PRODUCTION RISK AND INPUT USE IN BANANA PRODUCTION IN UGANDA

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DECLARATION

I, OLLEN WANDA HEREBY DECLARE THAT THE WORK EMBODIED IN THIS THESIS IS MY OWN AND HAS NEVER BEEN SUBMITTED FOR ANY AWARD IN ANY OTHER UNIVERSITY. WHERE OTHER SOURCES OF INFORMATION HAVE BEEN USED, THEY HAVE BEEN RIGHTLY ACKNOWLEDGED.

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DEDICATION

I dedicate this book to my late father Mr. Elimunsi Kahurubuka, may his soul rest in eternal peace.

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LIST OF ACRONYMS

APEP	Agricultural Productivity Enhancement Program
BBW	Banana Bacterial Wilt
FAO	Food and Agriculture Organisation
IITA	International Institute of Tropical Agriculture
MLS	Multi-Stage Linear Least Squares
MPP	Marginal Physical Product
MVP	Marginal Value Product
NARO	National Agriculture and Research Organisation
NGO	Non Governmental Organisation
OLS	Ordinary Least Squares
SPSS	Statistical Package for Social Scientists
SWC	Soil and Water Conservation
UBOS	Uganda Bureau of Statistic

ABSTRACT

This study investigated the effect of inputs and banana agronomic management practices on the mean yield and yield variability of bananas in Uganda. In addition, the study estimated returns from different inputs used in banana production. The study was based upon a survey of 403 banana producing households selected from the major banana producing regions of Uganda that included western, central and eastern covering 12 districts. The study used the Just and Pope stochastic production function specification to analyse the relationship between inputs and banana yield of farmers under production risk. Estimation of the returns from different inputs was achieved by determination of marginal value products and the total value products. The results showed that generally, labour, performance of agronomic management practices, use of fertiliser, mulch and manure were the most important factors affecting mean yields of bananas in the study area. Findings further revealed that the marginal value products of all the inputs used in banana production were higher than the marginal input costs established at prevailing market prices implying that additional use of the above inputs is profitable.

In addition, labour, mulch and manure had a negative effect on variability in banana yields while fertiliser, agronomic frequency and extension increased the variability in yields of bananas across the sample farmers and hence are yield risk increasing. Given the high cost of fertiliser and its unavailability, manure and mulch use remain the only viable alternatives and hence promotion of their use should be emphasized in the extension package. Promotion of use of complementary agronomic practices such as weeding, deleafing, desuckering among others in addition to inputs should be given adequate emphasis in the extension package to enable farmers achieve stable yield levels. Overall, results imply that in addition to their effect on mean yields of crops, inputs and agronomic practices should be tested for their effect on yield variability in the target areas.

CHAPTER ONE

INTRODUCTION

1.1 Background

Banana is the single most important staple crop in Uganda contributing about 30 percent of total food consumption and 14 percent of total crop value. About 24 percent of all agricultural households are engaged in banana production (Kalyebara *et al.* 2005). Compared to other important crops in the country, banana occupies the biggest proportion of utilized agricultural land (about 1.4 million hectares or 38 percent of the total utilized land), making it the most widely grown crop and serves as one of the most important food security crops for central, western and eastern Uganda (NARO, 2001). Uganda is currently the world's largest producer and consumer of bananas, accounting for approximately 10 percent of total global production (FAOSTAT, 2006).

However, Uganda is among the smallest exporters as most of its production is consumed domestically, with some regional trade and very small quantities exported to Europe. Although the export potential for bananas produced in Uganda appears to be limited, the future prospects for local banana markets look good (Tushemereirwe *et al*., 2003). The main constraint limiting the profitability of banana marketing stems from the high cost of transportation from major suppliers who are over 300 kilometers away from the major market located in the capital Kampala. Transport costs account for as high as 80 per cent of total marketing costs (NARO, 2005). In Uganda, banana can be used in many ways and forms. It is eaten as cooked food, juice or beer, as roasted or sweet snacks, or as dessert. The cooked food and juice also have cultural functions in some stages of the wedding and funeral rites. The different parts of the crop have different uses in the daily life of a farm household.

Uganda is the second greatest centre of banana diversity after East Asia (Edmeades *et al*., 2005).

Banana varieties grown in Uganda are differentiated by the differences in their genome groups and observable characteristics. Edmeades *et al*. (2005) classify the bananas grown in Uganda as either endemic (or consistently present) in East Africa and non-endemic. An estimated 61 percent of the national banana crop is produced in the western region of the country, 30 percent produced in the central region and the remainder in the eastern region (UBOS, 2002). Most banana production takes place on small scale subsistence farms of less than 0.5 ha (Gold *et al*., 1999). The crop is mainly grown for home consumption and a contribution of 8 to 22 percent of rural revenue is realized (Ssenyonga *et al*., 1999).

In the past few decades, bananas were a highly sustainable crop in Uganda, with a long plantation life and stable yields. Over the last 30 years, banana production patterns have been changing, with acreage increasing or stable in most of the western region, while declining mostly in the central and eastern regions. Also banana productivity has been declining, from more than 18 kgs per bunch in 1971 to, in some cases, less than 1 kg per bunch (Woomer *et al*., 1998). The acreage shift and productivity decline have been attributed to the increasing severity of production constraints, particularly the declining soil fertility, pests and diseases that severely reduced production in some areas (Rubaihayo, 1991; Gold *et al*., 1999). Included among the most widespread pests and diseases are weevils, banana nematodes, Black Sigatoka disease, Panama disease or *Fusarium* wilt, and banana bacterial wilt (BBW), which cause significant yield reductions of up to 80 percent (Katungi *et al*., 2007).

Faced with the decline in national banana crop yields, the government and NGO have identified and developed a number of management technologies that show potential for alleviating disease constraints, and consequently, for increasing yields and reversing the downward trend in banana yields. Banana is a highly competitive crop in Uganda in terms of profitability compared to other crops but its competitiveness depends on the level of management (Bagamba *et al.*, 1999). Thus factors that affect the choice of management practices influence the returns from the crop. The recommended management technologies involve both the management of the natural resource base and that related to the crop itself (Katungi *et al.,* 2007). Natural resource management practices recommended for banana production include: mulching, manure application and construction of bands along contours for soil and water conservation. Mulching is done with dry organic materials that are spread between the banana mats to suppress weed growth, conserve soil moisture and add nutrients to the soil when the organic materials are decayed. In addition to mulching, farmers are advised to apply certain other fertilizers in restoring the nutrients lost due to crop harvests (Tushemereirwe *et al.,* 2003).

Further more, farmers are encouraged to carry out a number of other crop management practices to ensure good sanitation in plantations in order to reduce pests and disease infestation as well as contributing to the good management of soil fertility (Robinson, 2000). Sanitation practices include corm pairing (removal of the outer sheath from the corm of a sucker before planting it), de-trashing or de-leafing (removal of dry leaves and sheath), de-suckering (removal of excess plants on a mat) and a number of post-harvest residue management practices (stumping, corm removal, splitting or chopping pseudo-stems, and weevil trapping). However, most of the practices and inputs recommended for banana management are used irregularly and sometimes not all, which encourages bare soil between mats, where erosion starts too readily and where pests (e.g. weeds, weevils, nematodes etc.) are allowed to take hold (Katungi *et al.*, 2007).

There is a wide acceptance amongst scholars of rural development that farmers only partially adopt or do not adopt at all even when the new technologies provide higher returns to land and labor than the traditional technologies (Yusuf, 2003). Agricultural production is typically a risky business and farmers face a variety of price, yield and resource risk which make their income unstable from year to year. Due to unstable incomes, farmers are more likely to increase the use of yield risk reducing innovations and decrease the use of yield risk increasing innovations (Koundouri *et al.*, 2006).

1.2 Statement of the Problem

There is consensus in rural development literature that technological change is crucial in achieving sustained agricultural productivity growth. Despite the importance of bananas in the nation's farming systems, actual banana yields are low (5-30 tonnes/hectare/year) when compared to potential yields (50-70 tonnes/hectare/year) and continue to decline due to increasing diseases, pests, drought and soil fertility decline (Kalyebara *et al.,* 2005). The decline in yields is exacerbated by the fact that bananas are heavy feeders requiring large quantities of nutrients especially potassium and nitrogen. Although banana residues are recycled, large quantities of nutrients go into the fruit, which are lost when the fruit is harvested (Tushemereirwe *et al.,* 2003). To restore nutrients to the soil, farmers have been advised to use animal manure, mulch, other organic manure (composted crop residue) and artificial fertilizers. However, use of such yield augmenting practices necessary for restoring soil fertility has remained low and factors that influence their use have not been well established.

In addition, a substantial amount of adoption literature (Hiebert, 1974; Feder *et al*, 1985; Feder and Umali, 1993; and Cornejo and McBride, 2002) has reported on the determinants of adoption and a good deal of it showing that poor farmers are risk-averse (Moscardi and de Janvry, 1977; Dillon and Scandizzo, 1978; Binswanger, 1980; 1981), and that their production decisions are characterized by a high degree of uncertainty (Roumasset, 1976). Uncertainty results into variability in yields which exposes the farmer to production risk (Hurd, 1994). Faced with the variability in yields, Pope and Kramer (1979) show that a risk averse farmer tends to use more of yield risk reducing technologies and less of yield risk inducing technologies than a risk neutral farmer. If risk plays an important role in farmer decision making, it is inevitable that it will affect agricultural productivity and hence, growth and development. Past research on agricultural technology adoption in Uganda has concentrated only on socio-economic factors that influence adoption. However, in a period when use of yield enhancing practices has remained low, it is imperative to further explore the effect that considerations of risk have on adoption of agricultural technologies by farmers.

1.3 Objectives of the study

The overall objective of the study was to investigate and estimate the returns from agricultural inputs as well as effect of use of these inputs and other agronomic practices on banana yields variability in Uganda. The specific objectives are;

1. To examine the socio-economic characteristics of banana farmers in the study sample

2. To determine the effect of inputs and agronomic practices on variability in yields of bananas

3. To estimate the returns to use of inputs in banana production

1.4 Hypotheses

1. Fertilizer, manure and mulch decrease banana yield variability and hence are yield risk decreasing.

2. All inputs provide positive returns to banana production.

1.5 Justification

Agricultural producers make decisions in a risky environment resulting from production (weather, disease, pests etc.), market and price (input and output), and financial (interest rates) uncertainty. How farmers manage these risks is greatly influenced by their attitudes toward or willingness to take risk (Bard and Barry, 2001). There is strong evidence that farmers are universally risk averse and that they seek to avoid risk through various institutional and managerial mechanisms (Binswanger, 1980). For example they may diversify their crops, favor traditional farming techniques using less modern inputs, and enter into share cropping arrangements. Empirical research shows that risk averse producers optimally use less of a risk inducing input than they would under certainty (Hurd, 1994).

Increasing yields and hence mitigating the downward trend in banana production requires the use of improved inputs and management technologies in the face of production, market and price uncertainty. Therefore any insights into the influence of these improved inputs and management practices on the production risk faced by the farmers makes it possible in turn to determine packages of technological and institutional practices optimally tailored to smallholder farmer's economic behavior (Moscardi and de Janvry, 1977).

Studies on banana technology adoption in Uganda like Tushemereirwe *et al.* (2003) and Katungi *et al*. (2007) have concentrated on socio-economic factors with little insight on the risk nature of these technologies and inputs that impinges on their use. Knowledge of how banana farmers make decisions in the face of production uncertainty will assist practitioners in agricultural development in Uganda in developing appropriate extension packages. In addition, this study will contribute to literature by determining the returns to use of inputs as well as effect of these inputs and improved agronomic technologies on variability in yields of bananas.

CHAPTER TWO

LITERATURE REVIEW

2.1 Risk in agricultural production

Agricultural production is generally a risky process, and considerable evidence exists to suggest that farmers behave in risk-averse ways (Hazzell, 1982). Agricultural risk is associated with negative outcomes stemming from imperfectly predictable biological, climatic, and price variables. These variables include natural adversities (for example, pests and diseases), climatic factors not within the control of agricultural producers, and adverse changes in both input and output prices (World Bank, 2005). Agricultural risk can be categorized into two main types namely, production risk which is characterized by high variability of production outcomes and price risk resulting from volatility of the prices of agricultural output and inputs. The effect of risk and uncertainty is more significant in developing countries due to market imperfections, asymmetric information and poor communication networks (Fufa and Hassan, 2003). As a result, increased income risk is itself a loss of welfare to risk-averse households and might make modern crop technology less attractive to farmers leading to delay of agricultural development in developing countries.

The stochastic nature of agricultural production is in most cases a major source of risk, this is because as Antle (1983) notes, variability in yield is not only explained by factors outside the control of the farmer such as input and output prices, but also by controllable factors such as varying the levels of inputs. A risk averse farmer thus uses more (less) of a risk reducing (increasing) factor than a risk neutral farmer (Pope and Kramer, 1979). It follows that production risk has an important bearing in the design and transfer of new agricultural technologies as the rate of adoption is dependent not only on the yield but also on their risk effects (de Janvery, 1972). Thus, neglect of risk-averse behavior in agricultural models can lead to important overstatements of the output levels of risky enterprises, to overly specialized cropping patterns, and to biased estimates of the supply elasticities of individual commodities (Hazzell, 1982).

2.2 Empirical estimation of risk in agriculture

In agricultural production, risk plays an important role both in input use decisions and production of output (Kumbhakar, 2002). Considerable research has attempted to provide empirical evidence on how risk influences the nature of decisions in agricultural production. These attempts can be categorized into two groups of studies. The first group has aimed at estimating producer's attitude towards risk that influence input allocation and output supply decisions. These studies have employed either the experimental or econometric approaches to elicit risk attitudes of individual producers. The experimental approach is based on hypothetical questionnaires regarding risky alternatives or risky games with or without real payments (Wik *et al.*, 2004). Among the studies that have employed this approach include; Binswanger (1980, 1981) that used risky games with real payments to measure Peasant's risk preferences in an experiment in India.

The econometric approach is based on individuals' actual behaviour assuming expected utility maximisation. Studies that have used this approach to elicit producer's risk attitudes include; Antle (1983), Love and Bucolla (1991), Pope and Just (1991). However, the econometric approach has been criticized for confounding risk behaviour with other factors such as resource constraints faced by individual decision makers (Wik *et al.*, 2004). This is particularly important in developing countries where market imperfections are prominent and production and consumption decisions therefore are non-separable (Sadoulet and de Janvry, 1995).

The second group of studies have attempted to investigate influence of risk on agriculture production by directly incorporating a measure of risk in the traditional production functions.

Such studies include work by Just and Pope (1979) who focused on production risk, measured by the variance of output, and suggested use of the production function specifications satisfying some desirable properties. The main focus in their specification is to allow inputs to be either risk increasing or risk decreasing. The Just-Pope framework, however, does not take into account producer's attitude towards risk (Kumbhakar, 2002). Love and Buccola (1991) extended the Just-Pope function to consider producer's risk preferences in a joint analysis of input allocation and output supply decisions.

2.3 Econometric estimation of production risk

Risk considerations are necessary in the analysis of the agricultural sector as there exist a number of possible cases where intelligent policy formulation should consider not only the marginal contribution of input use to the mean of output, but also the marginal reduction in the variance of output (Koundouri *et al*., 2007). Since these inputs may be used both to increase output and output variability, changes in their utilization have implications for output variability. However, traditional econometric methods used in the analysis of agricultural production processes have implicitly introduced assumptions that preclude the opportunity to investigate the effect of inputs on output variability. To correct the restrictive nature of these traditional stochastic models, several methodologies have been developed to analyze the impact of production related risks and levels of inputs used on the distribution of yield (Fufa and Hassan, 2003). The traditional approach to evaluating the impact of the choice of inputs on production risk makes implicit, if not explicit assumptions to the effect that inputs increase risk. Just and Pope (1978) who identified this restrictiveness, proposed a more general stochastic specification of the production function which includes two general functions: one which specifies the effects of inputs on the mean of output and another on its variance, thus allowing inputs to be either risk-increasing or risk-decreasing (Koundouri, 2006).

While Just and Pope's model is flexible, as it does not restrict the effects of inputs on the variance to be related to the mean, it imposes restrictions on the relations between inputs and third and higher moments of output. Antle (1983) proposed a flexible moment based approach to stochastic production technology specification where all moments of the distribution of output are considered as function of input levels. However, moments beyond variance have been found to be insignificant components of the distribution of output (Anderson *et al.*, 1977). The Just-Pope stochastic production function model is appropriate for analyzing the risk effects of inputs on output distribution in cross sectional, time series and combination of time series and cross sectional production data (Fufa and Hassan, 2003). In this study, the Just and Pope stochastic production function is used to analyze the effect of inputs and improved agronomic practices on the distribution of banana yields in Central, Eastern and Western Uganda.

2.4 Empirical use of Just and Pope stochastic production function

Just and Pope (1979) modified the traditional stochastic models of agricultural production processes to facilitate more flexibility regarding risk. The basic concept introduced by Just and

Pope was to construct the production function as the sum of two components, one relating to the mean output level and one relating to the variability of output. This specification allows the econometrician to differentiate the impact of input on output and risk, and has sufficient flexibility to accommodate both positive and negative marginal risks with respect to inputs. Thus, a production function can be represented as a stochastic process where the distribution of yield is conditionally determined by input levels and the technology parameters (Fufa and Hassan, 2003).

A number of empirical studies such as Farnsworth and Moffitt (1981), Smale *et al*. (1998), Fufa and Hassan (2003) and Di Falco *et al*. (2007) have used Just and Pope stochastic production function to determine the effect of inputs and levels of input use as well as technology on output distribution. Farnsworth and Moffitt (1981) used the risk flexible Just and Pope Production model to examine cotton production under risk in California. Their results indicated that farm machinery, labor and fertilizer were risk reducing. They argued that in the cases of labor and machinery, increasing these inputs should permit growers to respond more rapidly to problems, particularly during harvest when a rapid response may be crucial in reducing crop losses. They further observed that fertilizers reduce yield variability by maintaining plant volatility despite occurrence of adverse weather conditions or agricultural pests. This is because the fertilizer-induced overgrowth offers a prime breeding ground and unlimited food source.

Fufa and Hassan (2003) used the Just and Pope stochastic production technology specification to analyze the crop production and supply response behavior of farmers in Ethiopia under production risk. Their results showed that improved seed and fertilizer were risk increasing inputs in the production of maize and sorghum crops. They noted that the risk increasing nature of fertilizers could be attributed to variation in interaction between the levels of fertilizer used and other inputs. For example, high levels of fertilizer used with inadequate moisture burn the crop leading to low crop yield levels and in instances where there is adequate moisture, increased use of fertilizer leads to higher crop yields. They also observed that early planting, use of hired labor and oxen labor for crops grown were found to have yield risk reducing effects.

2.5 Functional forms of the Just and Pope Production Function

The commonly used functional forms of production functions are the Cobb-Douglas, quadratic and the translog. The unrestricted translog production function is sometimes preferred because it is general and flexible and allows analysis of interaction of variables (Byiringiro and Reardon, 1996). The Cobb-Douglas is a special case of a translog function, when the interaction terms have zero coefficients (Gujarati, 1995). Unlike the Cobb-Douglas, the translog function does not always generate elasticities of substitution of one, and the isoquant and marginal products derived from the translog depend on the coefficients on the interaction terms. However, under low-input agriculture, most smallholder farmers produce on the increasing side of the production function, and the translog production function may not represent an actual data generating process (Kaliba and Rabele, 2004).

Because of these and other reasons, the study chose to use a Cobb-Douglas production function to estimate the relationship between banana output, inputs, and management practices used. The Cobb-Douglas production function in its general form is multiplicative and exponential but it is linearised by transformation into logs. The logarithmic transformation of the production function provides a log-linear form which is convenient and commonly used in econometric analyses using linear regression techniques. One of the challenges with using logarithmic functional forms with the data available for this study is the presence of zero values for many variables/inputs included because not all the farmers use the inputs included in the model like fertilizers, manure and mulch. This non-use of some inputs creates a zero input problem which would require a new specification of the Cobb-Douglas production function that is somehow different from one considered when all the inputs are fully used.

A number of solutions have been suggested by researchers to treat the zero input problem. One such remedy is to apply a quadratic production function instead of the logarithmic specification. However, this has the major limitation of affecting the global concavity of the production surface (Sousa *et al.*, 2006). Another possibility is to consider only those farmers who have positive values of the key inputs or explanatory variables. However, as Battese (1997) observed, confining the analysis to only those farmers who apply a positive amount of the fertilizer may not be the most appropriate method of estimation because the data on farmers who applied no fertilizer may be useful in estimation of the parameters which are common to all farmers. Another commonly proposed solution to the zero observation problem is by substitution of zero in the non-use cases by one or an arbitrary small number greater than zero. However, as Battese (1997) further adds, if the number of zero cases is a significant proportion of the total number of sample observations, then the procedure may result in seriously biased estimators of the parameters of the production. Battese proposed a modification of the Cobb-Douglas production function to solve the zero observation problem where by a dummy variable is introduced such that efficient estimators are obtained using the full data set but no bias is introduced. In this method, a dummy variable for each unused input is introduced that takes a value of one if the farmer did not use the input and a value of zero if farmers reported use of the input. The important assumption of this procedure is that farmers who did not use any inputs have different intercept from those who used the input. This assumption is true if the parameter/coefficient of the dummy variable introduced is statistically different from zero.

CHAPTER THREE

METHODOLOGY

3.1 The study area

This study was conducted in major banana producing regions of Uganda that is eastern, central and western Uganda covering 12 districts. The districts are; Masaka, Mbale, Bushenyi, Mbarara, Luwero, Mpigi, Wakiso, Mukono, Isingiro, Manafwa, Bududa and Rakai. These districts lie in the banana coffee system that is characterized by fertile soils and more reliable rainfall of over 1000mm on average (Nabbumba and Bahiigwa, 2003). It is able to sustain the growth of a variety of crops including coffee, banana, maize, sorghum, finger millet, beans, ground nuts, root crops and vegetables plus other horticultural crops. Livestock production also plays an important role in farmers' livelihoods. The livestock reared in this zone include cattle, goats which are either tethered or kept in fenced off areas.

All the districts selected are beneficiaries of Agricultural Productivity Enhancement Program (APEP) technology transfer program which used field demonstrations as a means to increase banana productivity and as part of the extension package; some farmers received free inputs like fertilizers. It is through these demonstration sites that farmers were exposed to appropriate technology transfer package that include: improved banana crop management practices which involve use of both organic fertilizers like manure and mulch, and inorganic fertilizers to restore soil fertility. In addition, farmers were advised to carry out a number of other crop management practices to ensure good sanitation in their plantations in order to reduce pests and disease infestation.

In this study a total of 12 districts were purposively selected from three regions namely Masaka, Luwero, Mpigi, Wakiso, Mukono and Rakai from central region, Bushenyi, Mbarara and Isingiiro were selected from western while Mbale, Manafwa and Bududa were chosen from the east. The choice of the districts was based on participation in the APEP/IITA banana project.

3.2 Sampling procedure and sample selection

A sample of respondents for the study was obtained through the use of a combination of purposive and simple random sampling procedures. The total sample for the study was 403 farmers of which 93 were project farmers while 310 were not participating in the project. The sample farmers were selected with the help of project personnel and local leaders. All the sub-counties where APEP/IITA banana project had demonstration plots were chosen and all the participating farmers in the project were included in the sample. In addition, with in the same sub-county non-participants in the project were randomly selected so that the total number of farmers chosen in each sub-county was 12. Given that 35 sub-counties were considered, the total number of farmers sampled for the study was 420 from 12 districts in the three regions. However, 17 sampled respondents were unable to participate in the study which brought the actual number of sampled observations to 403.

3.3 Data Collection

The study used primary data that were collected using a structured questionnaire administered by the researcher with the assistance of enumerators in face to face interviews. The interviews were supplemented with on-farm observations to harmonize the responses given. The data collected covered different farmers' socio-economic and demographic characteristics that included: age and gender of the household head, output from banana plots, size of land (hectares), labor used in banana plots (in person days), farming experience (years), banana management practices such as, frequency of deleafing, sheaths removal, removal of corms, de-suckering, frequency and amount of mulch applied, price of bananas (Ushs per bunch), price of fertilizer (Ushs per kg). The data were collected from October to December 2007. The data from questionnaires were entered in excel and cleaned to eliminate errors and then analyzed.

3.4 Analytical Methods

3.4.1 The Theoretical framework

Positive approaches to supply response analysis use econometric methods that involve the estimation of the production technology parameters from observed input and output values (Fufa and Hassan, 2003). The deterministic production technology specifies production relations in terms of mean input and output levels. Alternative specifications of the stochastic production function involve the inclusion of the error term to the deterministic production function to reflect the effect of uncontrollable factors such as weather and technical inefficiency in production. According to the traditional econometric specifications of stochastic production function, if any input has a positive effect on the mean of output, then a positive effect on variability of output is also imposed (Just and Pope, 1979). However, the effects of any input on mean output should not be tied to the effects of inputs on variability of output a priori (Fufa and Hassan, 2003).

Adequate production function specifications should include specifications that show the effect of input on both the mean and the variance of output (Just and Pope, 1979). However, the Just and Pope model imposes restrictions on the relations between inputs and third and higher moments of output (Koundouri *et al.,* 2006). Antle (1983) proposed a flexible moment based approach to stochastic production technology specification where all moments of the distribution of output are considered as function of input levels. The stochastic production function model and the moment-based model of production technology specification are appropriate for analyzing the risk effects of inputs on output distribution in cross sectional, time series and panel data. However, moments beyond variance were found to be insignificant components of the distribution of output (Anderson *et al.*, 1977). In this study the Just and Pope stochastic production function was used to determine the effect of inputs as well as different improved banana agronomic management technologies on yield distribution in bananas.

Consider a farm household involved in the production of output y. The farm technology is represented by the production function $y = g(x, v)$, where y is output, x is a vector of controllable inputs such as fertilizers, land, labor, agronomic practice, v is a vector of non-controllable inputs such as weather conditions, and g(x, v) denotes the largest feasible output given x and v (Di Falco *et al.,* 2007). This study focused on the scale of production uncertainty as represented by the stochastic production function $y = g(x, v)$. Just and Pope (1978) proposed to specify $g(x,v) = f(x,\beta) + [h(x,\theta)]^{1/2}\varepsilon$, where $h(x) > 0$ and ε is a random variable with mean zero and variance 1. In this context, the Just-Pope production function is

$$y = f(x,\beta) + h^{1/2}(x,\theta)\varepsilon \ \ldots\ldots\ldots\ldots\ldots \ (1)$$

This implies that $f(x,\beta)$ represents the mean production function, while $h(x,\theta)$ is the variance of output: $E(y) = f(x,\beta)$ and $\text{var}(y) = \text{var}(\varepsilon)h(x,\theta) = h(x,\theta)$

Just and Pope developed this production model and its properties with emphasis on its flexibility with respect to impact of inputs on the variance of output (Farnsworth and Moffitt, 1981).

Given $\partial\,\text{var}(y)/\partial x = \partial h/\partial x$, it follows that $\partial h/dx < 0$ identifies inputs that are risk decreasing, while $\partial h/dx > 0$ identifies inputs that are risk increasing (Di Falco *et al.,* 2007). Note that $[h(x,\theta)]^{1/2}\varepsilon$ behaves like an error term with mean zero and variance $h(x,\theta)$. This reflects the fact that the Just - Pope specification corresponds to a regression model with heteroscedastic error terms.

Several econometric procedures have been developed to correct for heteroscedasticity in such cases. Following Just and Pope (1979), a Multi stage Non-linear Least squares (MNLS) estimation procedure can be applied to generate consistent and asymptotically efficient estimates of the parameters of the stochastic production function in equation 1. Hurd (1994) proposed a multi-stage linear least squares estimation procedure that involves three steps and it is what this study followed.

Let the stochastic production function in equation 1 be represented as $y = f(x,\beta) + u$ where $u = h^{1/2}(x,\theta)\varepsilon$. The first step concerns the empirical specification of the model and the use of ordinary least squares (OLS) to obtain consistent estimates of $\hat{\beta}$ and $\hat{u}$ from the regression of y on $f(x,\beta)$ or in logarithms, $\ln y$ on $\ln f(x,\beta)$. The residual, $\hat{u}$ is then calculated as: $\hat{u} = y - f(x,\hat{\beta}) = \hat{h}(x,\theta)\varepsilon$ or $\hat{u} = \ln y - \ln f(x,\hat{\beta})$ --------- (2).

Next, the estimated residues $\hat{u}$ are squared and transformed by taking natural logarithms and then regressed on the inputs to obtain consistent estimates of $\hat{\theta}$.

In the final step, these estimates of $\hat{\theta}$ are used to construct a feasible generalized least squares estimate $\hat{\beta}$ that is both consistent and efficient.

A consistent estimator of β is finally obtained by weighted regression of y^* on $f^*(x,\beta)$ or $\ln y$ on $\ln f(x,\beta)$

where, $y^* = \dfrac{\ln y}{h^{1/2}(x,\hat{\theta})}$, $f^* = \dfrac{f(x,\beta)}{h^{1/2}(x,\hat{\theta})}$ or $y^* = \dfrac{\ln y}{1/2 \ln h(x,\hat{\theta})}$, $f^* = \dfrac{\ln f(x,\beta)}{1/2 \ln h(x,\hat{\theta})}$ -------------(3)

If the function $y = f(x,\beta)$ is heteroscedastic, the predicted values of the residuals from the regression on the explanatory variables will enable to capture the values of the residuals related to these variables (Fufa and Hassan, 2003). The weighting of this function by the predicted values of the residues from equation 2 will give consistent and asymptotically efficient parameter estimates of the function.

3.4.2 Empirical Model Specification

The Just – Pope stochastic production provides a convenient and flexible representation of the effects of inputs on means and variances (Di Falco *et al.*, 2007). Widely used, this study applied it to investigate the effects of inputs and agronomic management practices on banana yield variability to answer objective two. The production function takes the form $Y_i = f(x,\beta) + h(x,\alpha)u_i$ ….(2) Where Y_i is banana yield, x is a vector of explanatory variables, β and α are parameter vectors, and u_i is a random variable with zero mean. Taking the expectation and variance of the above function, the mean relationship is $E(y) = f(x, \beta)$, and variance relationship is $v(y) = h^{1/2}(x, \alpha)\varepsilon$. Explanatory variables need not be identical between the mean and variance functions (Di Falco *et al.*, 2007).

The mean and variance relationships $f(x, \beta) + h(x, \alpha)u_i$ were specified as a Cobb-Douglas type of production function which incorporates stochastic aspects (Farnsworth and Moffitt, 1981). Although it imposes well known restrictions on production parameters, the Cobb-Douglas functional form is frequently used in partial productivity studies (Smale *et al.,* 1998). The mean function $f(x, \beta)$ is specified as,

$$Y_i = A \prod_{i=1}^{m} X_i^{\beta_i} u_i \text{ ------------- (4)}$$

Y_i is the banana output per hectare for the i[th] farmer, β_i is the vector of coefficients, X_i is a vector of explanatory variables, A is the technology parameter and u_i is the error term.

A logarithmic transformation of equation (4) for the mean function gives a linear function,

$$\begin{aligned} \ln YIELD = {} & \ln \beta_0 + \beta_1 \ln LAB + \beta_2 \ln FERT + (\beta_0 - \lambda_2) D_1 FERT + \beta_3 \ln MAN + \\ & (\beta_0 - \lambda_3) D_2 MAN + \beta_4 \ln MUL + (\beta_0 - \lambda_4) D_3 MUL + \beta_5 \ln AGRO + \\ & \beta_6 \ln EXT + \beta_7 \ln EDU + u_i \end{aligned} \text{ --------- (5)}$$

Where LAB, FERT, MAN, MUL, AGRO, EXT and EDU are the explanatory variables that influence banana yields and they are explained as;

YIELD= Banana yields in Kilograms per hectare (kg/ha).

LAB= Quantity of labor used in person hours/hectare

FERT= Amount of fertilizer used per hectare (Kg/ha)

MAN= Amount of manure applied in kilograms per hectare (kg/ha)

MUL= Bundles of dry grass or crop residue used for mulching (bundles/ha)

AGRO= Agronomic frequency, captures the average frequency of deleafing, weeding, sheaths removal, removal of corms, de-suckering in a year.

EDU= Education level of the household head (number of years of formal schooling).

EXT= Frequency of extension visits received by farmer six months before the survey.

D_1FERT , D_2MAN , D_3MUL = Dummy variable introduced to capture the influence of non-use of inputs fertilizer, manure and mulch as suggested by Battese (1997). The dummy variable is such that: D_1FERT = 1 if the farmer did not use the input, D_1FERT = 0 if the farmer reported the use of the input. In addition, according to this approach, the zeros reported for non-use of input are replaced by ones for the model to be identified.

$\beta_1 - \beta_7$ are coefficients associated with each explanatory variable. A coefficient measures the partial elasticity of production of factor i, which is the percentage change in yields, given the percentage change in the input used while holding other inputs constant. β_0 is a technology constant.

The variance function $h^{1/2}(x,\alpha)$ was also specified as a Cobb-Douglas type of production function, $h^{1/2}(y) = A\prod_{i=1}^{m} X_i^{\alpha_i} v_i$

Logarithmic transformation of the variance function yields the linear function

$$\ln h^{1/2}(YIELD) = \ln\alpha_0 + \alpha_1 \ln LAB + \alpha_2 \ln FERT + (\alpha_0 - \lambda_2)D_1FERT + \alpha_3 \ln MAN + (\alpha_0 - \lambda_3)D_2MAN + \alpha_4 \ln MUL + (\alpha_0 - \lambda_4)D_3MUL + \alpha_5 \ln AGRO + \alpha_6 \ln EXT + v_i \quad \text{------- (4)}$$

Where LAB, FERT, MAN, MUL, AGRO and EXT are the explanatory variables that influence banana output variance and they are the similar variables that influence mean yield as earlier indicated. $\alpha_1 - \alpha_n$ represents the coefficients associated with the explanatory variables that contribute to the variability in banana output. v_i is the random error term with mean zero and variance 1. As in the mean function, $D_1 FERT$, $D_2 MAN$, $D_3 MUL$ are the dummy variables introduced to capture the influence of non-use of input.

Given the above parametric forms for $f(x, \beta)$ and $h^{1/2}(x, \alpha)$, the model can be consistently and efficiently estimated using a Multi stage linear Least squares (MLS) as proposed by (Hurd, 1994). The model and econometric approach enable us to explore the role of inputs and agronomic practices on yield variability in banana production.

The coded data were entered into excel and analyzed using SPSS 12 and STATA 9 analytical tools. Descriptive statistics (mean, frequencies, standard deviation) were generated first for all variables to spot any data entry errors and to examine the nature of the data such as presence of outliers. Econometric analysis based on multistage linear least squares estimation procedure was used to generate consistent and asymptotically efficient estimates of the parameters for the specified models that answered objectives one and two. The estimation procedure involved three steps. The first step involved empirical specification of the model and the use of ordinary least squares (OLS) to obtain consistent estimates of β & and u in equation (2) reproduced below.

$$Y_i = f(x, \beta) + h(x, \alpha) u_i$$

Next, the estimated residuals $\hat{u}$ were squared and transformed by taking natural logarithms and then regressed on the inputs to obtain consistent estimates of $\hat{\alpha}$. In the final step, these estimates of $\hat{\alpha}$ were used to construct a feasible generalized least squares estimate $\hat{\beta}$ that is both consistent and efficient. The estimated values of the regression coefficients were tested for statistical significance using the t-test.

Objective two sought to estimate the returns from inputs used in banana production. From the mean Cobb-Douglas type production function estimated, the marginal physical products for all the input were calculated and then the corresponding value of marginal products. The computed value of marginal products for the different inputs and agronomic practices were compared with the respective marginal costs. Total returns were captured as the total value product of the input used. Given the estimated Cobb-Douglas type of production function for bananas, the marginal physical product for input X_i can be derived as follows,

$Mpp_{x_i} = \frac{\Delta Y}{\Delta X_i} = \beta_i \frac{Y}{X_i}$ Where Y is the geometrical mean of the yields (that is the mean of its natural logarithm); X_i is the geometric mean of input X_i, β_i is the ordinary least square (OLS) estimated coefficient of input X_i which is also the elasticity of input X_i (Grazhdaninova and Lerman, 2005). The respective marginal value products (MVP) were obtained by multiplying MPP with the price of banana output P_y (Ushs). Therefore, $MVP_{x_i} = MPP_{x_i} * P_y$ where p_y is the price of banana output. The MVP obtained measured the increase in the value of banana output when one additional unit of input was employed. Total value product (TVP) measured the returns of input use per hectare and was calculated by multiplying the MVP of the input with the amount of input used per hectare (X_i) that is $TVP = MVP_{x_i} * X_i$. Returns of the given input were determined by comparing the marginal value product of input X_i (MVP_{x_i}) with the marginal input cost (MC). Banana farmers were assumed to be price takers in the input market, so that the price of input X_i approximates to marginal input cost (MC). If $MVP_{x_i} > P_{x_i}$, input X_i is underused and farm profits can be raised by increasing the use of this input. If, conversely, $MVP_{x_i} < P_{x_i}$, the input is overused and to raise farm profits its use should be reduced.

The point of maximum profit is reached when $MVP_{x_i} = P_{x_i}$

3.5.3 Definition of variables and a priori expectations

Banana yields (Y_i) were determined from farm level data and used as the dependent variable.

Quantity of labor used (X_1), labor measured in person hours was expected to positively influence mean output of bananas while having a negative effect on yield variability. This is because increasing the amount of labor should help farmers to carry out critical agricultural operations on time and thus permit farmers to respond more rapidly to problems when a rapid response may be crucial in reducing crop losses (Fufa and Hassan, 2003).

Fertilizer use replenishes depleted soil nutrients and hence increases agricultural productivity. Thus, the impact of fertilizer on mean yields of bananas should be positive. Fertilizer's effect on the variability of banana output was hypothesized to be negative and thus risk reducing. Farnsworth and Moffitt (1981) note that, fertilizers appear to reduce output variability perhaps by helping maintain plant vitality amidst adverse weather conditions or agricultural pests.

With limited use of inorganic fertilizers among banana farmers due to high costs, farmers have resorted to use of own supplied inputs especially manure and crop residues to restore the depleted soil fertility. Manure applied contributes to soil nutrients and thus its use increases the productivity of land allocated to bananas (Katungi *et al*., 2007). Application of manure was therefore expected to have a positive influence on mean output of bananas and a negative effect on banana output variability.

Mulching suppresses weed growth, conserves soil moisture and add nutrients to the soil when the organic materials are decayed hence it improves plant's tolerance to harsh environmental conditions. Mulching positively influences the mean yields of bananas Bagamba (2007) while its effect on yield variability was expected to be negative.

In addition to soil management practices, farmers were further advised to carry out a number of other crop management practices to ensure good sanitation in their plantations in order to reduce pests and disease infestations. Such practices among others included; weeding, deleafing, sheaths removal, stump removal, removal of corms, desuckering etc. Farmers were asked to report the number of times such activities are carried out and the frequency of doing them in a year. The frequencies of the major activities were aggregated and the agronomic frequency measured as the average frequency of performing them in a year computed. Agronomic frequency was hypothesized to have a positive impact on the mean yields of bananas. As noted by Musanza *et al.* (2005), improved crop sanitation management contributes to banana productivity. On the other hand, effect of agronomic frequency on banana output variability was expected to be negative.

Frequency of extension visits: Agricultural extension represents a mechanism by which information on new technologies, better farming practices and better management can be transmitted to farmers (Birkhaeuser *et al*., 1991). Agricultural extension not only accelerates the diffusion process and the adoption of new varieties and technologies but also improves the managerial ability of farmers by improving farmers' knowhow (Dinar *et al*., 2007). In banana cultivation, extension visits have been shown to have a positive effect on banana output, this is because interaction with extension agents could enable farmers to adopt new farming techniques and be able to raise their production output (Bagamba, 2007). Therefore frequency of extension visits is hypothesized to have a positive effect on banana output and a negative effect on banana output variability.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

This chapter presents and discusses findings based on a sample of 403 farmers that grow bananas drawn from 3 regions of Eastern, Western and Central Uganda. It documents a summary of socio-economic characteristics of the sample farmers selected from the various districts for the study. This summary offers guidance to understanding the variability in banana yields across households which might be attributed not only to the levels of inputs used by a given household but also to the capacity of the household to choose the amount of the input. Descriptive statistics were used to compare the socio-economic and demographic characteristics of the sample farmers and their effects on the use of inputs and banana management practices across households and geographic regions. Discussion of empirical findings on the effects of inputs and banana agronomic management practices on output variability follows.

4.1 Socio-economic characteristics of the households

4.1.1 Demographic characteristics

Demographic characteristics of the respondents are presented in table 4.1. Some of these characteristics that include age, gender and education level are those of the household head who was assumed to be the primary banana production decision maker. Results revealed that there was a significant difference between the mean age of farmers in the three regions with eastern having the lowest at 45 while western had the highest at 51. The average age of the household heads was 48 years which means that the majority of the banana farmers lie in the productive age group. The regional age difference could be explained by the geographical shifts in the production of bananas that has been witnessed over the past 50 years. Gold *et al*, (1999) observe that over the past 20 to 50 years, banana has replaced millet as the key staple in much of south-western Uganda. Therefore the low average age of banana producers in the east suggests that the region adopted banana production late compared to the other regions.

Education is very vital for boosting the productivity of the human factor and making people more aware of opportunities for earning a living (Okurut *et al*, 2002). The average level of education attained by the household head in years was approximately seven and it was highest in the central region, with eastern having the lowest but slightly lower than that in the western. The difference in the mean level of education attained by the household head was significant across the regions. The difference in education levels of the farmers could be attributed to the geographical locations of the regions, the central region which is closer to the capital has better access to education and other social services compared to the other regions. This suggests that the majority of the farmers had the necessary education to process information on improved technologies instrumental for increasing banana productivity.

Table 4.1: Household demographic characteristics

Variable	**Western**		**Central**		**Eastern**		**ANOVA test**	
	Mean	**S.E**	**Mean**	**S.E**	**Mean**	**S.E**	**F-value**	**P-value**
Age	51.20	1.19	47.6	0.82	44.8	1.70	3.21	0.041
Education (years)	6.87	0.57	8.02	0.23	6.9	0.51	6.09	0.003
Not educated (%)	17.7		4.0		9.0			
Primary level (%)	41.8		49.8		48.9			
Post-primary (%)	40.5		46.6		42.6			
Household size	7.94	0.31	5.2	0.15	6.91	0.39	18.4	0.000
N	79		277		47			

SE = Standard error

In the study, the difference between the means across the regions was captured using the standard error instead of standard deviation because as argued by Nagele (2003), such quantities have uncertainty due to sampling variation and therefore for such estimates, a standard error can be calculated to indicate the degree of uncertainty.

Household size is the most important source of labour available to a given household for farm work. Results showed a significant difference in the mean size of the households across the three regions. The size of the household was, on average, six persons, with the western having the largest number of persons in a household (8), followed by the eastern (7) while central region had the lowest (5). Considering the labour intensive nature of banana agronomic practices like mulching, manure application and weeding, households with large families are more likely to perform these technologies effectively and on time.

4.1.2 Land ownership and utilization

On average, each household owns about three hectares of land, with the landholdings being highest in the western region where 3.2 hectares are owned and lowest in the eastern where 2.3 hectares are owned. However, the mean difference was not statistically significant ($p=0.532$). Cropped area accounted for the biggest proportion of land allocation to the various farm activities, contributing on average to 2 hectares (65.7%) of the total land owned by the household. The large allocation of land to crop cultivation by households underlines the predominance of the crop sub-sector in Uganda's agriculture (MAAIF and MFPED, 2000). Eastern and central regions had the largest land allocated to crops (62.3%) while the west had the least allocation to crops (58.5%). This could be attributed to the nature of farming systems in the regions where crops are more important in the livelihoods of the people of central and eastern Uganda than those of western where a significant proportion keeps livestock. The major crops grown in the different regions differ due to variations in the agro-ecological conditions. Apart from bananas, households in the western region grow mainly annuals such as beans, maize, potatoes, cassava and groundnuts. In the eastern region, coffee is another major perennial grown by farmers and this is grown along annuals such as maize, beans, cassava and groundnuts.

Other land allocations apart from crop included pasture land for grazing whose allocation was highest in western Uganda (29%) and lowest in eastern region at (7.2%) which confirms the importance of livestock in the western region compared to the eastern. Land was also allocated to forests and the proportion to this was highest in central and western regions and lowest in the east. The proportion of land under fallow was highest in central region (16.9%) followed by western (2.02%) and least in east (0.79%). The low proportions of land under fallow could be attributed to decrease in land holdings due to population pressure which forces farmers to cultivate the land continuously without allowing it to rest.

Table 4.2: Household land access and utilization in hectares

variable	Western		Central		Eastern		ANOVA-test	
	Mean	**S.E**	**Mean**	**S.E**	**Mean**	**S.E**	**F-value**	**P-value**
Land use (ha)	3.20	0.306	3.16	3.105	2.38	0.198	0.63	0.532
Crop	1.87	0.161	1.99	0.089	1.47	1.990	0.72	0.489
Pasture	0.93	0.181	0.25	0.111	0.17	0.245		
Forest	0.14	0.045	0.15	0.049	0.01	0.147		
Fallow	0.07	0.035	0.54	0.182	0.02	0.540		
Major crops								
Bananas	0.95	0.079	0.59	0.028	0.69	0.598	12.38	0.000
Beans	0.38	0.043	0.23	0.016	0.34	0.225		
Cassava	0.09	0.019	0.23	0.019	0.12	0.228		
Coffee	0.13	0.036	0.28	0.031	0.35	0.283		
Maize	0.11	0.027	0.25	0.028	0.30	0.253		
N	79		277		47			

S.E = Standard error

The largest proportion of land under crop cultivation was allocated to bananas and on average it fetched about 59.9% of the total crop land. This underscores the dominance of banana as the most widely grown crop in Uganda. Results showed a statistically significant difference in the mean average of crop land allocated to bananas across the regions. The proportion was highest in eastern region (59.9%), followed by that of western (47.8%) and lowest for the central region (30%). The largest proportion of crop land allocated to bananas in eastern and western regions reflects the importance of the crop to the farming systems of the regions. While banana production has its roots in the central region, over the years, banana cultivation moved further to the non-traditional areas of the eastern and western parts of the country (Bagamba, 2007). In addition to bananas, all regions were diversely involved in the production of other food crops like beans, cassava and maize. Coffee was the major cash crop produced by all the regions with eastern devoting the largest proportion of crop land to its production (30.2%), followed by central (8.9%) and western allocating the least (3.89%). The allocation of a large proportion of land to coffee in the eastern region demonstrates the significance of the crop in the region's farming system. Farmers in this region predominantly grow Arabica coffee because of the favorable climate conferred by the high altitude of the area.

4.1.3 Labour use and wages in Banana production

Labour allocation and usage in the three regions is presented in table 4.3 below. Results show a significant difference in the mean of labor allocation across the regions at one percent level. In addition, the table serves to illustrate the importance of family labour (measured in work hours per year) in banana production in all the three regions. Family labour provided the highest proportion to total labour used in banana production in all the regions, averaging 84.3 %. This finding underlines the role of family labour in African farming systems and Uganda in particular. As noted by Anselm *et al*. (2005), family labor is a very important source of labor in African agriculture.

Farmers in the western region allocated the largest amount of family labour hours to banana production, followed by farmers in eastern region while farmers in the central region had the least allocation. The mean difference in family labor allocation to banana production was also statistically significant at one percent level. The pattern of family labor allocation across the regions is similar to that of household size observed earlier which confirms Kanwar's (2004) argument that the larger the family, the more the labor for work including farm work.

To supplement family labor, hired labor was used (in terms of hours used per year) and it was highest in western region followed by eastern and lowest in the central region. The differences in the means of hired labor utilization across the regions was also significant at one percent level (p=0.000). However, in all the regions the standard error was very high implying that there is a large variation in labour allocation by households in the various regions but the magnitude was highest in west followed by east and lowest in the central region.

Table 4.3: Labour used in banana production (hours/year) by average household

Variable	Western		Central		Eastern		ANOVA-test	
	Mean	**S.E**	**Mean**	**S.E**	**Mean**	**S.E**	**F-value**	**P-value**
Total labour	1286.2	99.4	840.1	24.1	1142.7	122.6	107.93	0.000
Family labour	1110.3	75.1	735.7	19.3	1035.5	96.3	113.35	0.000
Men	451.7	99.4	330.7	13.1	377.1	64.7		
Women	474.7	66.7	247.9	13.3	451.7	73.1		
Children	183.9	65.1	157.1	18.2	206.8	56.1		
Hired labour	175.8	39.5	105.2	9.1	107.2	37.7	33.11	0.000
Men	138.3	70.9	79.9	13.7	98.3	39.4		
Women	33.6	55.9	23.4	1.5	6.7	3.6		
Children	3.9	10.8	1.8	0.6	2.3	2.1		
N	79		277		47			

S.E = Standard error

The study findings also postulated differences in the allocation of labour by gender across the three regions. From the table (4.3), it can be observed that the allocation of male labour (in terms of hours per year) was highest in the western region, followed by eastern and lowest in the central region. However, the allocation of female labour was higher in the western and central regions compared to eastern region thus illustrating the difference in importance given to bananas by gender across the three regions. The differences in labour allocation according gender across the three regions could be attributed to the varying economic importance attached to the crop. In the western and eastern regions, men participate more than ladies in the production activities because the crop is more relied upon for income generation through sale than for consumption. In the central region bananas are predominantly for home consumption, this is further reflected by the output levels between the regions.

The results of wage rates paid by farmers across the three regions who hire labour for different agronomic practices are presented in table 4.4. The findings illustrate that only 12.4% of the sample farmers used hired labour for banana production. The average wage rate paid (in terms of U.shs per hour) was highest in the central region, followed by western and the lowest in eastern region. However, the mean differences in wage rates between the regions was not significant.

Table 4.4: wage rates paid by farmers per hour across the regions

Variable	Western		Central		Eastern		ANOVA test	
	Mean	**S.E**	**Mean**	**S.E**	**Mean**	**S.E**	**F-value**	**P-value**
Wage rate (Ushs)	392.06	30.17	426.6	14.39	352.69	29.29	0.69	0.509
Hired Labour (hours/year)	175.8	39.5	105.2	9.1	107.2	37.7	31.11	0.000
N	20		27		13			

S.E = Standard error

The above wage rates reflect the market wage rates determined by the opposing forces of demand and supply of labour in the different regions. The high wage rates offered in the central region reflect the scarcity of labour for the agricultural farm sector which could be attributed to competition from other rural sectors like the non-farm sector which also utilise the unskilled labour and are more developed and remunerative in this region (Bagamba, 2007). Further more, the off-farm labour market is more vibrant in the central region due to the proximity of the region with in easy reach of the key urban centres (Kampala, Entebbe, Jinja) that offer an expanded range of employment opportunities for unskilled and semi-skilled workers.

Figure 4.1 shows labour allocation to the different agronomic management practices in banana production. In the western and central regions, crop sanitation received the largest amount of labour hours followed by weeding, then manure and mulch application. However, in the eastern region, the largest labour was allocated to weeding though slightly more than crop sanitation while application of manure and mulch received minimal labour allocations. The disproportionate allocation of labour to crop sanitation and weeding practices as compared to manure and mulch application could be attributed to little attention given by farmers to soil fertility management practices.

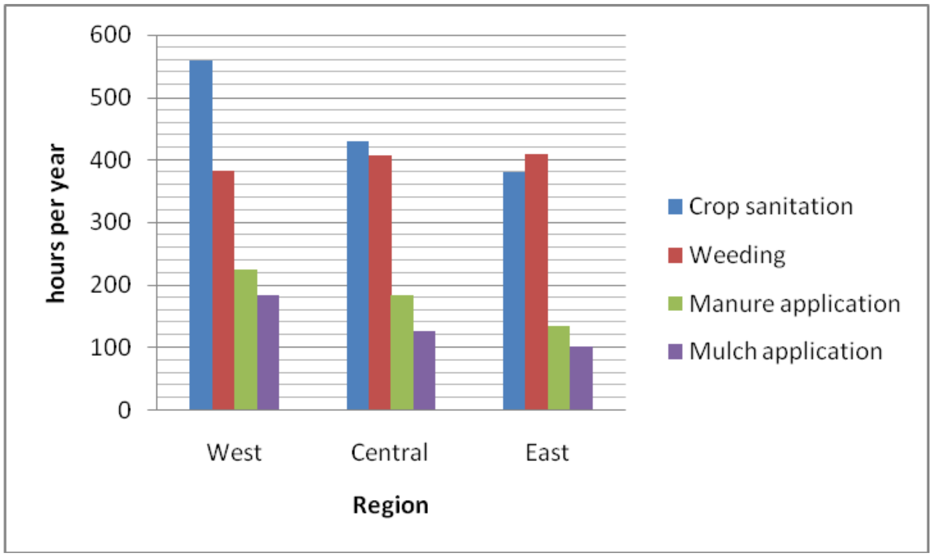

Figure 4. 1: Labour used (hours/year) in banana production by type of activity and region

4.1.4 Other inputs used in banana production

Apart from land and labour, farmers used a wide range of other inputs and carried out a number of agronomic management practices to replenish soil fertility. Results on use of soil fertility management practices by farmers are shown in table 4.5. Mulching was done with dry organic materials that often include dry grass and crop residues such as maize stalks, bean trash and sorghum or millet stover. On average, nearly all farmers used at least one of the above soil fertility augmenting practices with fertilisers showing the lowest proportion of use across the three regions. Manure registered the largest proportion of use followed by mulch. The low use of fertiliser is consistent with other study findings that have reported use of purchased inputs to be very low in Uganda (Nkonya *et al.*, 2004). The low use of fertiliser is attributed to the high costs of the input that are unaffordable to the majority of the small scale farmers. These high costs emanate from the nature of the fertiliser industry in the country. Omamo (2002) observed that Uganda fertiliser procurement and distribution is dominated by retail level trade and high prices that discourage farmers to use the fertiliser and low net margins that discourage traders to market fertiliser. The principal means of managing soil fertility on agricultural land in most of East Africa is through recycling of crop residues, transfer of plant materials from non-cropped areas to arable land, biological nitrogen fixation through leguminous crops, utilization of animal manure, and occasional application of inorganic fertilizers (Bekunda *al*., 2002). Most of the farmers for this study that used fertiliser received it for free or at subsidised prices from APEP. Spatial differences in the use of soil fertility management practices are apparent across the regions. Except for fertiliser whose rate was more even across the regions, use of other soil fertility management practices exhibited high standard errors across farmers showing high variability in the use patterns.

Table 4.5: Use of soil fertility management inputs in banana production

Input	**Western**		**Central**		**Eastern**		**ANOVA-test**	
	Mean	**S.E**	**Mean**	**S.E**	**Mean**	**S.E**	**F-value**	**P-value**
Fertilizer (kg/year)	86.8	5.6	85.2	2.8	89.5	21.9	0.85	0.461
Manure (Kg/year)	959.9	106.4	459.6	91.2	455.1	89.3	4.11	0.017
Mulch (Bundles/year)	241.8	60.2	125.9	37.7	117.4	60.4	0.48	0.616

S.E = Standard error

The low fertiliser use rates aside, quantities of organic inputs used by farmers for soil fertility management were on average relatively high for manure and mulch. The average amounts of manure used by farmers were reported highest in the western region followed by the central and least in the eastern region. The difference in means of fertiliser used across the three regions was statistically significant at five percent level. Farmers in the western region used almost twice the amount of mulch used in the east and central regions. The main reason reported for non-use of manure by some households was that farmers lack access to it (that is they do not have livestock) while others reported the high intensive nature of its application and lack of implements like wheel burrows for carrying manure to the banana plots. Similarly, for grass mulch, farmers cited scarcity as the main reason for non-use which could be attributed to increasing population pressure on land that has resulted in decreasing farm size thus makes grass mulch less available (Gold *et al*., 1999).

4.1.5 Variable costs of other inputs apart from labour used in banana production

A number of studies have reported low use of purchased inputs especially inorganic fertilisers for boosting agricultural production. Pender *et al.* (2001) reported that less than 10% of the small holder farmers in Uganda use inorganic fertiliser, one of the most likely technologies to improve soil fertility. Among other constraints, high cost of these purchased inputs has been presented as the most important factor inhibiting their adoption. As a result, extension agents have promoted the use of alternative yield enhancing inputs that can be locally obtained and these include manure and mulch in banana production.

Table 4.6: Variable costs of inputs used in banana production

Variable	Western	Central	Eastern	ANOVA-test

	Mean	S.E	Mean	S.E	Mean	S.E	F-value	P-value
Fertilizer Ushs/kg	1100.37	57.86	1058	29.80	1001.82	61.61	0.11	0.897
Manure Ushs/kg	15.35	6.57	25.35	3.69	27.42	2.02	1.57	0.209
Mulch Ushs/bundle	58.86	2.84	78.24	2.84	74.66	23.40	35.55	0.000

S.E = Standard error

The study estimated the costs incurred by farmers using these soil fertility enhancing inputs as shown in table 4.6. For farmers that bought fertiliser, the cost was easy to establish from traders that deal in agricultural inputs. The costs for organic inputs like manure and mulch which were not traded in the local markets were obtained from estimates by the farmer of the transport, search and access costs involved in the delivery of the input to the banana garden. Those that performed the task themselves were asked to provide estimates of the costs involved in hiring someone to do the task. As indicated in table 4.8, the cost of fertilizer was on average Ushs 1059.6 per kg, and this was highest in the western region, followed by central and lowest in the eastern region. However, the difference in means of the cost of fertilizer across the regions was not significant. The cost of manure was highest in the eastern region followed by central and lowest in the western region but this variation in the mean cost was not significant. The high cost in east and central regions could be attributed to the scarcity of manure because fewer households own livestock. The difference in the mean cost of mulch across regions was significant at one percent level. It was highest in the central region, followed by eastern and lowest in the western region which could be attributed to the variation in the availability of mulching material.

4.1.6 Banana output and prices

Findings on banana output and prices are presented in table 4.6. The table shows that across all regions, bananas are produced both for home consumption and sale. Generally, two seasons were reported in banana production for all the regions that is the peak production period and the low production period. In the western region, the low production period normally stretches from November to January while the high production period occurs from June to September. However, this production pattern is different from the one experienced in the central region where peak production period occurs from January to May while the low production period occurs from July to October. Production during other months of the year usually lies along the continuum between the low and the peak production periods.

Table 4.7: Banana output (kg per season) and prices for 2007

Variable	Western		Central		Eastern		ANOVA-test	
	Mean	**S.E**	**Mean**	**S.E**	**Mean**	**S.E**	**F-value**	**P-value**
Season1								
Total output	1701.78	34.15	529.6	29.6	1094.1	92.1	22.58	0.000
Qty Consumed* (kgs)	441.3	31.1	213.9	9.7	305.2	20.9	46.00	0.000
Qty Sold (kgs)	1260.5	120.9	315.7	9.7	788.9	81.7	16.77	0.000
Price (Ushs/kg)	142.5	3.5	202.7	22.8	150.8	5.1	23.06	0.000
Season2								
Total output	2245.1	44.9	769.4	7.2	2233.4	168.9	31.14	0.000
Qty Consumed* (kgs)	514.7	41.5	304.7	5.5	508.2	30.2	26.12	0.000
Qty Sold (kgs)	1730.4	189.5	464.7	14.5	1725.2	161.5	26.44	0.000

Price (Ushs/kg)	64.3	3.3	152.8	26.8	118.6	4.9	72.04	0.000
N	79		277		47			

S.E = Standard error

Note: Consumed* refers to subsistence consumption that is quantity of banana in kgs that is used for home consumption by the households.

Like for any other commodity, the pattern of banana prices varies during the course of the year according the conditions of supply and demand. The prices were reported highest during the low production periods (season 1) and lowest during the peak production period (season 2) with difference in magnitudes almost double between the two periods. For the two seasons, banana prices were reported highest in the central region, followed by the eastern and lowest in the western region with the difference in mean price being significant at one percent level. The high prices in the central as compared to other regions could be attributed to its close location from Kampala which is the major market. Results also revealed a significant difference in means of banana output across the regions at one percent level. For both seasons, output was reported highest in western region, followed by eastern and lowest in the central region which supports the fact that there have been shifts in banana cultivation from the central to non-traditional areas. In addition to variations in banana management across the regions, the differences in output could be attributed to variations in agro-ecological conditions such as soil type, rainfall patterns and incidences of pests and diseases in the regions.

All households reported selling their bananas at farm gate with only a few also selling at local markets. The table (4.7) also shows that the amount of bananas sold was highest in the western region, followed by the eastern and lowest in the central region. This could be attributed to the differences in the economic importance attached to the crop across the regions. While in the western and eastern regions, bananas are relied upon for household income, in the central they are mainly for home consumption. The existence of a variety of other crops to sell in the central region provides farmers with alternatives for cash other than heavily relying on bananas. The relatively high proportions of farmers that sell across all regions underscores the commercial importance of bananas in the economic wellbeing of the farmers.

4.1.7 Credit and information access

Access to credit may enable farmers to purchase inputs or acquire physical capital, thus contributing to technology adoption and increased capital and input intensity in agriculture (Feder *et al*., 1985). The findings establish as indicated in table 4.8 that western region had the highest proportion of farmers that used credit (29.1%) followed by central (20.2%) and eastern had the lowest (17%). In terms of the amount borrowed, east had the highest amount of credit borrowed, followed by west while central had the lowest. However, the difference in means borrowed across the regions was not significant. Access to credit by farmers facilitates labour hiring and thus promotes labour intensification (Pender *et al.,* 2003). Considering the labour intensive nature of some banana management practices such as manure and mulch application, access to credit enables farmers to meet additional labour requirements. The largest provider of credit to the farmers was the local financial associations (45.6%), followed by money lenders (28.7%), friends and relatives (21.3%) and other sources provided 6.8%.

Table 4.8: Credit access by households and extension visits 6 months prior to the survey

Variable	Western		Central		Eastern		ANOVA test	
	Mean	S.E	Mean	S.E	Mean	S.E	F-value	P-value

Use credit (%)	29.1		20.2		17			
Credit(U.shs)	55,880.3	6475.6	44,485.7	1353.1	65,250	6207.3	0.80	0.451
Extension visits	2.3	0.15	2.6	0.14	2.9	0.19	1.87	0.155
Proportion visited	84.8		60.6		72.3		66.7	
N	79		277		47		403	

S.E = Standard error

Regarding extension visits, west had the highest proportion of extension visits (84.8%) followed by east (72.3%) and central had the lowest (60.6%). The difference in frequency of extension visits across regions was not significant but farmers in the east registered the most number of visits while west recorded the lowest. However, out of the total farmers interviewed in each region, on average, each household visited had received approximately two visits in the previous six months before the interview. As indicated in Figure 2, most of the agricultural extension agents came form NAADS, followed by NGOs.

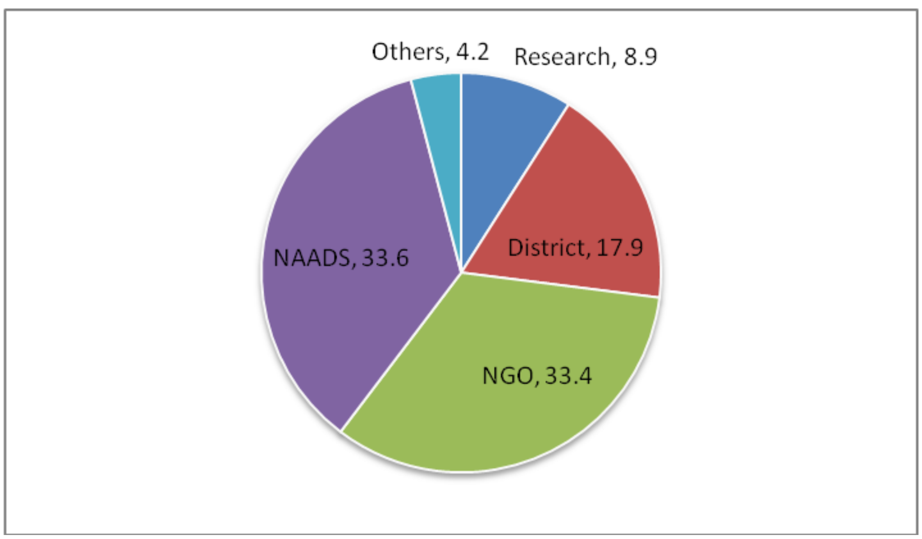

Figure 4.2: Percentage of the source of agricultural extension agents

4.2 Effects of inputs and agronomic practices on mean output of bananas

The estimation results from the econometric analysis for the mean output function are presented in table 4.9. The estimated coefficient of determination (R^2) for the overall model was 56.8% implying that the model explains at least 56.8% of the variation in the banana output as reported by the sample respondents. On regional basis, R^2 was highest in the estimated model for western Uganda (54%), followed by eastern (51.4%) and lowest in the model for central (48.2%). Because the variables used in the model are in logarithmic form, the estimated coefficients for continuous variables are the elasticities, and for the dummy variables, the coefficients are intercept shifters (Hurd, 1994).

Table 4.9: Estimated effect of inputs and agronomic practices on mean yields of bananas by region

Variable	Western Coefficient	Central Coefficient	Eastern Coefficient	Overall Coefficient
Labor	0.354^{*}	0.336^{**}	0.365^{***}	0.385*
	(3.77)	(2.06)	(1.42)	(6.35)
Agronomic frequency	0.256^{***}	0.277^{**}	0.247	0.209*
	(1.42)	(2.64)	(1.11)	(3.98)
Extension	0.079^{**}	0.044	0.059	0.097^{***}
	(2.08)	(0.63)	(0.57)	(1.73)
Education	-0.083^{*}	-0.077	0.014	-0.082^{*}
	(-3.62)	(-0.95)	(0.34)	(-3.64)
Manure	0.129^{*}	0.192^{***}	0.119^{**}	0.124^{*}
	(4.48)	(1.75)	(2.59)	(3.58)
Fertilizer	0.138	0.164	0.107	0.127^{***}

	(0.92)	(1.21)	(0.23)	(1.29)
Mulch	0.014***	0.075***	0.042*	0.119***
	(1.96)	(2.02)	(4.65)	(1.84)
Constant	0.411	4.91*	5.966*	4.052*
	(0.90)	(5.22)	(4.05)	(5.71)
Adjusted R^2	0.54	0.482	0.514	0.568
N	79	277	47	403

****, ** and * mean significance at 10%, 5% and1% levels respectively.*
Figures in parentheses are the t-values of the coefficients.

Total labor used as expected had a positive and significant effect at 1 percent level on banana output, implying that farmers who devote more labour to banana production derive higher output. Most farmers heavily rely on human labour to carry out different activities involved in banana production and therefore an increase in the amount of labour available for production, increases output. This finding is consistent with evidence by Dvorak (1996) that labor as a factor of production is generally of overwhelming importance and makes up about 90% of the costs of production in many African farming systems. The magnitude of the impact of labour on banana output was highest in western and lowest in the central. This corroborates with the earlier finding of labour allocation by region where western region allocated the highest labour to banana production and central region registered the least. In addition western region had a higher availability of other complementary factors of production like land that make use of labour more productive.

Fertilizer was one of the inputs promoted for use by the APEP extension package in the study area. On average, fertilizer showed a positive and significant effect at 10 percent level on the banana output underscoring its importance in crop production. However, the impact of fertilizer on output was only significant in the overall model. The non-significance of fertilizer use in the regions could be attributed to the fact that few farmers used fertilizer out of the total sampled in these regions. Compared to other soil fertility enhancing inputs such as manure and mulch, generally, the impact of fertilizer on banana output was higher. This could be attributed to the low nutrient composition of organic fertilizer sources that can not meet crop nutrient demand over large areas (Palm *et al.*, 1998).

Manure is another important input recommended for use in banana production, and unlike fertilizer, it is relatively more available to farmers who own livestock. As expected, manure had a positive effect on banana output and was statistically significant at 1 percent level though the magnitude of the impact was low except in the western region. The elasticity of output to manure use was highest in western and lowest in the central which corroborates with the earlier finding that recorded highest rates of manure use in the western. The inferior magnitude of its impact on output could be attributed to the limited availability of nutrients in animal manure to plant growth. Seong *et al*. (2007) note that unlike commercial fertilizer, all nutrients in animal manure are not available for plant uptake because they exist in an insoluble form. In addition, the method of application and quantity used by farmers could have limited its efficiency. In the study area, the quantity of manure used that averaged 625 kg per hectare per year was very low and far short of the recommended rates that usually range as high as 10 to15 tonnes per hectare per year (Grant, 1981) depending on the fertility status of the soil. Application of manure through spreading on the soil surface that was a common practice among the farmers reduces its efficiency. Application methods such as placement of manure in the planting hole (spot application) have been proven to reduce leaching and volatilization effects and hence maximize yields (Mafongoya, 2006).

As part of the extension package promoted by APEP to restore soil fertility, combat weeds and mitigate pests and diseases, farmers were also advised to apply mulch to their banana plantations. Like other soil fertility enhancing inputs, generally, the effect of mulch on banana output was positive and significant at 10 percent level implying that farmers who allocated more bundles of mulch to their banana gardens registered higher output. Addition of mulch serves to increase the capacity of the land to produce higher output by improving the chemical and physical characteristics of the soil, and combating the growth of weeds. Grass mulch is composed of elements phosphorous and potassium which are in great demand of bananas. However, mulch application is a labor intensive process which requires to be applied in bulk and must be given sufficient time to decay and release nutrients to the soil, which may thus be responsible for the low elasticity of output on mulch.

Overall, education of the household head negatively affects banana output as indicated by a negative and significant coefficient at 1 percent level. On regional basis, except for the eastern region where it was positive and non-significant, education showed a negative effect on banana output which was only significant in western. The results led to non-acceptance of the hypothesis that increase in education results to increase in banana output. The negative impact of education and its significance in western region as compared to the central could be explained by the level of development of off-farm activities in the two regions. In western, participation in off-farm activities is preserved for those with good education that are able to obtain jobs in local government, community development organizations or participate in business. In central region, the off-farm business is more developed and can therefore accommodate people of all education categories. The negative effect of education on banana output contradicts expectations since studies indicate that education may induce a positive use of improved management practices through increased ability to acquire information. For example, Feder *et al.,* (1985) observed that education may promote the adoption of new technologies by increasing households' access to information and their ability to adapt to new opportunities.

As hypothesized, extension visits had a positive and significant effect at 10 percent level on banana output, but across the regions, they were only significant for the western region. This could be explained by the difference in economic importance of bananas in the farming systems of the regions. While in the western region bananas are the most important crop and therefore are more targeted by the extension agents, in the central and eastern regions, the extension package is more spread out to emphasize the role of other crops like coffee, cereals and legumes. Extension agents interact with farmers, providing information and aiding in developing their managerial skills (Birkhaeuser *et al*., 1991). Interaction with extension agents could therefore enable farmers to adopt improved farming methods and be able to increase their output. In addition, the non-significance could be attributed to the fact that not all farmers are beneficiaries of extension visits as in most cases these are limited only to the progressive farmers (Bagamba, 2007).

Overall, agronomic frequency was associated with a positive and significant effect at one percent level on banana output outlining the importance of good management on banana output. Regular performance of crop sanitation measures reduces pest and disease infestation as well as contributing to good management of soil fertility (Katungi *et al.,* 2007). However, within the individual regions, the agronomic frequency had a positive and significant effect on the output in western region and central region while the effect in eastern region was non-significant. This finding is backed by the earlier fact that eastern region allocates the least amount of labor to banana management vis-à-vis other regions.

4.2.2 Risk effects of production inputs and agronomic practices on output of bananas

A variance function that took the form of a Cobb-Douglas production function was estimated to determine the effect of inputs and agronomic practices on the variability in the yields of bananas. As illustrated in table 4.10, it is apparent that the magnitudes of the coefficients for this variance function are smaller than the observed coefficients for the mean production function. These coefficient estimates and their associated t-statistics indicate the magnitude and strength of the relationship between the various inputs and agronomic management practices on the variability in the yields of bananas. The estimated coefficient of determination (R^2) for the overall model was 72.5% implying that the model explains at least 72.5% of the variation in the variance of banana yields as reported by the sample respondents.

Results showed that labour had a negative and significant effect at 1 percent level on the variance in the yields of bananas implying that increase in the amount of labour available for banana production activities increases yield stability and hence reduces risk faced by the farmer. The risk reducing effect of labour bodes well with expectations since increasing labour use should enable farmers to use other inputs efficiently and carry out crucial management practices more frequently. The findings therefore led to acceptance of the null hypothesis that labour reduces the variability of banana yields across farmers. The results corroborate with Fufa and Hassan (2003) findings who reported that labour decreases variability in crop yield because it enables farmers to carryout critical agricultural operations on time. Similar results were obtained by Farnsworth and Moffitt (1981) who reported that labour decreases variability in yields because it enables farmers to respond more rapidly to problems, especially during harvest when rapid response may reduce decline in crop losses. On regional basis, the magnitude of the impact of labour on banana output variability was highest in western and lowest in the central something that could be attributed to the labour allocation patterns in the three regions. It was earlier reported that western region allocates the largest amount of labour while central region registered the lowest labour allocation to banana production.

Table 4.10: Estimated effects of inputs on output variability

Variable	Western Coefficient	Central Coefficient	Eastern Coefficient	Overall Coefficient
Labour	-0.183*	-0.099*	-0.151*	-0.120*
	(-7.37)	(-8.50)	(-5.39)	(-12.77)
Agronomic frequency	0.054***	0.159*	0.033	0.112*
	(1.70)	(9.74)	(0.63)	(9.14)
Extension	0.011	0.024**	0.067***	0.029*
	(0.40)	(2.51)	(1.21)	(3.34)
Manure	-0.028*	-0.032*	-0.039**	-0.033*
	(-2.59)	(-4.43)	(-2.14)	(-5.86)
Fertilizer	0.070**	0.034**	0.053***	0.037*
	(2.08)	(1.87)	(1.59)	(2.67)
Mulch	-0.032**	-0.038	-0.083*	-0.034*
	(-2.09)	(-3.75)	(-4.49)	(-4.52)
Constant	2.549*	3.282*	2.94*	3.063*
	(10.82)	(26.78)	(9.47)	(30.4)
Adjusted R^2	0.56	0.772	0.631	0.725

N	79	277	47	403

****, ** and * mean significance at 10%, 5% and1% levels respectively.*
Figures in parentheses are the t-values of the coefficients.

According to Nkonya *et al*. (2004), use of purchased inputs in Uganda is very low with less than 10 percent of small holder farmers reported to use fertilizer. To restore soil fertility in their fields, farmers have relied on own supplied inputs mainly manure and crop residues (Bagamba, 2007). Manure application had a negative and significant effect at one percent level on banana output variability implying that increasing manure use increases stability in the yields of banana across the sample farmers. The results obtained were consistent with the null hypothesis that manure use decreases banana yield variability and hence risk. This finding lends support to the importance of manure that has traditionally been used as a source of nutrients in the production of bananas in Uganda. Manure can be an important source of nutrients especially nitrogen (N), phosphorous (P) and potassium (K) (Mafangoya *et al*., 2006). These nutrients especially nitrogen and potassium are required in large quantities since bananas are heavy feeders that lose nutrients into the fruit when harvested and sold in urban areas (Tushemereirwe *et al*., 2003). The essential nutrients supplied from manure reduce yield variability by helping maintain plant vitality despite adverse weather conditions or attack by agricultural pests and diseases (Farnsworth and Moffitt, 1981).

Mulch another important input included in the APEP extension package aimed at restoring soil fertility had a negative and statistically significant effect at 1 percent level on banana output variability which conforms to a priori expectations. Increased use of mulch results in increase in stability of banana output across the banana farmers which is consistent with expectations. The yield risk decreasing effect of mulch across farmers could be explained by the fact that increased use of mulch allows moisture conservation and replenishes soil fertility through addition of nutrients like phosphorous and potassium. This leads to increased stability in banana output across farmers.

Fertilizer use was associated with a positive and significant effect at one percent level on the variability in the yields of bananas across all regions thus it is a yield risk inducing input in banana production. Thus the null hypothesis that fertilizer use reduces variability in banana yields hence yield risk reducing was rejected. The deviation in banana yields associated with use of fertilizer could be attributed to the variation among the fertilizer user farmers in its application and management (that is rate, time and method of application). Further more, research stations are strategically located in different agro-ecological zones in Uganda where recommendation rates for soil fertility inputs are developed and disseminated to farmers. However, even with in a similar agro-ecological zone, great variations exist in soil type, rainfall patterns and other socio-economic characteristics that confer different responses across farms from use of the same input. Similar results were obtained by Fufa and Hassan (2003) in their study on effect of fertilizer use on yield variability of crops in Ethiopia. Fufa and Hassan (2003) argued that the yield response of crops to levels of fertilizer under farmer's management conditions depends on the number of interacting factors that include bio-physical factors such as soil type, the time and amount of rainfall, date of planting and management practices like the rate and method of application of fertilizers.

Agronomic frequency captured as the average frequency crop sanitation practices are carried out in a year showed a positive and significant effect at 1 percent level on the variability in the yields of bananas except for eastern region. This suggests that increase in the frequency of performance of crop agronomic management practices for banana decreases the stability in banana yields across farmers. The finding disagrees with the expectations and null hypothesis that increased performance of agronomic practices results in decreased variability in banana yields. This may be due to the fact that the realization of stable yields from performance of crop sanitation measures depends on the extent to which other complementary recommended practices in the package are followed appropriately. Among banana farmers there is a high variation in use of recommended banana management practices across farmers and differences in application rates for yield enhancing inputs that fall short of those recommended by extension agents. Therefore, in cases where complementary recommended rates of soil fertility inputs were appropriately followed, increased performance of agronomic practices might have resulted to increased yield.

Conversely, in situations where agronomic practices were performed in isolation without appropriately following other recommendations, this might have resulted to low yields. Consequently, increased performance of crop sanitation measures might lead to decreased stability in the yields of bananas across farmers due to differences in management practices.

Frequency of visits by extension agents to banana farmers had a positive and significant effect at one percent level on the variability in the output of bananas. Although not expected, the yield risk increasing role of extension visits could be explained by the nature of these visits that normally target progressive farmers. Therefore some of those farmers that gain access to interactions with extension agents on improved technologies adopt them to increase their output while others that do not access these visits stick to their old techniques that offer low output. Therefore increased extension visits could lead to increased variability in banana output across farmers due to differences in use of the yield enhancing technologies acquired by farmers.

4.3 Estimating the returns of different inputs in banana production

The marginal value and total value products of the different inputs used in banana production are shown in table 4.11. Generally, results indicated that fertilizer had the highest marginal productivity in banana production followed by labour, manure and mulch had the lowest. The high marginal returns of fertilizer compared to other inputs could be attributed to low rates of fertilizer used in the study area. On average, 87 kg/ha of fertilizer were used compared to 625 kg/ha for manure and 161.4 bundles/ha for mulch. At this level of fertilizer use, additional use of fertilizer generates higher returns and would be more profitable.

Table 4.11: Estimated marginal value products (MVP) and the total value products (TVP) of inputs in banana production

Variable	West		Central		East		Overall	
	MVP	TVP	MVP	TVP	MVP	TVP	MVP	TVP
Labour (hrs/ha)	410.82	692,889.01	565.28	688,499.73	420.17	552,180.62	477.50	671,565.55
Fertilizer (kgs/ha)	1,262.03	109,544.20	1,304.76	111,165.55	1,125.84	100,762.68	1,120.22	118,720
Manure (kgs/ha)	296.64	284,744.74	279.08	128,265.17	329.05	149,750.66	200.65	125,386.19
Mulch (bundles/ha)	183.98	44,484.36	220.42	27,750.88	535.99	62,925.23	194.34	31,366.48
Yield (kgs/ha)	5328.94		2,277.54		6,754.05		3,056.01	
Output price (Ushs/kg)	123.36		177.76		134.67		148.64	

Labour had the highest returns per hectare followed by manure, fertilizer while mulch had the lowest. This could be explained by the fact that labour is the most frequently used input in banana production in the study area and it facilitates the use of other inputs. The marginal value product of labour of Ushs 477.50 implies that the return for an additional man hour of labour allocated to banana production was Ushs 477.50. Given the fact that the marginal cost of labour measured as the average wage rate for an hour was approximately Ushs 408.19 in the study area, the marginal value product of labour was greater than its price implying that hiring more labour for banana production is profitable. The results corroborate with Pander *et al.* (2003) who established that the value of crop production was substantially higher on plots where bananas were grown compared to other crops such as cereals. However, economic theory stipulates that under perfect competition profits are optimized at a point where value of marginal product (VMP) of an in input is equal to its price which would occur in region two of the classical production function. Therefore, labour was underutilized in the study area. Marginal productivity of labour was highest in the central while western had the lowest which seems to support the fact that in the central, labour was diverted from production of perennials like bananas to annuals. This is in agreement with a study by Bagamba (2007) who obtained high marginal value products for bananas.

Manure use generated the second largest returns in banana production which is consistent with the finding that it was the most used soil fertility enhancing input by the farmers. The marginal value product of manure of Ushs 200.65 was far higher than the average unit cost of manure that was found to be Ushs 22.87. Since at the point of profit maximization, the MVP of each input should be equal to the unit price of that input (Doll and Orazem, 1984), this finding suggests that manure is underused and therefore, additional use of manure would be more profitable to the farmer. The marginal productivity of manure was highest in western, followed by eastern and lowest in the central. The high productivity of manure in western region as compared to other regions could be attributed to availability of complementary inputs like land and labour in the west than in the east and central that make additional use of manure more productive.

Fertilizer, another important input for restoring soil fertility but which is expensive had the marginal value product of Ushs 1,120.22. Given that the average cost of fertilizer in the study area was Ushs 1059.66, this implies that additional use of fertilizer in banana production in the study area was profitable. Therefore since the price of fertilizer is below the marginal return, one can conclude that fertilizers are underused. This fact is in agreement with the study's earlier findings and other literature (Pander, 2004) that there is a low rate of fertilizer use in Uganda. The low rates of fertilizer use translated into low returns per hectare as compared to manure. The marginal productivity of fertilizer was highest in central region and lowest in eastern region. The high marginal productivity of fertilizer in the central as compared to other regions could be attributed to shifts in economic importance attached to different crops grown in the region. Diversification from perennials such as bananas and coffee to annuals such as beans led to shifting of inputs from perennials to annual production. As a result there is a sub-optimal allocation of inputs including fertilizers to banana production.

It was observed that use of mulch generated the lowest returns to banana production. On average, the marginal value product of mulch was Ushs 194.34. Considering that the average unit cost of mulch in the study area was Ushs 70.13, this suggests that mulch is profitable in banana production and therefore additional use of the input generates higher returns. The productivity of mulch was highest in eastern and lowest in central region. The low productivity of mulch in the central region could be attributed to limited availability of complementary inputs like labour and land that enhance its productivity. While the high productivity in the east could be attributed to limited availability of mulching material especially grass due high population pressure that constrains the farmer to a less than optimal use of mulch.

Generally, the above results indicate that for all the inputs considered in banana production in the study area, their marginal value products are greater than the marginal costs implying that additional use of the inputs is profitable. It is also evident that the productivity of a given input is enhanced by the availability of other inputs essential in banana production.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary and conclusion

Banana production faces severe constraints especially due to soil fertility decline and increased incidence and intensity of pests and diseases (Tushemereirwe *et al.,* 2003). These together with other constraints have posed the biggest challenges to increasing banana productivity in Uganda. A number of crop management technologies that could help mitigate the negative effects of these constraints have been developed though their adoption remains low. Understanding the determinants of technology adoption has long been a subject of interest among agriculturalists and researchers. The existing literature on banana technology adoption has mainly concentrated on socio-economic factors with little insight on the risk nature of these technologies and inputs that impinges upon their use by farmers.

The purpose of this study was to investigate the returns from use of inputs as well as effect of use of these inputs and agronomic practices on banana yield variability in Uganda. The main objectives of the study were; to determine the effect of inputs and agronomic practices on the mean and variability in the yields of bananas, and to estimate the returns from the inputs used in banana production. Empirical analysis was based on primary data collected in a survey of 403 banana producing households that were selected from three major banana producing regions of Uganda that is Eastern, Central and Western Uganda covering 12 districts. The study used the Just and Pope stochastic production function specification to analyze the effect of inputs and agronomic practices on the mean and variability in yields of bananas. The returns from use of inputs were estimated by determination of the marginal value products and total value products from the mean yield function. Results of the mean production function indicated that labour was the most important factor in banana production followed by fertilizer while manure and mulch had the least impact. On the other hand, the results of the variance production function showed that labour, manure and mulch had a negative effect on the variability of banana yields while the effect of agronomic frequency, fertilizer and extension was positive. Findings also revealed that generally, all inputs were profitable as they generated higher marginal returns to banana production compared to marginal costs incurred implying that inputs were underutilized.

The study findings postulate that to a varying degree, labour, performance of agronomic practices, use of fertilizer, mulch and manure were the most important factors affecting the mean output of bananas in the study area. In terms of magnitude, labour had the largest impact on banana output which is consistent with a priori expectations considering that the two resources have been extensively relied upon to increase crop yields in Uganda. Findings further show that the marginal value products for the different inputs were higher than the marginal input costs implying that additional use of the inputs generates more profits to the banana producers. With regard to the effect of the inputs and agronomic practices on the stability of banana yields, results showed that except for labour, mulch and manure, all other inputs increased the variability in yields of bananas and hence are yield risk increasing. Therefore, overall, for fertilizer, the findings led to non-acceptance of the null hypothesis that it is yield risk decreasing. The differences in agro-ecological and socio-economic conditions with in which farmers operate could be the main reason for the variation in use of recommended technologies and hence spatial instability in the yields.

5.2 Recommendations of the Study

The study findings offer some recommendations with regard to improved technology adoption in Uganda.

The study reveals that labour is the most important determinant of banana yields since most farmers heavily rely on human labour to carry out crucial agronomic practices. In addition, labour had a negative effect on the variability in banana yields thus is a yield risk decreasing input. Therefore, allocation of more labour to banana production is justifiable since it would increase yields and also reduce production risk.

As expected all the soil fertility enhancing inputs such as fertilizer, mulch and manure applications were associated with a positive effect on the mean yields of bananas. Further more, results revealed that manure and mulch had a negative effect on the variability of yields and hence they are yield risk decreasing. Given the high cost of fertilizer and its unavailability, manure and mulch use remain the only viable alternatives. Therefore promotion of soil management technologies like mulch and manure application should be intensified in the extension package to enable farmers achieve both high and stable yield levels in banana production.

In addition, results revealed that fertilizer and performance of agronomic activities had a positive effect on the variability in yields of bananas. This might act as a constraint in the wider adoption of the technologies as most of the subsistent farmers are concerned mainly more with stable supply of food for the family than with higher yield levels. Differences in agro-ecological and socio-economic conditions with in which farmers operate influence the capacity of the farmers to use the technologies which results in variability in yields. The farmer's management practices play a significant role since their interaction with other inputs in the package maintains the stability of yields. To forestall the variability in yields associated with the use of fertilizers and performance of agronomic management practices in order to ensure adoption of these technologies by the farmers, policy makers need to design strategies that lead to yield stability. Such strategies include, but are not limited to, dissemination of knowledge to farmers that emphasizes appropriate use of fertilizers by farmers regarding the rate, time and method of application. Performance of complementary agronomic management practices should also be included in the extension package in order to reduce the risk of attack from pests and diseases.

In addition, study results indicated that the marginal value products of the inputs are greater than their marginal costs implying that the inputs were profitable in banana production. Since the study also shows that the use of inputs like fertiiser, manure and mulch is substantially low, the findings support attempts to intensify use of these inputs if farmers are to improve banana productivity and realize more profits from banana production.

5.3 Recommendations for further research

This study mainly focused on determining the effect of inputs and other agronomic practices on the mean and variability in yields of bananas across a section of sample farmers. Since there are likely to be variability in the yields over time within the same banana plot receiving similar amounts of inputs and management, this should be the focus for further research. In addition, it is clear that this study focused on one source of risk in agricultural production i.e. production risk therefore further research can look at other sources of risk like price volatility.

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APPENDIX I

PRODUCTION RISK AND INPUT USE IN BANANA PRODUCTION

1.0 IDENTIFICATION OF FARMER

1.1 Name of the enumerator__________________ 1.2 Date of interview___________

1.3 District __________________________ 1.4 Sub-County ______________

1.6 Parish___________________________ 1.7 Village/LC1 ______________

1.8 Name of Household head _________________________________

2.0 DEMOGRAPHIC DATA

2.1 Please list the members of your household and the activities they perform

Person ID	Name	Relation to household head (1) husband (2) wife (3) child (4) grand child (5) other	Sex 1=male 2=female	Age (years)	Years in school

3.0 FARM RESOURCES

3.1 Please tell us about your farm in general

A. Land holdings

Parcel name	Parcel ID	Area (acres)	Tenure: 1=mailo 2=customary 3=rented 4=borrowed 5=leased/hired	Land use (acres)				
				Crops	Pasture	Forest	Fallow	Other

ID = identification number

B. Other holdings

	Number	Value per unit (U.Shs)		Number	Value per unit (U.Shs)
Local cattle			Radios		
Improved cattle			Bicycles		
Exotic cattle			Motorbikes		
Goats			Furniture		
Sheep			Hoes/forked hoes		
Pigs			Spades		
Local chicken			Wheel barrows		
Improved chicken			Knapsack sprayers		
Other birds			Sickles		
			Other (specify)		

3.2 Do you usually hire in land for crop production? 1=yes 2=No
3.3 If yes, how much land did you hire this current season?

Amount of land hired					Payment to land lord	
Parcel name	Parcel ID	Area (acres)	Major crop grown	Expected crop output harvested	Payment unit	Number of units

3.4 Please tell us about the soil type and soil quality of your plot today

Parcel name	**Parcel ID number**	**Farmer name for Soil Type**	**Soil fertility** 1=high 2=moderate 3=low	**Drainage** 1=well drained 2=moderately 3=poorly

4.0 CROP RESOURCES

4.1 Please list all the crops that were grown last season on your different land parcels

Parcel name and ID	**Crops grown in parcel**	**Area** (acres)	**Grown in** 1=pure 2=mixed stand	**If mixed stand,** list crops grown along in the mixture		
				First intercrop	Second intercrop	Third intercrop

4.2 For each of these parcels, answer the following questions about the major crops apart from bananas that were grown in the parcels last season and their utilization.

Parcel name and ID	Type of crop	code	Cropping System 1=pure 2=inter	Qnty of seed (kg) planted	Price (per kg)	Qnty harvested (kg)	Qnty consumed (kg)	Qnty Sold (kg)	Price (per kg)	Revenue (Shs)

5.0 HOUSEHOLD OFF-FARM ACTIVITIES

Name of household member involved	**Person ID**	**Off-farm activity:** 1= Agricultural wage 2=non-agricultural wage 3=regular (salary) 4=self employed	**Income previous two months** (U.Shs)

6.0 BANANA PRODUCTION

A. PRODUCTION CHARACTERISTICS

6.1 For each of the parcels under banana production, indicate the time the banana plantation has been in existence (only for major plantations

Parcel name	Parcel ID number	Year planted	Main type of bananas 1=cooking 2=kayinja 3=highland beer 4=Ndizi 5=other

6.2 Please tell us about the productivity your banana plots during low production period of the year (**indicate months of low production**: ____)

Parcel ID number	Number of bunches harvested per month				Bunch weight (kg)		
	Consumed at home	Sold	Price per bunch if sold	Given away	Min	Max	Most bunches

6.3 Please tell us about the productivity of your banana plots during peak production period of the year (**indicate months of peak production**: ______________________________________)

Parcel ID number	Number of bunches harvested per month				Bunch weight (kg)		
	Consumed at home	Sold	Price per bunch if sold	Given away	Min	Max	Most bunches

B. LABOUR USE

6.4 Please tell us the **frequency** (number of times for the whole year) the following activities are done in your banana plots when **family labour** is used (use codes: 0= not done at all 1= once every week 2= once every two weeks 3= once every months 4= once every two months 5= once every three months 6= once every 4 months 7= once every five months 8= once every six months 9= once every year 10= other (specify). Also tell us the amount of **FAMILY LABOUR** used for each activity.

Activity	Parcel name	Parcel ID number	**Frequency**	Number persons			Days worked	Hours/day
				Men	Women	Children		
Weeding								
Soil loosening								
De-leafing								
Sheaths removal								
Stump removal								
Split pseudo stems								
Remove corms								
Cover corms								
De-suckering								
Trapping								
All the above are done together								
Apply fertilizer								
Apply animal manure								
Apply grass mulch								
Apply coffee husks								
Apply crop residue								
Digging trenches								

6.5 Please tell us the **frequency** (number of times for the whole year) the following activities are done in your banana plots when **hired labour** is used (use codes: 0= not done at all 1= once every week 2= once every two weeks 3= once every months 4= once every two months 5= once every three months 6= once every 4 months 7= once every five months 8= once every six months 9= once every year 10= other (specify). Also tell us the amount of **HIRED LABOUR** used for each activity.

Activity	**Parcel name**	**Parcel number**	**Frequency**	**Number persons**			**Cost of labour** (U.Shs)	**Days worked**	**Hours/ day**
				Men	Women	Children			
Weeding									
Soil loosening									

De-leafing									
Sheaths removal									
Stump removal									
Split pseudo stems									
Remove corms									
Cover corms									
De-suckering									
Trapping									
All the above done together									
Apply fertilizer									
Apply animal manure									
Apply grass mulch									
Apply coffee husks									
Apply crop residue									
Digging trenches									

C. INPUT USE

6.6 Indicate the inputs you have used during the last one year on your banana plots

Type of input commonly used	Parcel name	Parcel ID	Number of applications in a year	Amount per application (Specify units)	Unit cost (U.Shs)
1. Soil amendments					
Artificial fertilizer					
Manure					
Crop residue					
Mulch					
Other (specify)					
2. **Herbicide** (specify)					
3. **Pesticides** (specify)					
4. **Others** (specify)					

7.0 EXTENSION SERVICES

7.1 Did you interact with agricultural extension agents in last six months? (a) Yes (b) No

7.2 If yes, how many times did you interact in the six months? _________ (Number times)

7.4 From which organization do these people normally come?

(a) Research (b) District department (c) NGO (d) NAADS (e) Private service providers

7.5 State the purpose of their visits

(a) Teach improved farming methods (1) Yes (2) No
(b) Provide market information (1) Yes (2) No
(c) Provide inputs (1) Yes (2) No
(d) Other (specify) ____________________ (1) Yes (2) No

7.6 Have you had any formal training in crop production? (1) Yes (2) No

7.8 If yes, how many times have you had this formal training in last one year? __________

8.0 ROAD INFRASTRUCTURE

8.1 Please tell us about the road used and time taken to access your village and farm plots

Dist from home to nearest banana plot	Time taken to nearest banana plot	Distance to furthest banana plot	Time taken to furthest banana plot	Distance to nearest banana market	Time taken to nearest banana market	Dist from household to the road (km)	Distance from village to nearest tarmac road (km)

9.0 CREDIT AVAILABILITY

9.1 During the past six months, have you sought to obtain or used credit for farm production or for other purposes? (a) Yes (b) No

9.2 If yes:

What was the purpose the credit Sought	Did you obtain it? 1=yes 2=no	How long did it take to obtain the loan (days)	Source of Credit (specify)	Amount borrowed last time (*in U.Shs*)	Amount of interest payment	How long did/will it take to pay back the loan?	What use was it put to? 1=buy fertilizer 2=buy manure 3=buy mulch 4=hire labour 5=other (specify) ________________
Banana production							
Other farm production							
Food, clothing, medical, school							
Special events (wedding, baptism)							
Buy assets (land, animals etc.)							
Other (specify)							

Source codes 1= money lenders, 2= cooperative, 3= farmer group 4=commercial 5= NGO 6= government 7= other (specify)