The IPM practices under consideration included early planting, correct spacing and three rationalised chemical sprays. The criteria used for categorising the farmers followed that used by Ekiyar *et al.* (2003). If a farmer employed at least two of the three technologies, he or she was selected as an IPM user who is referred to in this study as IPM farmer. The traditional technology user is referred to as a non-IPM farmer in the study. From each sub-county, 40 farmers (20 IPM and 20 non-IPM farmers) were select, making a total sample of 240 (120 IPM and 120 non-IPM) farmers for this study.

3.3 Data sources and data collection procedures

Data used in this study was from both primary and secondary sources. Primary data were collected through face-to-face interviews with the farmers using a structured and pre-tested questionnaire (appendix 1) from the respondents during the survey conducted for the period of December, 2004- January, 2006 (for the first and second season of 2005). Questionnaire pre-testing was done using 12 farmers (including users and non-users of the IPM technologies) in Pallisa district. In February 2005, prior to data collection, farmers were trained on how to keep records of their production practices to supplement on the information got from the questionnaire. Information recorded by cowpea farmers included the cultural practices, resource availability, as well as their utilisation.

The primary data collected using questionnaire included;

- Quantity of inputs farmers allocate to different crop enterprises. The inputs include land, labour (family and hired), seed, manure, fertilizers and agricultural chemicals
- Costs of the inputs and farm operations.
- Amount of output got from enterprise mix and the amount sold.
- Amount of farm commodities consumed by the farm household.
- Prices of the different crop products.

Secondary data on cropping calendar and crop production in the study area were collected from the respective district agricultural officials and farmers.

To determine the major crops in the study area, farmers where asked to report their important crops grown in the year in terms of food security and income generation and rank them. From the list given and basing on the crops grown as reported from the interviews for the two seasons under consideration, the major five crops in the area for the two farmer categories were generated. The quantities were standardised to kilograms. For those which are not commonly weighed like cassava (both harvest and planting material), farmers were asked to give quantities in sacks and with the help of measurements from extension workers, these quantities were standardised to kilograms.

3.4 Analytical methods

The analytical tools used included Descriptive Statistics, Enterprise Budgeting and Linear Programming. Production costs and returns from cowpea with competing crop enterprises (objective 1) were obtained by use of enterprise budgeting methods. According to Castle *et al.* (1987), construction of enterprise budget is one method by which producers compare directly the revenues and costs of alternative enterprises. Enterprise budgets consist of statements of expected revenues and expenses from a crop enterprise mix. Returns were expressed in terms of gross margins.

There are a number of measures of profitability which include net farm income, rate of return on farm assets and gross margin analyses. Net farm income is the difference between the total revenue and total costs (Tweeten, 1979). The major setback of using net farm income analysis is the fact that the costs of owner's labour and management are imputed, leaving non-human capital as a residual claimant on net farm income.

Rate of return on the other hand, is the net return divided by an estimate of the value of equity invests assets minus debts (Bruce and Bruce, 1983). This method involves use of records kept on the farm. However, farmers have little or no habit of keeping records which makes it hard to compute equity investment and debts. Another problem associated with using return to is, annual rates of return on assets, even if poorly measured, have a quite limited economic meaning. Also, in an inflationary environment, measurement procedures result in a substantial understatement of net income because the inflation premium in interest costs is charged against current income flows. This leaves gross margin as a better proxy for profit.

Gross margin is an appropriate measure to use for comparing enterprises that produce similar demands upon limiting resources of a farmer, for short run and annual planning decisions (Castle *et al.,* 1987). According to Johnson (1990), gross margin is the difference between value of production and the marginal cost of that production. The basis of gross margin analysis is that the farm is seen as a group of independent, productive enterprises, centered on the same farm unit, which provides common services and the necessary coordination. It follows from the nature of variable costs, that there should be a constant relationship within a given enterprise, between revenue, variable costs and gross margin, whatever the size of that enterprise, provided technical efficiency, costs and price remain constant. This helps when gross margin analysis is used, for planning. It forms the basis for most analysis and planning procedures and enables a practicing farmer to understand his business better.

Gross margin is useful especially when the productive cycle is a year or less. Gross margins are useful for; comparing relative costs and returns for similar farm activities, comparing performance of activities in hindsight, or to predict the performance of potential alternative activities and helping to plan your farm enterprise mix.

Limitation of using gross margin is that single season analysis does not consider future benefits and interactions; they do not easily take into account dual enterprise benefits. Like all budgeting techniques, gross margins are based on assumptions that may or may not actually turn out that way. If you account for every possible potential cost item (even if it has a low probability of actually happening) then you will end up with a very low gross margins result.

Gross margin analysis is a simple but a realistic measure of enterprise performance and economic comparison of different enterprises operated by a producer and was computed as:

$$G_j^s = Q_j^s P_j^s - \sum_{x=1}^{n} V_x^s P_x^s \quad \text{.....(1)}$$

Where;

G_j^s = gross margin per ha of the jth activity (for crop enterprise) in s^{th} season.

Q_j^s = production (per ha) for a given crop enterprise in s^{th} season.

P_j^s = unit price of crop product for a given crop enterprise in season s

V_x^s = quantity of variable inputs (per ha) used in a given crop enterprise in season s

P_x^s = unit cost of variable inputs for a given crop enterprise in season s

j = indexes for crop enterprises (cowpeas, groundnuts, maize, sorghum, and cassava)

x = indices for variable inputs such as labour and pesticides.

Equation 1 shows the difference between the value of total output and the total variable production costs for a given crop enterprise in a particular season. In this case, first and second rainy seasons of 2005 were considered.

The costs and gross margin were then compared across competing crop enterprises using the one-way analysis of variance (ANOVA) method. The null hypothesis was that the cost means and mean gross margin are equal across crop enterprises and the alternative stated otherwise:

$H_o: \mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5$

H_a = *Otherwise*

After checking for the assumptions of constant variance and normal distribution of the means across the five enterprises, within sample variance which measures variable observations within each sample for the 5 enterprises were estimated. A post-hoc test was then carried out to determine where the differences were and if significant. The *Bonferroni* method was used for this purpose.

To determine the levels at which cowpea farmers can combine available farm resources to maximise farm gross margins (objective 2), a Linear Programming (LP) model was used. The LP model was chosen for this study because of its simplicity in terms of computations

compared to other tools when farmers have a wide range of production alternatives to select from but facing a resource constraint. Besides, it has less data requirements compared to other mathematical programming techniques. Several studies have used this model including Bagamba (1994) and Kasenge *et al.* (2001). The economic problem under deterministic conditions for a single cowpea farmer was assumed to be maximisation of returns from the fields.

The conceptual model as used by Kasenge *et al.* (2001) was as follows;

$$\text{Max } Z = \sum_{i=1}^{n} c_i X_i$$

Subject to

$$\sum_{i=1}^{m} a_{ij} X_i = b_i, \qquad \text{all } i \text{ to m}$$

And $$X_i \geq 0, \qquad \text{all } j \text{ to n}$$

Where;

Z = Total gross margin

X_j = Quantity of jth crop product. Let n denote the number of possible crop enterprises such that, j = 1 to n.

c_j = the forecast gross margin of a unit of the jth crop enterprise (such as shillings per hectare)

a_{ij} = The quantity of the ith farm resource (such as hectare of land) required to produce one unit of the jth crop activity. Let m denote the number of resources such that, i = 1

to m.

b_i = the quantity of the ith resource available.

The model was used to determine the optimum level at which cowpea farmers should allocate their scarce resources (land, labour and capital) to different crop enterprises in order to maximise whole-farm gross margin. The model considered the different production seasons given the fact that some crops may require longer growing seasons than others, a phenomenon that has an implication on farmers' inputs and returns. For instance, some crops take more than one season in the field and thus limit the size of land to be allocated to the other crops in the next season. Besides, some labour may be required to be allocated for the crop as well. The general formulation of the model (Hazell and Norton, 1986) was as follows:

$$Max \sum_{s=1}^{m} \sum_{j=1}^{n} Q_j^s P_j^s - \sum_{x=1}^{n} V_x^s P_x^s$$

.....(2)

Subject to

$$\sum_{j=1}^{n} \alpha_{ij} X_j^s \leq L^s$$

.....(3)

$$\sum_{j=1}^{n} \delta_{ij} X_j^s \leq H_i^s + F_i^s$$

.....(4)

$$\sum_{j=1}^{n} \phi_{ij} X_j^s \leq K^s$$

.....(5)

$X_j^s \geq 0$ .....(6)

Where;

P_j^s = unit price of crop products in season s

X_j^s = alternative activities (crop enterprises) in season s

L^s = land area (ha) available to the farmer in season s

V_j^s = quantity of variable input for crop j in season s

P_x^s = unit price of variable input x in season s

H_j^s = hired labour used in season s

F_i^s = family labour available for farm work in season s

K^s = capital available to the farmer in season s

α_{ij}, δ_{ij}, ϕ_{ij} are technical coefficients of land, labour, and capital for each activity X_j^s. α_{ij} is the average land usage per crop enterprise per hectare, δ_{ij} is the average labour (person day usage per crop per hectare) and ϕ_{ij} is the average value of capital inputs used by each crop per hectare. Equation 2 is the objective function which maximizes the gross margins from one hectare of each crop enterprise. It shows the difference between value of output from each enterprise and average variable costs across enterprises and seasons.

Inequality 3 is the land constraint that shows that total acreage allocated to the five crop enterprises should not exceed the average land available for farming. Since land available to the farmer is fixed for a given period, he or she cannot allocate land exceeding the size at his or her disposal (including the hired and borrowed) to the crops. It shows the limits on land levels that a farmer should employ in the cowpea growing systems. Respondents

were asked to record and report land available for farming and the size allocated to each crop enterprise in each of the seasons under consideration. The land sizes were later standardized into hectares.

Inequality 4 is the labour constraint that shows that family and hired labour used in the five enterprises should not exceed the sum of available family labour and hired labour accessible. Clayton (1989) depicted that human labour is the most common power for the performance of farm operations in tropical peasant agriculture but a highly constrained factor especially during the peak periods. The researcher further asserted that each selected crop has its own labour requirements which in aggregate, over a year, must relate to the labour available to the farm. With the available family labour, not all can be employed on the farm at the same time. For instance, school going children can only supply labour during off-school time. Besides, some household members may have non-farm activities or jobs to attend to during the farming period thereby making family labour limited. This calls for hiring regular or part time labour to supplement family labour. Due to the limited seasonal farm incomes, a farm household has a limit of income it can invest in hiring labourers in a season. Even if it had enough money, due to the fact that hired labour is a supplement, it still has a limit in order for its productivity to remain positive. Therefore, a farmer cannot employ more than the available labour or that required otherwise, the farm will experience diminishing returns to labour employed.

Labour input in farming is frequently calculated in terms of man-day equivalents, where different values are allocated to men, children, women and the aged. For example, taking

person days for men of 15-64 years equivalent to 1.0, Nomman (1967) counted children of 7-14 years equivalent to 0.5 person days, men and women over 65 years equivalent to 0.5 person days and adult women of 15-64 years equivalent to 0.75 person days. There are numerous methods of calculating man-equivalents but the problem is that all implicitly assume that performance rates are constant for all farm jobs. Basing on that, Swindell (1985) argued that women and children do some jobs such as grading produce and certain types of weeding better than men. The author further argued that if children contributed small amount of labour at critical points in the cultivation cycle, then the marginal productivity of their labour would be very high. If considering the above equivalents, their labour may be under valued.

Basing on the arguments above, for this study, labour was categorised into four: children, family female adults, family male adults and hired adults. The children's labour was equivalent to 0.5 person days while it was 1.0 person days for all adults bearing in mind that although children played an important role in labour contribution, they could not work as efficiently as the adults. To get the actual person days for each worker, the product of days worked and hours worked times the person day equivalent for the worker in consideration was calculated. This product was then divided by the average hours a cowpea farmer spends in the garden per day, which was reported as six hours to get amount of labour employed in person days.

Respondents were asked to report kinds of labour, number of workers, days and hours used by each person employed for each cropping activity in each season under

consideration for the study. The major cropping activities considered for this included land preparation, planting, weeding, chemical application and harvesting. They were further asked for days worked for each activity in each crop.

Inequality 5 represents the limits on the available capital that can be employed in the production process. The capital constraint requires that total of the average capital requirements of the five crop enterprises should be equal to or less than the capital available. Due to the fixed land size in a particular season and depending on the amount of money available, a farmer can only employ the capital at his disposal or less than that which is available. Capital inputs considered for this study included planting materials (kg ha^{-1}), agricultural chemicals (l ha^{-1}) and investment in oxen hire (Ush ha^{-1}). Equation 6 is the non-negativity constraint that shows that enterprise land, labour, capital, crop produce and price must all be greater than or equal to zero. It simply shows that negative production or resource use is impossible in the production process.

The model was run using General Algebraic Modelling System (GAMS) computer software. With the help of the cropping calendar, resource allocations to competing enterprises within a given period were determined. The ultimate product of the GAMS model was crop acreages that maximized gross margins given their standard hectare produce, crop resource coefficients and crop prices. Optimal farm plans for cowpeas farmers using traditional or IPM technologies were generated.

Farmers are price takers in both input and output markets. As such different levels of changes in output prices and capital cost were incorporated into the model to examine their effect on the optimal results (objective 3). Farm households in developing countries mostly operate under imperfect factor and /or product markets resulting from high transaction costs, shallow or thin markets for the factors or products or less accessibility to market information (Sadoulet and de Janvry, 1995). Under such circumstances, production and consumption decisions can not be easily distinguished (Taylor and Adelman, 2002). As such, when making resource allocation farm plans, it is imperative to test the stability of the gross margins under different situations in agricultural markets. Besides, with recommendations of use of IPM technologies by earlier researchers, if taken up, farmers will realize high yields and thus a production boom which will affect output prices negatively.

The analysis was based on the effects of possible changes in cowpea price and capital (due to increase in input price) on total farm gross margins realized by the farmers and the resulting gross margins re-estimated. Since inflation in Uganda has been oscillating between 5% and 10%, the changes were based on the same. Percentages of 5%, 10% and 15% were used for cowpea price reductions and capital increases, with 15% giving the extreme scenario. The optimal gross margins are said to be sensitive to a parameter if a small change in say, output price or capital input results in relatively large change in the gross margins. This may mean that the parameter has to be determined very accurately or that the alternative has to be redesigned for low sensitivity.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Resource endowment of cowpea farmers in Eastern Uganda, 2005

Land is one of the limiting factors of production in Uganda's agriculture due to the increasing population growth. On average, a cowpea farmer in Eastern Uganda who practiced IPM technologies owned 2.75ha and one who used the traditional technologies was endowed with 1.84ha (Table 4.1). Of the total owned, the land available for cultivation for an IPM farmer was 2.48ha and 1.57ha for a non-IPM farmer. Earlier studies by Adipala *et al.* (2003) indicated that on average, a farmer in Eastern Uganda owned 2.67ha and 1.82ha of this was cropped. According to Magino (2005), average land holding by farmers (irrespective of type of technology being applied) in Eastern Uganda was 2.5ha.

Table 4. 1: Land ownership and acquisition, 2005

Variable	IPM farmer	Non-IPM farmer
Average land owned (ha)	2.75	1.84
Average land available for cultivation (ha)	2.48	1.57
Major mode of acquisition (%)		
Inherited	51.33	57.02
Purchased	20.35	8.77
Hired	21.24	21.93
Given	7.08	12.28

Acquisition of land was mainly through inheritance, purchases, hiring or being given. With borrowing, a farmer is allowed to use another's piece of land for a specified period

of time for free. With increasing pressure on land in the country, borrowing has become a less popular practice among farmers. For hiring, the farmer uses another's land for a given period of time in exchange for cash or produce. The most popular mode of land acquisition in Eastern Uganda was reported as inheritance in both farmer categories.

Table 4.2 indicates the average number of farm implements in the farmer's possession at the time of the survey. The results showed that cowpea farmers in general had limited number of farm equipments. On average, each farmer had at least 4 hoes but none had more than 1 wheel burrow or plough in both farmer categories.

Table 4. 2 Tools and equipment in farmers' possession

IPM farmers				Non-IPM farmers			
	Min	Mean	Max		Min	Mean	Max
Hoes (n=120)	1	5	16	Hoes (n=120)	1	4	10
Slashers (n=69)	1	2	8	Slashers (n=40)	1	2	4
Panga(n=102)	1	2	8	Panga (n=90)	1	1	4
Spray pump(n=23)	1	1	3	Spray pump(n=10)	1	1	2
Wheel burrow(n=22)	1	1	2	Wheel burrow(n=14)	1	1	1
Basket (n=48)	1	4	8	Basket (n=35)	1	4	10
Gunny bags(n=46)	2	9	30	Gunny bags(n=43)	2	8	43
Oxen (n=52)	1	2	4	Oxen (n=30)	1	3	4
Plough (n=48)	1	1	4	Plough (n=29)	1	1	1

From this study, none of the respondents reported the use of a tractor (even those with relatively large size of land). In the late 1990s, it was estimated that 65% of the cultivated area in sub-Saharan Africa was prepared by hand, 25% by draught animals, and 10% by tractor (Bishop-Sambrook, 2004). It was further projected that, unless there is a change,

much of the region will continue to be tilled by hand or draught animals, although there will be some movement away from humans as the principal source of farm power.

Most of the land was prepared by animal draught power. This is in line with earlier studies by Sabiiti *et al.* (1994) which revealed that cowpea producing systems were characterized by use of rudimentary tools such as hand hoes with limited labour saving technologies such as ox-plough being limited to a few farmers. The few who owned them, hired them out during peak periods of labour requirement. This plays a major role in availability of labour to the farm households and implies that farmers in the study area are still labour constrained.

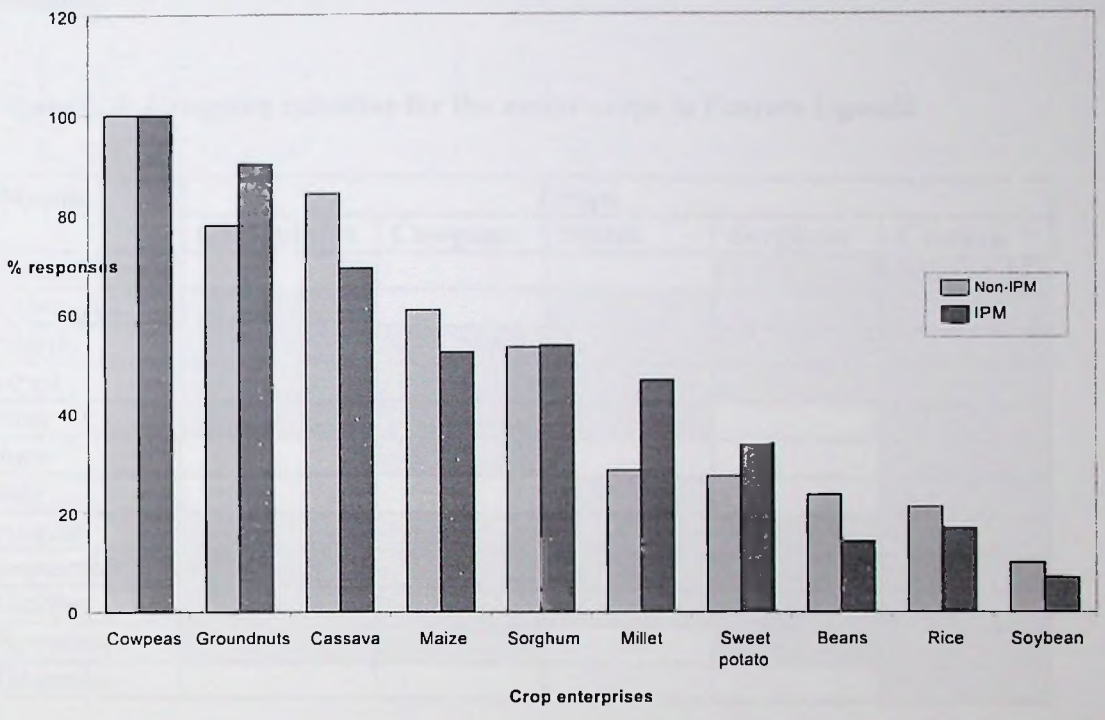
4.2 Crop production organization in Eastern Uganda

Crop production in the study area was highly diversified with over ten different crops which included cowpeas, groundnuts, maize, sorghum, cassava, millet, pigeon peas, rice, sweet potatoes and beans, soybean, sunflower, cowpea+sorghm, cassava+millet and sorghum+groundnuts (Fig 4.1). However, as reported by the majority of farmers, the major five crops in terms of food security and income generation in both categories included cowpeas, groundnuts, maize, sorghum as well as cassava and these were used in the study.

With the exception of cassava which is a perennial crop and thus occupied land almost through out the year, the other crops were grown twice a year during the two rainy seasons of February/march and August/September. Most cropping activities were seasonal and

were confined to periods of the year when temperature and rainfall are conducive to plant growth.

Figure 4. 1: Percentage response of major crops grown in Eastern Uganda, 2005



Studies have clearly demonstrated that seasonal distribution of rainfall has a dominant influence on tropical, small holder agriculture (Joy, 1971; Chang, 2002). Tropical rainfall regimes influence a farmer's choice of crops, planting strategy and the appropriate farm practices as weather conditions unfold (Collinson, 1979). Within cropping seasons, cultural operations are also performed in set sequences, and most of these are performed within a relatively short period of time. For instance, sowing is usually performed in one or two days within a field so that the crop grows evenly. According to Hazell and Norton (1986), these characteristics lead to distinct seasonal patterns in resource use. For example, available supplies of land, labour and other fixed factors may be fully utilised

during certain parts of the year. The authors further stress that if seasonal patterns of resource use are ignored in constructing an optimisation model, it is likely that the solution obtained will be unrealistic by requiring more resources in some periods than available.

Figure 4. 2: Cropping calendar for the major crops in Eastern Uganda

Month	Crops				
	Groundnuts	Cowpeas	Maize	Sorghum	Cassava
January					
February					
March					
April					
May					
June					
July					
August					
September					
October					
November					
December					

The shaded months on the cropping calendar (fig 4.2) show months of the year when a selected crop occupies the land from planting up to harvesting time and its production time during the two seasons. In order to meet food security and income requirements, a farmer grows more than one crop and this results into overlaps in the different cropping calendars. Due to the fact that a farmer has limits on available resources, during the overlaps, the crops are forced to compete for the available resources such as land, labour and capital. Crops mainly compete for capital during planting time while labour is competed for almost throughout the growing period (planting, weeding and harvesting).

Cowpea is planted in February/march and July/August in the first and second seasons, respectively, and usually takes 3 to 4 months in the fields.Cowpea competes for land with other crops during the months of March to June for the first season and August to November for the second season. The months with low land competition among the crops included January, June and December (harvesting time in the study area). This implies that there is a lot of labour and capital in the market and therefore, their respective prices are expected to be low during that period. The months of March and August represent the highest competition for labour and capital because the period involves planting for most of the crops in the area. This indicates that demand for labour and capital is high and as such, the associated cost is high as well. Cassava is grown once a year and takes about 9 months (minimum) to harvest. A farmer can take three or more months to fully harvest the crop from the fields especially if it is for subsistence. This implies that although the crop is grown during the first season, the output is realised after the second season.

4.2.1 Input cost for the major crops grown in Eastern Uganda

Prices farmers pay for inputs used in the production of the major crops are presented in Table 4.3. Survey results showed that farmers did not use pesticides in larger amounts or on other crops and further imply that farmers regard the two crops (cowpeas and groundnuts) with more importance.

Table 4. 3: Average input prices (Ush per unit) in cowpea production system, 2005

Season	Input	Ush per unit				
		Groundnut	Cowpea	Maize	Sorghum	Cassava
Season I	Planting material (kg)	1,384.6	831.0	754.5	371.5	56.2
	Pesticide (l)	15,661.9	12,775.9			
	Family labour (person days)	833.0	117.5	804.0	926.6	829.2
	Hired labour (person days)	1,140.40	727.1	1,109.0	1,279.9	1,191.9
Season II	Planting material (kg)	1,151.9	915.5	859.1	309.2	
	Pesticide (l)	17,571.4	10,916.7			
	Family labour (person days)	661.5	963.5	932.2	620.7	
	Hired labour (person days)	1,242.3	1,142.5	1172.7	1,296.9	

Among planting materials, the two crops had the highest prices because most farmers used improved seed, which is at a higher price compared to the local planting materials. The most expensive input per unit was pesticides. From economic theory, quantities demanded of any input partly depend on price of that commodity. According to Isubikalu *et al.* (1998), the use of pesticide is limited by the financial position of a farmer since they are costly.

4.2.2 Inputs quantities used in the production of the selected crop enterprises

Table 4.4 represents the different inputs and their respective quantities used in the production of the major crops. In the first season, IPM farmers allocated more land to cassava, followed by groundnuts, and cowpeas while it was groundnuts, followed by sorghum, cowpea and maize in the second season. For the non-IPM farmers, more land was allocated to groundnuts followed by maize, cassava, cowpeas and sorghum.

It was noted that farmers in both categories allocated more land to cowpeas during the first season. In line with this study, Kongai (2005) reported that farmers in Eastern Uganda allocated more land to cowpea production during the same season. Contrary to this, earlier studies by Adipala *et al.* (1997) indicated that the crop was grown as a second season crop. However, this could be due to the increasing commercialisation of the crop, and as such, farmers find it profitable to grow more of the crop during the first season than in the second season.

Table 4. 4: Average inputs quantities used in the production of the selected crop enterprises, 2005

Season	Input (unit/ha)	IPM farmers					Non-IPM farmers				
		Groundnut	Cowpea	Maize	sorghum	Cassava	Groundnut	Cowpeas	Maize	Sorghum	cassava
Season I	Planting material (kg/ha)	40.47	21.07	17.00	12.97	1202.68	49.98	29.56	37.46	19.03	1575.76
	Pesticide (l/ha)	0.98	1.76				1.78	2.31			
	Family labour (person days/ha)	143.24	129.35	148.84	106.00	134.65	102.93	133.22	143.20	100.83	447.33
	Hired labour (person days/ha)	114.71	52.22	66.53	39.81	60.08	116.93	100.44	50.91	40.37	65.55
	Oxen hire ('000 ush/ha)	47.72	16.75	23.70	27.03	19.58	44.02	25.52	33.64	41.25	20.15
	Land allocation (ha)	0.58	0.55	0.32	0.37	0.63	0.41	0.32	0.35	0.30	0.33
Season II	Planting material (kg/ha)	43.06	30.56	20.09	12.69		50.05	48.07	50.54	23.44	
	Pesticide (l/ha)	0.96	1.54				1.57	1.55			
	Family labour (person days/ha)	102.04	93.44	145.73	76.29		137.55	119.21	181.32	95.21	
	Hired labour (person days/ha)	100.67	43.00	48.73	33.36		108.95	70.48	79.11	22.12	
	Oxen hire ('000 ush/ha)	34.64	30.13	54.80	22.02		52.16	27.59	19.35	26.36	
	Land allocation (ha)	0.51	0.39	0.33	0.42		0.44	0.29	0.28	0.43	

Cowpea farmers in Eastern Uganda heavily depend on family labour supplemented by hired labour during peak production periods. In the first season, IPM farmers allocated more labour to groundnuts. For the non-IPM farmer, more family labour was allocated to maize and cassava while more hired labour was allocated to groundnuts and cowpeas. Earlier studies by Gowa (2000) and Busingye (2004) also reported that family labour consisted of the major source of farm labour in Central Uganda. According to studies by Lim and Schumway (1999) and Diiro (2006), demand for human labour depends on output price, wage rate, price of planting material and farm size. These studies reported that there is a negative relationship between demands for human labour employed and wage rate, price of seed, but a positive one with farm size and output price. This study does not entirely agree or otherwise disagree with these observations. For instance, for the IPM farmers, cowpea comes third in land allocation but comes fourth in terms of labour allocation. But this could have been due to the low wage rate that farmers pay for the labour input employed in cowpeas as compared to those of competing enterprises.

It was shown that only cowpea and groundnuts enterprises used pesticides. The major pesticides used in the area included dimethoate and fenkil. Among the IPM farmers, cowpea had the biggest share of pesticides in both seasons while for non-IPM farmers, it was cowpeas in the first season and groundnuts in the second seasons with the highest share. The level of use and allocation among crops is partly due to relatively high prices of pesticides as reported earlier in the study. For instance, Cheryl *et al.* (2003) reported that 78% of the adopters and 88% of the non-adopters of improved wheat varieties in Ethiopia did not apply fertilizers due to the high prices.

Ploughing of land using oxen is a very common practice in Eastern Uganda but due to the fact that they costly to acquire, possession of the equipment is limited to a few farmers as reported earlier in this study. Besides, hiring of ox plough is more cost effective than owning one since they are only required during peak labour requirement periods and thus, the less endowed farmers take on hiring. Since it has a cost tagged to it, oxen hiring for the different crops is done according to importance of the crop to the farmer. In an effort to minimise this cost, in some cases part of the land allocated to a particular crop is cleared using hand hoes and the other part, using the hired oxen. It was reported among IPM farmers that oxen hiring was done mainly for groundnuts followed by sorghum and then maize in the first season. During the second season, it was done mainly for maize followed by groundnuts and then cowpeas. For the non-IPM farmers, in the first season, the trend followed that of their counterparts in the IPM group but for the second season, it was groundnuts and cowpeas.

Generally, groundnuts had the biggest per hectare share of almost all the resources and yet its acreage of 0.58ha in the first season was less than that of cassava (0.63ha) for IPM farmers. It would be expected that the cost of hiring oxen for land preparation would be in relation to land size (i.e. more land means more of the cost). According to Sidhu and Baanante (1981), animal power requirement is positively related to size of the farm. This implies that large farms require more quantities of animal power.

On the contrary, cassava had the least cost of hiring oxen compared to other crops which had less pieces of land allocated to them. This could be due to the fact that for cassava, ploughing was done once unlike other crops which required relatively soft soil for germination. The implication of this is that farmers consider groundnuts as an important crop in terms of either food security or income generation or both and thus allocate more resources with the hope of achieving higher returns.

4.2.3 Comparison of Costs incurred in production of cowpeas and those of other competing crop enterprises in Eastern Uganda, 2005

The comparisons were done using analysis of variance tool. Tables 4.5 and 4.6 show cost of producing the major crops in the study area and mean differences between cowpeas and the other competing crops. Although analysis of variance showed that the average production costs across crops were different, the significance was not for all the crop mean differences. The costs for a particular crop represent the average of the total production costs.

Table 4. 5: Differences between cowpea production costs ('000 sh.ha^{-1}) and those of competing crop enterprises among IPM farmers, 2005

Crop	Season I		Season II	
	Average costs	Mean difference	Average costs	mean difference
Cowpeas	109.90		214.07	
Groundnuts	369.23	-259.33**	293.67	-79.60
Maize	229.98	-120.07	265.05	-50.98
Sorghum	181.02	-71.11	116.56	97.51
Cassava	270.41	-160.51		

** Significant at 5%.

During the first season, cowpeas had the lowest production cost (Ush. 109.90) compared to other crops in the IPM group but this was only significantly ($P \leq 0.05$) lower than that of groundnuts (Ush. 369.23) which had the highest production cost among IPM farmers.

In the second season, sorghum had the lowest cost followed by cowpeas while groundnuts still registered the highest cost although not significantly more than that of cowpeas. The low cost of producing cowpeas in the first season is partly attributed to less person days employed. This low wage rate is probably due to the relatively lower importance tagged to cowpea as observed from proportion consumed. As such, a farmer is not expected to spend much on a crop which mainly subsistence. The high cost of groundnuts is attributed to the relatively large quantities of resources allocated to the crop such as pesticides (which are costly), hired labour and oxen hire. Besides employing no pesticides in sorghum, low cost of producing the crop is partly due to low levels of the other inputs allocated to it.

Among the non-IPM farmers, groundnut production costs were the highest in the first and second seasons while cowpeas and sorghum had the least in the first and second seasons respectively (Table 4.6). The costs of cowpeas were significantly lower than those of groundnuts ($P \leq 0.05$ and $P \leq 0.1$ in the first and second season respectively) and higher than that of sorghum ($P \leq 0.05$).

Table 4. 6: Differences between cowpea production costs ('000 sh.ha^{-1}) and those of competing crop enterprises among Non-IPM farmers, 2005

Crop	Season I		Season II	
	Average costs	Mean difference	Average costs	Mean difference
Cowpeas	168.27		283.89	
Groundnuts	360.19	-191.92**	363.73	-79.84*
Maize	233.50	-65.23	324.56	-40.67
Sorghum	193.41	-25.15	121.39	162.51**
Cassava	557.74	-389.48**		

** Significant at 5%., *Significant at 10%

4.2.4 Value of production and consumption proportions of major crops during production period, 2005

Generally, the area registered a higher production in the first season compared to the second season (Table, 4.7). In both categories, cassava registered the highest average production which is mainly attributed to its bulkiness. It is important to note that in the second season, both farmer categories had cowpeas registering the lowest quantity of production. Earlier studies by Magino (2005) and Ekiyar (2003) also registered production levels in the same range. On the contrary, Magino *et al.* (2004) recorded 194.00kg in the same study area. This could be due to the fact that this average represented a value for an average farmer (either practicing IPM or traditional technologies

Table 4. 7: Average production (kg), value of production (Ush.ha^{-1}) and output prices of the major crops in Eastern Uganda, 2005

	Crop	Production (kg)		Price (Ushkg^{-1})		Value of production ('000 Ush.ha^{-1})	
		Season I	Season II	Season I	Season II	Season I	Season II
IPM farmer	Cowpeas	287.58	143.35	575.83	1,067.86	301.08	392.51
	Groundnuts	372.55	347.47	832.40	1,981.68	534.67	1,350.14
	Maize	299.97	385.51	233.46	258.21	218.85	301.65
	Sorghum	255.80	222.11	228.59	246.6	158.04	130.41
	Cassava	1,327.50	-	293.29	-	564.27	-
Non-IPM farmer	Cowpeas	126.00	115.37	515.19	663.5	202.86	263.96
	Groundnuts	168.43	150.02	730.92	1,115.85	300.27	380.46
	Maize	262.39	310.86	218.13	247.12	163.53	274.36
	Sorghum	221.26	151.63	235.85	235.85	173.95	83.17
	Cassava	702.33	-	314.64	-	669.64	-

Unit prices varied across crops and farmer categories in the cowpea growing system with cowpeas and groundnuts fetching higher prices than the other crops. This is also in agreement with FAO (2002) that legume crops were considered as high value crops. According to findings by Ekiyar (2003), cowpeas were fetching prices between Uganda shillings 235-871 and groundnuts 546-1280 per kg. The price of cowpeas was higher than that of other crops except groundnuts. Since the supply is low, this was expected but the probable reason as to why it was not greater than that of groundnuts is because groundnuts has a better established market both domestically and internationally as compared to cowpeas.

The high prices of cowpeas and groundnuts resulted into higher values of production as compared to the other crops. In the first season, the highest per hectare Uganda shilling was registered by cassava (564,266.50 and 669,638.87 for IPM and non-IPM farmers

respectively), followed by groundnuts (534, 667 and 300,269 for IPM and non-IPM farmers respectively) and cowpeas (301,084 and 202,856 for IPM and non-IPM farmers respectively) while it was groundnuts (1,350,138 and 380,460 for IPM and non-IPM farmers respectively) first followed by cowpeas (392,513 and 263,960 for IPM and non-IPM farmers respectively) in the second season.

This study was in line with the theories of demand and supply which describe how prices vary as a result of a balance between product availability at each price (supply) and the desires of those with purchasing power at each price (demand) (Ruffin and Gregory, 1993). They further depict that, an increase in demand with a consequent increase in price and quantity required results in reductions in quantities supplied. As such, from the survey results, cowpeas and groundnuts which had registered low quantities of production implying low supply on the market and thus high demand as expected results into higher prices.

Proportions of household consumption of each crop are indicated in Table 4.8. In the first season, the most consumed crop was cowpea (0.82) followed by groundnuts (0.63) among IPM farmers and maize (0.55) followed by sorghum (0.46) among the non IPM farmers. The high levels of consumption emphasise the fact that Uganda's agriculture is still highly subsistence. For the second season, both farmer categories consumed mainly sorghum (0.63 and 0.56 for IPM and non-IPM farmers respectively) and cassava (0.56 and 0.76 for IPM and non-IPM farmers respectively).

Table 4. 8: Proportion of quantities of major crops produced that is consumed of the crops in Eastern Uganda, 2005

Crop	IPM farmer		Non-IPM farmer	
	Season I	Season II	Season I	Season II
Groundnuts	0.63	0.37	0.33	0.44
Cowpeas	0.82	0.49	0.40	0.43
Maize	0.62	0.41	0.55	0.32
Sorghum	0.47	0.63	0.46	0.56
Cassava	0.56		0.76	

Factors that determine amount of produce consumed by farm households include the available quantities (quantities harvested), prevailing market price and the socio-cultural factors (Hawkins *et al.*, 1995). For instance, cassava is produced in large amounts and the unit prices are low as reported earlier in the study, which partly explain why consumption proportions are above average. Some communities consider particular foods as staple and thus can not sell unless have surplus quantities or there is an urgent need for cash. In the study area, cassava and sorghum are staple food crops thus the high proportions consumed.

Grains which can be dried and kept, some farmers sell off what they had kept for consumption if prices are attractive. Prices of cowpeas and groundnuts in the second season for example, at least double those of the other competing crops which to some extent explain the low proportions consumed to below 0.50. Cowpeas are also harvested in smaller quantities as compared to the other crops. Since the price is fairly attractive, as expected, the proportion consumed is small. The results implied that cowpea is not a

major income generating crop in both seasons in Eastern Uganda as compared to the other crops. The implication of this is that the crop is still highly subsistence. Although cassava registered higher proportions, this is realised after the second season (after harvest).

4.2.5 Gross margins of the major crops grown in Eastern Uganda

Analysis of variance revealed that crop gross margins of the competing crops were different from that of cowpeas (Tables 4.9 and 4.10). Among IPM farmers, in the first season, cowpeas registered the highest gross margin after cassava, followed by maize and then sorghum. In this season, cowpea gross margin was only significantly ($P \leq 0.05$) greater than that of groundnuts and sorghum. In the second season, groundnuts registered the highest followed by cowpeas. The difference between cowpeas' gross margin and other competing crops was only significant ($P \leq 0.05$) for groundnuts.

Table 4. 9: Differences between cowpea production gross margins ('000 sh.ha^{-1}) and those of competing crop enterprises among IPM farmers, 2005

Crop enterprise	Season I		Season II	
	Gross margin	Mean difference	Gross margin	mean difference
Cowpeas	191.18		178.44	
Groundnuts	165.43	25.75	1056.47	-878.03**
Maize	-11.13	202.31**	36.60	141.85*
Sorghum	-23.00	214.18**	13.86	164.59*
Cassava	293.85	-102.67*		

** Significant at 5% ; *Significant at 10%

From the economics theory, profits are positively related to quantity produced or price of output or both. In other words, profits can be increased by increasing either quantity

produced or price of output provided all other factors are kept constant. This partly explains why cowpeas and groundnuts registered higher gross margins especially due to the relatively higher prices fetched by the two crops. Besides, for both crops, IPM technologies were developed and disseminated in the same area.

It was also observed that, cowpea realised higher gross margins during the first season. This could be explained by the fact that, during the first season, there was adequate rainfall which resulted into more vegetative and denser cowpea plants. The denser plants provide greater soil cover and reduced the strength of the visual contrasts between earth and plants for the pests (A'Brook, 1968). The heavy rains in the season also kill the aphids (Karungi *et al.*, 1999)

Table 4. 10: Differences between cowpea production Gross margins ('000 sh.ha^{-1}) and those of competing crop enterprises among Non-IPM farmers, 2005

Crop enterprise	Season I		Season II	
	Gross margin	Mean difference	Gross margin	Mean difference
Cowpeas	67.71		44.17	
Groundnuts	-61.00	128.71**	239.92	-195.74**
Maize	-10.82	78.53	-7.08	51.25
Sorghum	37.47	30.24	-35.54	79.72*
Cassava	109.93	-42.22		

**** Significant at 5%., *Significant at 10%**

Results for non-IPM farmers' showed that in the first season, cowpeas had the highest gross margin followed by sorghum. In the second season, groundnuts registered the highest gross margin (which was significantly higher than that of cowpeas by Ush.

195.74). Maize and sorghum registered negative gross margins. This is partly due to the high cost of inputs employed in the crops compared to the low prices received by the farmer per unit output.

4.3 Resource allocation plans for cowpea farmers in Eastern Uganda

The resources to be allocated included land, capital, family and hired labour. Although labour constitutes the major production cost, land under an enterprise to a large extent determines the level of allocation for the other two resources. The results in this section therefore, are based on production coefficients in the study area to design efficient farm resource use plans for cowpea farmers in Eastern Uganda.

Basing on the assumption of proportionality, since the technical coefficient of land per hectare is one, and the coefficients of capital and labour are constant, any increase in land allocation to any enterprise would ultimately increase capital and labour by the same proportion. And also given the linearity of the production function, gross margin realizations would be affected similarly provided other factors remain constant. Therefore, an optimal land allocation plan would ensure optimal allocation of the available resources. Production parameters in the current situation were compared with those after optimisation. Percentage changes in available resources and gross margin realised in the current situation required to attain maximum gross margins were there after calculated. Different optimal resource use farm plans for IPM and non-IPM farmers were generated.

4.3.1 Resource allocation level for IPM farmers

From the recommended farm plan, in order to maximise returns, an average IPM farmer in the study area would have to allocate his resources in such a way that the five crops are produced according to their acreage allocations. Table 4.11 shows the current and recommended optimal resource use levels among IPM farmers. The model recommended that if a farmer was to maximise returns, he would have to increase the land allocated to cowpeas in the first season by 278.185% and reduce that to the other crops. Subsequently, the other resources would be allocated to the crop enterprises in a similar manner. This would result into an increase in land allocated to all crop enterprises in season one by 1.22% but reductions in labour in labour and capital allocated by 12.73% and 18.83% respectively. The seasonal gross margin would also increase by 78.80%.

Results for the first season implied that labour and capital were sub-optimally allocated in the current situation and as such, used below their production potential. According to Clayton (1989), an optimum allocation solution has to take into account diminishing return relationship between output and inputs. In this context, any additional units of labour or capital results into reduced units of output and, the resulting gross margins are reduced for each additional unit. Since there are other farm activities besides the production of the five major crops, additional requirements on land could be compensated for by reducing that under the other activities such as livestock and other crops grown.

Table 4. 11: Comparison of the current and optimal resource allocation level for IPM farmers , 2005

Variable	Crop	Season I			Season II			Annual % change
		Current	Model	% change	Current	Model	% change	
Land (ha)	Groundnuts	0.58	0.10	-82.76	0.51	2.08	307.84	225.08
	Cowpeas	0.55	2.08	278.18	0.39	0.10	-74.36	203.82
	Maize	0.32	0.10	-68.75	0.33	0.10	-69.70	-138.45
	Sorghum	0.37	0.10	-72.97	0.42	0.10	-76.19	-149.16
	Cassava	0.63	0.10	-84.13				-84.13
All crops		**2.45**	**2.48**	**1.22**	**1.65**	**2.38**	**44.24**	**18.54**
Labour	Groundnuts	257.95	44.47	-82.76	202.71	826.73	307.84	89.12
	Cowpeas	181.57	686.67	278.18	136.44	34.99	-74.36	126.93
	Maize	215.37	67.30	-68.75	194.46	58.93	-69.70	-69.20
	Sorghum	145.81	39.41	-72.97	111.55	26.56	-76.19	-74.37
	Cassava	194.73	30.90	-84.13	0.00	0.00	0.00	-84.13
All crops		**995.43**	**868.75**	**-12.73**	**645.16**	**947.20**	**46.82**	**10.69**
Capital ('000 shs./ha)	Groundnuts	119.10	20.53	-82.76	101.11	412.37	307.84	225.08
	Cowpeas	56.74	214.58	278.18	74.92	19.21	-74.36	203.82
	Maize	36.53	11.42	-68.75	72.06	21.83	-69.70	-138.45
	Sorghum	31.85	8.61	-72.97	25.94	6.18	-76.19	-149.16
	Cassava	87.15	13.83	-84.13	0.00	0.00		0.00
All crops		**331.37**	**268.97**	**-18.83**	**274.03**	**459.59**	**67.71**	**20.34**
Gross margin ('000 shs./ha)	Groundnuts	165.43	122.82	-25.76	1056.47	2311.30	118.78	75.88
	Cowpeas	191.18	799.10	317.98	178.44	125.61	-29.61	12.92
	Maize	-0.13	11.39	886.10	36.60	28.69	-21.61	-89.50
	Sorghum	-13.00	9.37	172.08	13.85	77.08	-85.63	171.76
	Cassava	283.84	147.59	-48.00	0.00	0.00	0.00	-89.54
All crops		**627.32**	**1090.27**	**73.80**	**1285.36**	**2542.68**	**97.82**	**67.66**

Another alternative could be not to produce the minor crops in the season at all. The reduction in capital inputs would imply that there would be a slack in the resource market .The excess capital could be saved for the next season or allocated to other activities. Excess labour could be employed in other activities as well or engaged in off-farm income generating activities. Since the resulting seasonal gross margin is positive, it implies that

the recommended plan enables the farmer to achieve his objective of maximizing profits. This is in line with study by Amede *et al.* (2004), where household food demand in cereal-based cropping systems of Ethiopia were fulfilled using the existing resources of land, rainfall and labour through reallocation of land for more productive crops.

For the second season, a farmer would have to switch more resources to groundnuts and as such, reduce those allocated to cowpeas, maize and sorghum. This would lead to a seasonal increase in land, labour and capital allocated to all enterprises by 44.24%, 46.82% and 67.71% respectively. If an IPM farmer followed the recommended optimal resource use plan, the annual gross margin would increase by 67.66%. The increased requirements for capital and labour input would imply increase in their respective market prices. This is in line with findings of Ekiyar (2003) which indicated that increasing the use of labour and capital would increase the benefits of using IPM technologies by the farmers. Since there was a slack in capital in the first season, this can be used in the second season to offset the deficit. For the case of labour, the farmer can reduce on the hours spent off farm or on other farming activities.

4.3.2 Resource allocation levels for Non-IPM farmers

A non-IPM farmer would have to increase all the resources for cowpeas by 500% in the first season but reduce the same resources for the other competing crop enterprises. This would result into an increase in land allocated to all enterprises in the season by 35.7%, labour by 31.6% and capital by 31.63%. As a result, the gross margins of cowpeas would increase by 188.72% while those of the other crops reduce. Subsequently, the farmer

would realise an increase in the seasonal gross margin by 155.24%.

In the second season, the farmer would have to increase the resources allocated to groundnuts and reduce those allocated to the other crop enterprises. In the process, the land and capital allocated to all enterprises would increase by 54.17% and 104.88% respectively but labour would be reduced by 33.74%. The resulting seasonal gross margin would be increased by 83.26%. According to the optimal resource use plan, if followed, an optimising non-IPM farmer would realise an annual increase in the gross margin by 102.21% over what is currently being realised.

However, these increases in resource use are less than those recommended by Magino (2005), who indicated that gross margins of an optimising cowpea farmer in Kumi and Soroti districts of Eastern Uganda could increase by 117.0% if he or she increased his current resource use by at least 400%. The required resource levels (in addition to the current levels) to reach optimum could be obtained by reducing or employing all those used in the production of the minor crop enterprises or other farm activities.

Table 4. 12: Comparison of the current and optimal resource allocation levels for non-IPM farmers, 2005

Variable	Crop	Season I			Season II			Annual % change
		Current	Model	% change	Current	Model	% change	
Land (ha)	Groundnuts	0.41	0.1	-75.61	0.44	1.92	336.36	137.65
	Cowpeas	0.32	1.92	500	0.29	0.1	-65.52	231.15
	Maize	0.35	0.1	-71.43	0.28	0.1	-64.29	-68.25
	Sorghum	0.3	0.1	-66.67	0.43	0.1	-76.74	-72.6
	Cassava	0.33	0.1	-69.7	0	0	0	-69.7
All crops		**1.71**	**2.32**	**35.67**	**1.44**	**2.22**	**54.17**	**44.13**
Labour	Groundnuts	219.86	53.62	-75.61	246.51	473.3	92	12.98
	Cowpeas	233.63	1401.78	500	189.69	18.97	-90	235.62
	Maize	194.11	55.45	-71.43	260.43	26.04	-90	-82.07
	Sorghum	141.2	47.07	-66.67	100.85	10.08	-90	-76.39
	Cassava	512.88	155.4	-69.7	0	0	0	-69.7
All crops		**1301.68**	**1713.32**	**31.62**	**797.48**	**528.39**	**-33.74**	**6.79**
Capital ('000 shs./ha)	Groundnuts	141.1	34.41	-75.61	137.4	599.56	336.36	20.02
	Cowpeas	79.6	477.6	500	88.52	30.52	-65.52	160.17
	Maize	61.9	17.68	-71.43	62.77	22.42	-64.29	-77.38
	Sorghum	48.32	16.11	-66.67	33.61	7.82	-76.74	-80.77
	Cassava	108.78	32.96	-69.7	0	0	0	-69.7
All crops		**439.7**	**578.76**	**216.59**	**322.30**	**660.31**	**129.81**	**62.61**
Gross margin ('000 shs./ha)	Groundnuts	-81	0.23	-100.28	239.92	432	80.06	171.98
	Cowpeas	67.71	195.49	188.72	44.17	5.78	-86.91	79.9
	Maize	-39.82	1.43	-103.59	-7.08	4.14	-158.47	-111.88
	Sorghum	37.47	7.44	-80.14	-35.54	0.6	-101.69	316.58
	Cassava	101.93	15.66	-84.64	0	0	0	-84.64
All crops		**86.29**	**220.25**	**155.24**	**241.47**	**442.52**	**83.26**	**102.21**

The slack in labour in the second season could be employed in other activities that could bring in extra income for the family. These could mainly non-farm activities such as hiring out labour. This is in agreement with Oren and Alemdar (2006) who noted that through better use of available resources, while using the current technology, efficiency could be increased by 45%. The resource use allocation in the study depicts that the farm household was employing less of the available resource into the production of the major

crop enterprises. Farmers were allocating less capital than optimal partly due high cost of inputs especially agro-chemicals. This is inline with the fact that pesticides are costly and as such, there use is limited by financial position of the farmer (Isubikalu *et al.*, 1999). Mwakalobo (2000) and Omongo *et al.* (1998) also noted that farmers can not afford agro chemicals and even those who can, may not be in position to use the recommended dosages. This is in agreement with who noted that coffee farmers applied fertilizer below recommended rates due to the high fertilizer prices.

4.3 Effects of reductions in output price and increases on capital cost on optimal gross margins

Agricultural production is typically a risky business and agricultural risks are particulary burdensome to small-scale farmers (Hazell and Norton, 1986). Farmers have a variety of price, yield and resource risks that they face from year to year and these tend to determine their production and hence optimal farm plans (Nyikal and Kosura, 2005). As such, farmers prefer plans that provide a satisfactory level of security even if it means sacrificing average income. The more secure plans may also involve using established technologies rather than new ones. Tables 4.13 and 4.14 show the resulting optimal gross margins after reductions in output prices and increases in capital cost at percentages of 5, 10 and 15.

For an IPM farmer, a reduction in output price by 5% or 10% in the first season would result in an optimal value though less than the recommended, but greater than the current gross margin realised by the farmer. The same scenario would be observed at 15% reduction in cowpea price but the resulting gross margin would be far less than the current

value. As a result, gross margin of groundnuts (which is also an IPM technology crop) would increase to Ush. 835.41ha^{-1}, a level almost five higher than its current value. In the second season, cowpea gross margins would follow the same trend as in the first season. The resulting annual gross margin reductions are almost negligible. For instance, 10% reduction in output price would reduce the annual optimal gross margin by only 4.22% and the value remains positive. This implies that the optimal resource allocation plan is stable. In an earlier study by Mugisha *et al.* (2006) it was reported that gross margins from IPM technologies remained positive even if output prices fell by up to 20%.

Table 4. 13: Optimal gross margins (GM) ('000 Ushha^{-1}) changes with changes in cowpea price and capital among IPM farmers.

Season	Crop	Current GM	Optimal GM	Output price reduction			Increase in capital		
				5%	10%	15%	5%	10%	15%
I	Groundnut	165.43	122.82	122.82	122.82	835.41	122.82	122.82	122.82
	Cowpea	191.18	799.10	705.45	673.24	29.41	787.19	775.37	610.35
	Maize	-0.13	11.39	11.39	11.39	11.39	11.39	11.39	11.39
	Sorghum	-13.00	9.37	9.37	9.37	9.37	9.37	9.37	9.37
	Cassava	283.84	147.59	147.59	147.59	147.59	147.59	147.59	147.59
All crops		**627.32**	**1,090.27**	**996.62**	**964.41**	**1033.17**	**1,078.36**	**1,066.54**	**901.52**
II	Groundnut	1,056.47	2,311.30	2,311.30	2,311.30	2,311.30	2311.30	2311.30	2,311.30
	Cowpea	178.44	125.61	110.06	97.99	84.18	122.97	120.33	84.18
	Maize	36.60	28.69	28.69	28.69	28.69	28.69	28.69	28.69
	Sorghum	13.85	77.08	77.08	77.08	77.08	77.08	77.08	77.08
All crops		**1,285.36**	**2,542.68**	**2,527.13**	**2,515.06**	**2,501.25**	**2,540.04**	**2,537.40**	**2,501.25**
Annual Total		1,912.68	3,632.95	3,523.74	3,479.47	3534.42	3,618.41	3,603.94	3,402.78
Annual % change				**-3.01**	**-4.22**	**-2.71**	**-0.40**	**-0.80**	**-6.34**

For the resource use plan of a non-IPM farmer, a 10% reduction in cowpea price would result in a gross margin less than the original optimal value but greater than the current value. At 15% fall in output price, cowpea gross margin would reduce to Ush. 4.87 ha^{-1} in

the first season. This would result into an increase in the gross margin of sorghum to Ush.142.85 ha^{-1} implying that more resources would be allocated to sorghum. In the second season, the farmer realises 1.74 at 15% reduction in price which is far less what the farmer was realising before optimisation although it remains positive. This implies that it is risky to grow the crop under such circumstances since the farmer will be operating at a loss. This is in line with sensitivity analysis done by Mugisha *et al.* (2006) on effect of price change on cowpea gross margin. The researchers found out that traditional technologies in Pallisa and Kumi would remain profitable even at 20% price fall, but gross margins would be unreasonably low. The reductions in annual gross margin are low but remain positive implying that an optimising farmer is still safe to follow the recommended plan if faced by the challenges. The different gross margins at different price and capital levels are still positive and greater than the current values.

Table 4. 14: Optimal gross margins (GM) changes ('000 Ush/ha) with changes in cowpea price and capital among non-IPM farmers

Season	Crop	Current GM	Optimal GM	Reductions in output price			Increases in capital		
				5%	10%	15%	5%	10%	15%
I	Groundnut	-81.00	0.23	0.23	0.23	0.23	0.23	0.23	0.23
	Cowpea	67.71	195.49	161.44	127.36	**4.87**	**183.96**	**172.50**	**161.03**
	Maize	-39.82	1.43	1.43	1.43	1.43	1.43	1.43	1.43
	Sorghum	37.47	7.44	7.44	7.44	**142.85**	7.44	7.44	7.44
	Cassava	101.93	15.66	15.66	15.66	**0.39**	15.66	15.66	15.66
All crops		**86.29**	**220.25**	**186.20**	**152.12**	**149.77**	**208.72**	**197.26**	**185.79**
II	Groundnut	239.92	432.00	432.00	432.00	**479.52**	432.00	432.00	432.00
	Cowpea	44.17	5.78	3.64	1.49	**5.78**	**5.20**	**4.62**	**4.04**
	Maize	-7.08	4.14	4.14	4.14	4.14	4.14	4.14	4.14
	Sorghum	-35.54	0.60	0.60	0.60	0.60	0.60	0.60	0.60
All crops		**241.47**	**442.52**	**440.38**	**438.23**	**490.04**	**441.94**	**441.36**	**440.78**
Annual total		**327.76**	**662.77**	**626.57**	**590.35**	**639.81**	**650.66**	**638.62**	**626.57**
Annual % change		**279.84**		**-5.46**	**-10.93**	**-3.46**	**-1.83**	**-3.64**	**-5.46**

CHAPTETR FIVE
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary and conclusions

The study focused on examining the allocation of farm resources by farmers engaged in cowpea production and developing optimal farm plans for cowpea production systems in Eastern Uganda. The specific objectives included; comparing production costs and returns from cowpea with competing crop enterprises; determining the levels at which cowpea farmers can combine available farm resources to maximise farm gross margins. The study also aimed at determining the extent to which emerging challenges, such as changes in input costs and output prices, are likely to impact on the derived optimum resource allocation plans.

The survey was carried out in Pallisa and Kumi districts because this is where integrated pest management technologies were demonstrated and disseminated among cowpea farmers. With 120 IPM farmers and an equal number of non-IPM farmers who were purposively and randomly selected, a sample size of 240 farmers was used for this study. Using face-to-face interviews, data were collected using a structured pre-tested questionnaire. The analytical tools used included descriptive statistics, enterprise budgeting and linear programming.

Cowpeas registered the lowest per hectare production costs in both farmer groups in the first season but second to sorghum in the second season for the Non-IPM farmers while groundnuts had the highest in both seasons and farmer categories. The lowest production

costs for cowpeas would imply that it had the highest revenues. This was proved by results in season one and in contrast to this, although groundnuts had the highest production costs among IPM farmers in season two, it still registered the highest gross margin per hectare. The reason as to why groundnuts is the major competitor to cowpeas is mainly due to the fact that for groundnuts, IPM technologies were demonstrated and disseminated among farmers in the same study area.

The hypothesis that cowpeas significantly generate greater returns to farmers than other crops could not be rejected for season one in both farmer categories. The same hypothesis was only rejected for the mean difference between that of cowpeas and groundnuts. Therefore, cowpeas are the most income generating crop for the farmers in Eastern Uganda in the first season and second to groundnuts and sorghum in the second season (for IPM and Non-IPM farmers respectively). But judging from the proportion of household consumption, cowpea is still registered as a highly subsistence crop.

The optimisation results suggest that the average farm household in the study area could not achieve full satisfaction of its production goal of profit maximisation with the present structure of available farm production resources. It was shown that a farmer could improve his gross margins if existing crop enterprise mixes are re-planned. A cowpea farmer can maximise returns to a tune of 67.66% and 102.21% for IPM and non-IPM groups respectively if existing resources are optimally allocated among the competing enterprises. Therefore, the hypothesis that reallocating farm resources within farmers enterprise mix gives higher gross margins than the current situation was accepted. The

current low levels of gross margins could be because cowpea farming systems are much diversified in order to meet the farmer's goals of food security and income generation leading to inefficient allocation of the scarce resources among the competing crop enterprises.

Results further showed that reductions in cowpea prices and increases in capital reduced the overall gross margins by percentages of less than 11%. The sensitivity analysis indicated that an optimising farmer risked getting lower gross margins as output price reduced but remained positive and greater than the current values. As such, we still accept the hypothesis that emerging economic challenges do no significantly affect gross margins of a resource optimising farmer.

5.2 Recommendations

From the results, it is clear that cowpea has the least cost of production in season one and second to sorghum in season two in both farmer groups. It also has the highest per hectare gross margins in both farmer groups in the first season but second to groundnuts in the second season. Basing on the above conclusions and the fact that it can be grown in both seasons of the year, the following recommendations were made.

It is feasible to use the optimal plans for both farmer categories since they lead to increases in gross margins and some reductions in the resources used as compared to the current situation. Due to the fact that the optimal plan is relatively sensitive to reductions in cowpea prices, farmers should consider improving their bargaining power for better

prices and participating in markets with higher prices. This could be done through group marketing such that they are able to sell to urban markets and reduce per unit transportation costs as well.

5.3 Recommendation for further research

The study was only carried out for Eastern Uganda. Similar studies should be carried out and optimal resource use plans formulated in other parts of the country considering the ecological zones and the major crops in the areas. This would enable farmer to maximise the returns from their farming systems since it would be looking at ecological zones and considering the major crops in that particular zone.

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Appendices

Appendix 1 Farm household questionnaire

FACULTY OF AGRICULTURE, MAKERERE UNIVERSITY

OPTIMAL RESOURCE ALLOCATION IN COWPEA AND GROUNDNUT PRODUCTION IN EASTERN UGANDA

DATE.....
Identification

District..... Sub-county.....

Name of respondent..... Technology of cowpea production.....

Parish .....

Socio-economic characteristics

1. Household characteristics

	Sex	Age	Marital status (use codes 1 2 3 4 below)	Formal education (Yrs)	Current occupation(s)	Estimated income from the occupation
Household head						
Spouse (s)						

Dependants

	Total number in household		Not active in farm work		Part time labourers		Permanently active on farm	
	F	M	F	M	F	M	F	M
Children not yet in school								
Nursery								
Primary								
Secondary								
Tertiary								
Not in school but at home								
Total								

Codes: 1. Single 2. Married 3. Widowed 4. Divorced

2. Rank the 4 major crops grown (excluding cowpeas)
1.....
2.....
3.....
4.....

3. Who is the major decision-maker in the family? (Tick)
1. Father..... 2. Mother ... 3.Uncle... ...
4. Aunt ... 5.Brother/Son... 6. Sister/Daughter.... 7.Joint

4. How many years have you been farming?.....
5. How many years have you been in potato farming? ----------

6.Land use and agricultural production

	Area (Ha)	Mode of land acquisition	Farmer's production goals
Total area			
Area available for cultivation			
Land area under cultivation			

Mode:1. Inherited 2. Purchased 3. Hired 4. Given 5. Borrowed 6. Others (specify).....
GOALS: 1. Subsistence 2. Commercial 3. Both 4. Others(specify).....

7. What were the land requirements and output for the five major crops during the last two seasons?

Crop	Season I					Season II				
	Acreage	Qty harvested	Qty consumed	Qty sold	Price/ unit	Acreage	Qty harvested	Qty consumed	Qty sold	Pric unit
Cowpea										

8. Pesticide requirement

Crop	Type of pesticide	Season I			Season II		
		Qty applied	Unit cost	Total cost	Qty applied	Unit cost	Total cost
Cowpea							

9. Do you g*et al*.l the labour that you need for all activities?
(1) Yes (2) No
If no, why?.....

10. What is your labour source for the farm?
(1) Family (2) Hired (3) hired and family

12. Labour utilization with respect to crop enterprises

13. How many hours is your working day? .....

14. Hired machinery and equipment data

Crop	Type of machinery/equipment	Type of costs							
		Season I				Season II			
Cowpea		Fuel	Hiring	Repair	Other (specify	Fuel	Hiring	Repair	Other (specify

15. Tools and equipment

Common tools used	Number	Replacement cost	Original cost	Useful life
1. Hoes				
2. Slasher				
3. Pangas				
4. Spray pump				
5. Wheel barrows				
6. Baskets				
7. Gunny bags				
8. Oxen				
9. Plough				
10. Other (specify)				

16. What were your labour sources and associated costs?

Season I

Child labour (c) Adult family female(ff) and male (fm) labour Adult hired (h) labour		Labour requirement and wage rate (L = No. of workers, D=No. of Person days, H= No. of man hours, R= wage rate/day																			
Land preparation	C	Cowpea				Crop2				Crop3				Crop4				Crop4			
	Ff	L	D	H	R	L	D	H	R	L	D	H	R	L	D	H	R	L	D	H	R
	Fm																				
	h																				
Planting	C																				
	Ff																				
	Fm																				
	h																				
Weeding	C																				
	Ff																				
	Fm																				
	h																				
Chemical application	C																				
	Ff																				
	Fm																				
	h																				
Harvesting	C																				
	Ff																				
	Fm																				
	h																				

Season II

Child labour (c) Adult family female(ff) and male (fm) labour Adult hired (h) labour		Labour requirement and wage rate (L = No. of workers, D=No. of Person days, H= No. of man hours, R= wage rate/day																			
Land preparation	C	Cowpea				Crop2				Crop3				Crop4				Crop4			
	Ff	L	D	H	R	L	D	H	R	L	D	H	R	L	D	H	R	L	D	H	R
	Fm																				
	h																				
Planting	C																				
	Ff																				
	Fm																				
	h																				
Weeding	C																				
	Ff																				
	Fm																				
	h																				
Chemical application	C																				
	Ff																				
	Fm																				
	h																				
Harvesting	C																				
	Ff																				
	Fm																				
	h																				

17. Other inputs

Season 1

Crop enterprise	Input	Qty (kg, l)	Unit price	Total value
Cowpea	Planting material			
	Manure			
	Pesticides			
	Herbicides			
Crop 1	Planting material			
	Manure			
	Pesticides			
	Herbicides			
Crop 2	Planting material			
	Manure			
	Pesticides			
	Herbicides			
	Other (specify)			
Crop 3	Planting material			
	Manure			
	Pesticides			
	Herbicides			
Crop4	Planting material			
	Manure			
	Pesticides			
	Herbicides			

Season II

Crop enterprise	Input	Qty (kg, l)	Unit price	Total value
Cowpea	Planting material			
	Manure			
	Pesticides			
	Herbicides			
Crop 1	Planting material			
	Manure			
	Pesticides			
	Herbicides			
Crop 2	Planting material			
	Manure			
	Pesticides			
	Herbicides			
Crop 3	Planting material			
	Manure			
	Pesticides			
	Herbicides			
Crop4	Planting material			
	Manure			
	Pesticides			
	Herbicides			

18. For all the different income sources for the farm household, estimate the amount received per month/year

Income source	Income (USh/season or month or year
Crop sales	
Livestock sales	
Wages	
Salaries	
Non-farm business	
Remittances	
Rent	
Credit	

19. Of the total income received per year, how much do you allocated to crop farming?.....

20. On average how much do you allocated to each cropping season?

First season..... Second season.....

Thank you

Appendix 2: Socio-economic characteristics of farmers in Eastern Uganda

Variable		Percentage	
		IPM	Non-IPM
Sex of the household head	Male	83.7	79.8
	Female	16.3	20.2
Marital status of household head	Single	5.0	2.4
	Married	73.8	75.9
	Widowed	8.8	14.5
	Divorced	5.0	7.2
Primary occupation of household head	Farmer	82.6	85.5
	Civil servant	2.5	3.6
	Business person	7.5	3.6
	Casual worker		7.2
Primary occupation of household head	Farmer	71.3	91.9
	Civil servant	1.1	4.8
	Business person	2.6	
Farmer's goal	Subsistence	5.0	17.9
	Commercial		1.2
	Both	95.0	81.0
Major decision maker	Father	46.2	36.1
	Mother	13.8	18.1
	Joint	40.0	45.8

Education, household size and farming experience of the farmers

Variable	IPM		Non-IPM	
	mean	Std dev.	mean	Std dev.
Education of household head	8.08	1.10	7.15	4.19
Education of spouse	6.42	3.48	5.59	3.48
Household size	8.00	3.48	6.00	3.80
Farming experience	20.76	14.20	20.57	13.28
Cowpea farming experience	13.17	13.60	12.59	3.80

Appendix 3: Linear programming model for an IPM farmer

$Title ipm resource allocation model

Sets j Crops /groundnut1, groundnut2, cowpea1, cowpea2, maize1, maize2, sorghum1, sorghum2,cassava /

t Period /jan, feb, mar, apr, may, jun, jul, aug, sep, oct, nov, dec/;

table Landreq(t,j) months of land occupation by crop (hectares)

	groundnut1	groundnut2	cowpea1	cowpea2	maize1	maize2	sorghum1	Sorghum2	cassava
January	1		1		1		1		1
February	1		1		1		1		1
March	1		1		1		1		1
April	1		1		1		1		1
May									1
June									1
July									1
August		1		1		1		1	1
September		1		1		1		1	1
October		1		1		1		1	1
November		1		1		1		1	1
December									1

Parameters Yield (j) Crop yield (kg per hectare) /
groundnut1 =664.32, groundnut2 =703.31, cowpea1 =594.87, cowpea2 =399.57, maize1 =1009.41, maize2 =1190.22, sorghum1 =713.36, sorghum2 =550.84, cassava =1945.92/

Price (j) Crop prices (shs per kg) /
groundnut1 =934.40, groundnut2 =2083.68, cowpea1 =677.83, cowpea2 =1169.86, maize1 =335.46, maize2 =470.21, sorghum1 =390.59, sorghum2 =348.60, cassava =395.29/

flab (j) family labour requirement per crop per hectare (man days per ha) /
groundnut1 =143.24, groundnut2 =102.04, cowpea1 =139.35, cowpea2 =93.44, maize1 =128.84, maize2 =145.73, sorghum1 =106.00, sorghum2 =76.29, cassava =134.65/

hlab (j) hired labour requirement per crop per hectare (man days per ha) /
groundnut1 =114.71, groundnut2 =134.67, cowpea1 =52.22, cowpea2 =43.00, maize1 =66.53, maize2 =48.73, sorghum1 =39.81, sorghum2 =35.26, cassava =60.08/

fwage(j) family wagerate (ush per manday)/
groundnut1 = 830.22, groundnut2 = 368.56, cowpea1 = 89.50, cowpea2 = 976.99, maize1 = 785.28, maize2 = 936.64, sorghum1 = 886.31, sorghum2 = 332.2,

```
cassava = 813.87/

        hwage(j) hired wagerate (ush per manday)/
              groundnut1 = 1285.36, groundnut2 = 1376.49, cowpea1 = 753.56, cowpea2
= 1320.42, maize1 = 1200.15, maize2 = 1212.94, sorghum1 = 1425.32, sorghum2 =
1680.46, cassava = 1177.81/

        pcost (j) Crop production(cost of inputs) cost per hectare ( shillings per ha) /
              groundnut1 =126195.45, groundnut2 =131309.76, cowpea1 =63373.24,
cowpea2 =63291.06, maize1 =43712.93, maize2 =77194.79, sorghum1 =34285.78,
sorghum2 =30341.4, cassava =112968.42/

        mcrop (j) minimum crop acreage for crop enterprises (hectares) /
              groundnut1 =0.1 , groundnut2 =0.1 , cowpea1 =0.1 , cowpea2 =0.1 ,
maize1 =0.1 , maize2 =0.1 , sorghum1 =0.1 , sorghum2 =0.1, cassava =0.1 /

 Scalars    aLand  available land to the farmer(hectares)  / 2.48 /
            aflab  Family labour available (man days in a year)  /326.84  /
            ahlab  hired labour possible  (man days in a year)  /245.16/
            Workdays  Number of working days (days per month)      / 26 /
            acapt    capital available in a year (shillings)   /516025/;

 Variables  Xcrop (j) Cropping activities (hectares)
            GM    grossmargin        (shs)
            GMargin rev (sh)
            tlab(j)     total labour use (man days)
            flcost(j)   family labour cost     (shs)
            hlcost(j)   hired labour cost     (shs)
            TVP(j)   value of production   (shs)
            kcost(j)     production cost   (shs) ;

positive variable  xcrop, tlab;

Equations
            landbal    land balance       (hectares)
            acreage    crop land allocation (hectares)
            aTVP(j)    TVP accounting     (shs)
            acost(j)   pcost accounting  (shs)
            flbcost(j) family labour cost accounting  (shs)
            hlbcost(j) hired labour cost accounting  (shs)
            grossm(j)  gross margin          (shs)
            gross      objective function (sh)
            ;

 acreage (j)..      xcrop(j) =g= mcrop(j) ;
 landbal (t)..      sum(j, xcrop (j)*landreq (t,j)) =l= aland;
```

```
aTVP(j) ..      TVP(j) =e= xcrop(j)*yield(j)*price(j);
acost(j)..      kcost(j) =e= xcrop(j)*pcost(j);
flbcost (j)..   flcost(j) =e= xcrop(j)*flab(j)*fwage(j);
hlbcost (j)..   hlcost(j) =e= xcrop(j)*hlab(j)*hwage(j);
grossm(j)..     GMargin(j) =e= TVP(j) - kcost(j) -flcost(j) - hlcost(j) ;
gross ..        GM =e= sum(j,GMargin(j));


model ipm model /all/
solve ipm using lp maximising GM;
```

Appendix 4: Linear programming model for an IPM farmer

$Title non-ipm resource allocation model

Sets j Crops /groundnut1, groundnut2, cowpea1, cowpea2, maize1, maize2, sorghum1, sorghum2,cassava /

t Period /jan, feb, mar, apr, may, jun, jul, aug, sep, oct, nov, dec/;

table Landreq(t,j) months of land occupation by crop (hectares)

	groundnut1	groundnut2	cowpea1	cowpea2	maize1	maize2	sorghum1	sorghum2	cassava
January	1		1		1		1		1
February	1		1		1		1		1
March	1		1		1		1		1
April	1		1		1		1		1
May									1
June									1
July									1
August		1		1		1		1	1
September		1		1		1		1	1
October		1		1		1		1	1
November		1		1		1		1	1
December									1

Parameters Yield (j) Crop yield (kg per hectare) /
groundnut1 =409.33, groundnut2 =540.98, cowpea1 =442.95, cowpea2 =494.45, maize1 =919.47, maize2 =1284.78, sorghum1 =978.93, sorghum2 =363.97, cassava =2122.03/

Price (j) Crop prices (shs per kg) /
groundnut1 =730.92, groundnut2 =1115.85, cowpea1 =515.19, cowpea2 =663.50, maize1 =242.18, maize2 =247.11, sorghum1 =235.85, sorghum2 =324.00, cassava =314.64/

flab (j) family labour requirement per crop per hectare (man days per ha) /
groundnut1 =102.93, groundnut2 =137.55, cowpea1 =133.32, cowpea2 =119.21, maize1 =143.20, maize2 =181.32, sorghum1 =100.83, sorghum2 =78.73, cassava =447.33/

hlab (j) hired labour requirement per crop per hectare (man days per ha) /
groundnut1 =116.93, groundnut2 =108.96, cowpea1 =100.41, cowpea2 =70.48, maize1 =50.91, maize2 =79.11, sorghum1 =40.37, sorghum2 =22.12, cassava =65.55/

fwage(j) family wagerate (ush per manday)/
groundnut1 = 835.7, groundnut2 = 954.38, cowpea1 = 45.39, cowpea2 =949.93, maize1 = 822.77, maize2 = 927.73, sorghum1 = 966.88, sorghum2 = 909.09,cassava = 844.58/

hwage(j) hired wagerate (ush per manday)/
groundnut1 = 995.50, groundnut2 = 1108.10, cowpea1= 700.54, cowpea2 = 1264.57, maize1 = 1017.83, maize2 = 1132.41, sorghum1 = 1134.38, sorghum2 = 913.28,cassava = 1206.01/

pcost (j) Crop production(cost of inputs) cost per hectare (shillings per ha) /
groundnut1 =94428.07, groundnut2 =126637.40, cowpea1 =49991.37, cowpea2 =67908.33, maize1 =38773.75, maize2 = 18301.37, sorghum1 =13157.05, sorghum2 = 20110.92, cassava =54232.90/

mcrop (j) minimum crop acreage for crop enterprises (hectares) /
groundnut1 =0.1 , groundnut2 =0.1 , cowpea1 =0.1, cowpea2 =0.1 , maize1 =0.1 , maize2 =0.1 , sorghum1 =0.1 , sorghum2 =0.1, cassava =0.1 /

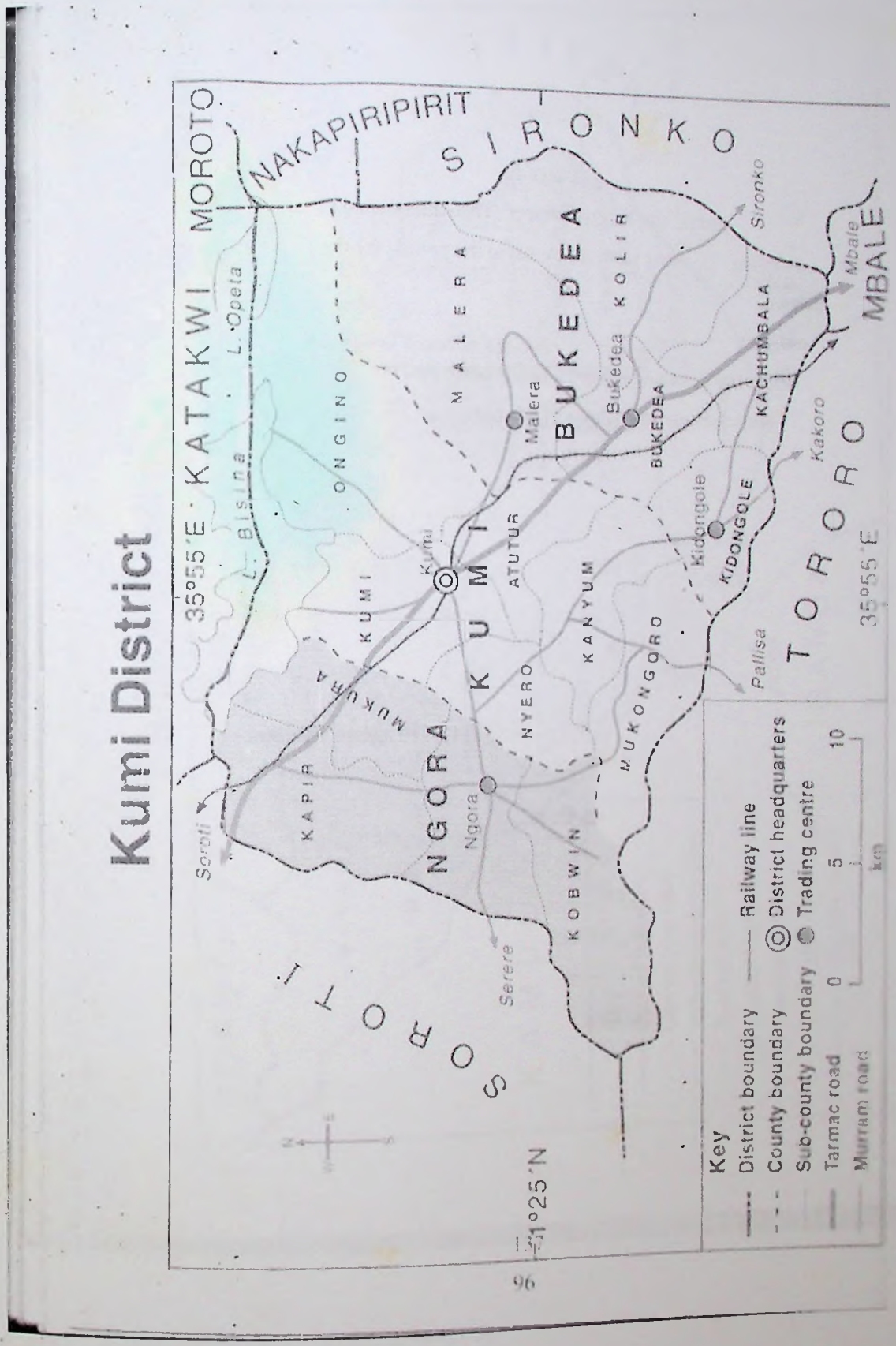
Scalars aLand available land to the farmer(hectares) / 2.32 /
aflab Family labour available (man days in a year) /326.84 /
ahlab hired labour possible (man days in a year) /245.16/
Workdays Number of working days (days per month) / 26 /
acapt capital available in a year (sh) /360000/;

Variables Xcrop (j) Cropping activities (hectares)
GM grossmargin (shs)
GMargin rev (sh)
tlab(j) total labour use (man days)
flcost(j) family labour cost (shs)
hlcost(j) hired labour cost (shs)
TVP(j) value of production (shs)
kcost(j) production cost (shs) ;

positive variable xcrop, tlab;

Equations
landbal land balance (hectares)
acreage crop land allocation (hectares)
flbbal(j) family labour balance (man days)
hlbbal(j) hired labour balance (man days)
kbal(j) capital balance (shs)
aTVP(j) TVP accounting (shs)
acost(j) pcost accounting (shs)
flbcost(j) family labour cost accounting (shs)
hlbcost(j) hired labour cost accounting (shs)

Appendix 5: Maps showing study area



Pallisa District

