

## **Determinants of resource allocation in low input agriculture: The case of banana production in Uganda**

### **Authors**

F. Bagamba<sup>1</sup>, R. Ruben<sup>2</sup>, A. Kuyvenhoven<sup>2</sup>, R. Kalyebara<sup>1</sup>, M. Rufino<sup>2</sup>, E. Kikulwe<sup>1</sup> and W.K. Tushemereirwe<sup>1</sup>

1. National Banana Research Programme, KARI, P.O. Box 7065 Kampala
2. Wageningen University, Development Economics Group, Hollandseweg 1 6706 KN Wageningen, the Netherlands.

*Paper Presented at the American Agricultural Economics Association Annual Meeting,  
Denver, Colorado, August 1-4, 2004*

Copyright 2004 by **F. Bagamba, R. Ruben, A. Kuyvenhoven, R. Kalyebara, M. Rufino, E. Kikulwe and W.K. Tushemereirwe**. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies

## ABSTRACT

Banana production provides suitable options for subsistence and income generation in the mid and high elevation areas of East Africa, including Uganda. Limited access to factor markets (labour, land and credit), as well as critical biophysical factors (pests, diseases and soil degradation) have led to the decline of banana production in central Uganda and its rise in the southwest of the country. We formulate a farm production model to analyze farm household behavior in developing countries regarding resource allocation to crop production with specific reference to banana production. Findings have implications for policies to support sustainable agricultural production and growth, contributing to on-going debates about the separability of consumption and production decisions in developing economies and the response of poor households to price incentives. Our adapted model considers the non-separability of household production and consumption decisions. Perfect market conditions rarely exist in developing countries because of limited access to credit and the seasonal nature of crop production. Households often fail to satisfy annual cash income constraints, their expenditures exceeding revenue at certain periods of the year. We estimated a production function econometrically with a double log functional form to analyze output response to input use. A reduced form of labour demand was estimated to analyse the determinants of farmers' investment in banana production. Primary data was generated through a random sample that includes 660 households of which 533 were used. The sample was drawn from 33 villages located in major banana production systems, stratified by elevation and previous exposure to new technology. Elevation is highly correlated with differences in farm and biophysical characteristics such as soil fertility, incidence of pests and plant disease. 'Exposure' captures the village-level effect on household decision-making of previous technology releases. Results from the production function showed positive and significant relationship between banana production and elevation, crop sanitation labour and natural pasture. Education of household head was negatively related to output, implying that improvements in education results to a withdraw labour from agriculture to other activities. Labour use in cooking banana responded negatively to wage rate but response to out price was not significant. Nonfarm self-employment was negatively related to labour use in cooking bananas implying withdraw of family labour from farm production to non-farm production. There was a negative relationship between distance to paved roads and labour use, which implies higher transaction costs for farmers staying far away from improved road network. Education of housewife was positively related to labour used in banana production in low altitude areas but not significant for high altitude areas implying that women have a big role in decisions regarding food crop production. Investment in education (improving farming skills) of women might increase food security in low input agricultural areas. The joint effect of household characteristics on labour use (output supply) was significant implying that the separability condition between production and consumption decisions among smallholder producers is not valid. The results indicate that, given the current environment constraints, investment in technology development and dissemination has positive implications for agricultural development in low input systems. Investment in human capital, especially in education of women, and providing an enabling environment for easy access to input markets play major roles in improving agricultural production.

## **BACKGROUND**

Increasing population pressure has been associated with agricultural intensification where land gets intensively cultivated through use of abundant labour in production . The driving forces assumed are (1) increased demand for food putting pressure on subsistence farmers to intensify agriculture production and (2) increases in prices encouraging farmers to intensify agricultural production . Higher population density permits and is associated with the development of markets and specialization . Although the population has been growing at a rate of 2-3% per year, growth of agricultural productivity has only been growing at a rate of 0.6% per year in the Sahel region (Reardon, 1997). Moreover, this growth in agricultural productivity has been dependent on own supplied farm inputs (mainly manure and crop residues), a method that only helps recycle nutrients within the farming system, and do not add to the stock of nutrients in the system . The agricultural system that has developed over the years is one where labour is the major variable input, with no or insufficient use of variable capital, including artificial fertilizer, combined with intensive methods that characterize most parts of Africa . In Uganda, there is scarcely any use of artificial fertilizer in banana plots. Use of manure and mulch has been on the decline because of the increasing pressure on land .

To reverse the situation of continued soil mining and land degradation, policies that encourage private investments, to improve the state of rural factor and product markets, have been proposed . Investment in public infrastructure and strengthening institutions are some of the ways that would encourage private investment in the rural sector, through lowering of transaction costs. However, there is still limited empirical evidence linking rural market development and adoption of sustainable agricultural intensification practices. For example, in Uganda, improved access to rural markets has been associated with greater decline in yields of

sweet potatoes and bananas . Less than 30% of farmers use improved seed varieties and the percentage that use fertilizers is close to zero. Development pathways for the East African highlands have been dependant on factors that influence comparative advantage, especially agricultural potential, access to markets and population pressure . Appropriate policies are needed for such development pathways to have a long-term positive impact especially with regard to agricultural intensification and sustainable land use.

Banana production provides suitable options for subsistence and income generation in the East Africa mid- and high elevation areas. It is the major staple food crop over much of Uganda. The country is currently the world's largest producer and consumer of bananas (9.0 million tones in per annum in 1996), accounting for approximately 15% of total global production . Production is mainly by smallholder farmers with total number of plots up to 2.7 million and averaging 0.24 ha, making it the most widely cultivated crop in the country. Productivity is highest in southwest of the country, where yield is estimated at 26.4 tones per ha and lowest in central region where it is estimated at 5.5 tones per hectare.

A remarkable diversity of bananas and plantains (*Musa spp.*) exists in the East Africa Great Lakes plateau with at least 84 locally evolved unique clones . The endemic clones have been collectively termed the East African highland banana (*Musa* genome group AAA-EA) consisting of both cooking and beer bananas . The non-endemic types grown in Uganda include the exotic beer bananas (*Pisang awak* ABB and *Kisubi* AB), the roasting (plantain *or gonja*) and the dessert bananas (*sukalindizi* AAB, *Cavendish* AAA and *Gros michel* AAA). Unlike other starch staples, *Musa* consists of a variety of cultivar-based attributes that differentiate it into cooking and non-cooking (fruit and beer) (Lynam, 2000). The progressive conversion of starch into sugars after harvest makes some banana cultivars to be consumed as fruits (e.g. Cavendish)

while others (e.g. plantain) are considered to be a carbohydrate staple. Depending on juice yield, some cultivars (mainly the fruit types) are used to produce wine and gin. The East African highland bananas are mainly produced as a starch staple, thus competing with crops such as maize and millet (cereals), and sweet potatoes and cassava (tubers). The fruit types (*Pisang awak*, *Kisubi*, *sukalindizi* and *Gros michel*) are mainly grown for sale. In our study, we consider the highland cooking bananas as a different commodity from the fruit types, whose production serves a dual purpose – subsistence and cash. Whereas the biotic factors could be favoring the fruit types, farmers could still be maintaining some banana plots under the highland cooking bananas to meet subsistence needs. Nevertheless, production in the tradition growing areas of central Uganda has been on the decline while increasing in the high elevation areas of southwestern Uganda (Gold et al., 1999). Apart from elevation, other factors influencing resource allocation to banana need to be elucidated. Limited access to factor markets (labour, land and credit), as well as critical biophysical factors (pests, diseases and soil degradation) have been hypothesized to have led to the decline of highland cooking banana production in central Uganda and while increased market access led to its rise in the southwest of the country (Gold et al, 1999).

Despite the decline in banana production in central region, expenditure on banana is still higher than on other food crops, among the rural and urban population in both central and western Uganda (UNHS, 1994). In central Uganda, expenditure on bananas is followed closely, by cassava and sweet potatoes. Maize follows at only 4.8% of total expenditure. Expenditure within the urban population is quite skewed to bananas among the food crops. Expenditure on sweet potatoes and cassava is close to that of cereals (bread, rice and maize), ranging from 3.7% for maize to 6.1% for millet. The low expenditure on these commodities within the urban areas

implies better market opportunities for bananas than for sweet potatoes, cassava and maize. Therefore, access to commodity markets should not be the driving force behind farmers' decision to reduce highland cooking banana production in favor of annual crops (cassava, sweet potatoes and maize) and fruit types (*kayinja, kisubi and sukalindizi*).

There are two distinct types of agricultural production: capital-led and capital-deficient . Capital-led agricultural production is referred to as one based on substantial use of non-labour variable inputs and quasi-fixed capital (e.g. soil and water conservation infrastructure), and leads to an increase in labour productivity. On the other hand, capital deficient production occurs when farmers depend mainly on labour as a variable input to production. Agricultural development has been viewed as one that encompasses the use of external inputs and management practices that improve nutrient use efficiency, thus leading to higher yields at lower costs. However, in a situation when factor and credit markets are non-existent or partially exist, labour can hardly be substituted with capital inputs. High transaction costs in both the labour and input factor markets can lead farmers to follow intensification methods that involve more use of family labour and less capital. This can be the case where wage rate increases lag behind price increases for variable input prices in which case the farmer opts to follow a path where he merely adds labour, allowing him to crop more densely, and weed and harvest more intensively. Also where land constraints increasingly bind and labour/land ratios are rising, one might expect farmers to choose production methods that are as labour intensive as possible . The seasonality of agricultural production in developing countries further constrains the use of purchased inputs in times when output is out of season and purchases must be funded from savings and/or loans. Moreover, financial institutions require collateral in form of land or other fixed assets as a condition of offering loans, which constrain farmers' access to credit .

Farmers with more access to liquidity are able to purchase cash inputs, finance land improvements, hire labour and smooth household consumption throughout the agricultural production cycle. In the absence of insurance markets, reliable access to credit allows farmers to invest in more risky but higher yielding crop management practices . However, because of risk and asymmetrical information inherent in agriculture, formal financial institutions ration the amount of credit supplied to the farm sector, leading to a cash constraint, in particular among the smallholder farmers . The response from farmers is to allocate their family labour to non-farm income generating activities (including wage employment) or to farm enterprises whose production characteristics enable farmers to relax the liquidity constraint (e.g. livestock and bananas). Bananas are harvested throughout the year and monthly sales can enable farmers buy the required inputs. Monthly production also enables the farmers have some food throughout the year, which is not the case with annual food crops such as maize and millet that are only produced once or twice a year with the probability of crop failure. Thus while farmers might mark negatively output prices for annual food crops (e.g. maize and millet) because of the risk involved, output prices for bananas are marked positively because of the relaxation in the liquidity constraint. Access to off-farm activities and farm assets (livestock) also enables farmers get regular income enabling them to take risky decisions with respect to resource allocation.

Most of the income among rural households in Uganda is derived from crop production, the proportion being higher for southwestern Uganda. The proportion of households owning cattle is higher for southwestern than central Uganda. Expenditure on purchased food is higher in central than southwestern Uganda, implying more households follow a self-sufficiency objective in terms of food in southwestern Uganda. To be able earn income off-farm, farmers in

central Uganda may opt for annual crops so as to get time off the farm during slack periods when labour is not much required (e.g. after land preparation and planting). Alternatively, farmers in this region may engage in off-farm employment to relax the liquidity constraint and risk associated with annual food crops.

An econometric model is formulated within a household theoretic framework to analyze the farmer production behavior with particular reference highland cooking bananas. Findings have implications for policies to support agricultural production and growth, contributing to ongoing debates about the separability of consumption and production decisions in developing economies and the response of poor households to price incentives.

### **CONCEPTUAL FRAMEWORK**

A typical agricultural household is hypothesized to make decisions between farm and nonfarm employment, and engage in a number of production activities, which include production of own subsistence and for the market. Household supply to farm and nonfarm sectors is depicted as a function of returns to and risks of farm and nonfarm activities, preferences and the household's capacity to undertake the activities, determined by access to public assets such as roads and private assets (e.g. education). Rural household members are motivated to enter the nonfarm labour market to earn high incomes from the nonfarm sector (pull factors) and push factors (e.g. risk in farming, and missing insurance, consumption and input credit markets) (Reardon et al., 2001). However households may fail to join the farm sector due to high entry costs of migration, low education levels and limited access to information.

Existence of a nearby town can offer direct employment in the manufacturing and service sector within the city or induce the development of the nonfarm sector by offering market for



already processed agricultural products. Thus households in the vicinity of the cities or towns are more likely to engage in nonfarm self employment (e.g. trade in agricultural products) thereby withdrawing some family labour from farm production. However, income derived from nonfarm self-employment could be invested into agriculture production in form of purchased inputs and hired labour. Rural to urban migration on the other hand reduces labour supply to the agricultural sector, thereby reducing use of labour intensive technologies or investment in quasi-fixed capital (e.g. land and water conservation infrastructure) that requires high amount of labour. Moreover, the option of rural to urban migration is available to the fit, leaving behind the young and the old people. With higher discount rates of the future incomes, the old people may not invest in practices that require intensive capital inputs, such as fertilizer, and quasi-fixed capital, resulting in lower farm productivity. However, some of the income earned in the nonfarm sector in urban areas could be repatriated back home and invested in farm capital. Urban residents have been reported to acquire land and services in rural areas, thus spurring rural nonfarm employment . However, such land acquired by urban residents is often left undeveloped or hired out to landless households. Hiring out land can hamper investment in capital inputs and can lead to soil mining, as the tenants have no incentives to invest in external agricultural inputs.

Limited access to information and credit, and risk associated with use of inputs are some of the causes for the low use of inputs and new technologies by a poverty stricken population (Pender et al., 1999). In turn, government policies such as market liberalization, credit policies, input supply and infrastructure influence these causes (Place and Hazell, 1993). Whereas liberalization strategies targeted more on improving prices of agricultural products but the benefits can be curtailed if reduction in government revenues results in reduced investment in

infrastructure. Empirical evidence suggests that liberalisation led to higher variances in prices although there was improvement in expected (mean) prices . Higher variability in prices can undermine investment in agricultural production, especially in quasi-fixed capital . Liberalisation eliminated public input distribution systems thereby increasing variable input costs for cash constrained small farmers. Investment, by small farmers, in such costly inputs could be hindered by imperfections in factor markets in particular if access to credit is restricted to those having sufficient collateral . High interest rates make investment in agricultural production risky given output prices that are uncertain and production being dependent on weather. The smallholder farmers are increasingly relying on cash crop and nonfarm earnings (through labour markets or small to medium-scale enterprises) to finance their production and smooth consumption . Others may choose subsistence production if transaction costs are such that the gap between selling and purchase price (price band) is wide. The farmer may take the option of self-sufficiency in that good or factor if its subjective price falls inside the band .

Under perfect market conditions, production and consumption decisions are assumed to be made recursively. Market prices support the separability condition with farmers making production and consumption decisions independently. On the production side, the household maximizes profit subject to a production function:  $q = f(\text{labour}, x; \text{fixed capital, farm size})$ ; where  $q$  = output and  $x$  = variable inputs.

The reduced model takes the form: supply function  $q_a = q_a(p_a, p_x, w, z^q)$ ; Factor demand  $x = x(p_a, p_x, w, z^q)$ ; and profit  $\pi = \pi(p_a, p_x, w, z^q)$  where  $q_a$  = amount produced,  $p_a$  = product prices,  $p_x$  = price of variable factors of production,  $w$  = wage rate and  $z^q$  = farm production characteristics (fixed capital and farm size). The household chooses the levels of labour and other variable inputs that maximize farm profits given farm given current configuration of

capital, land and an expenditure constraint. Optimal input choices depend on input prices, output prices, and wage rate, as well as the physical characteristics of the farm and technology level. The household behaves as if production and consumption decisions were decided sequentially, with production decisions made first and consumption and work decisions made later. The farmer behaves as a pure producer basing his decisions on the market price. The income derived from production determines the level of consumption.

On the consumption side, the household maximizes utility  $u = u(c, l_c)$  in presence of a budget constraint  $p_m c_m = p_a(q_a - c_a) - w(x_1 - f_1)$  and a time constraint  $L_C + L_S = E$ ; where  $p_m$  = purchase price,  $c_m$  = purchased commodities,  $c_a$  = quantities of commodities produced and consumed at home,  $x_1$  = labour used in farm production,  $f_1$  = family supplied labour,  $L_C$  = home time,  $L_S$  = time worked and  $E$  = total time available to the household. The reduced model takes the form: demand function  $c_i = c_i(p_a, p_m, w, E; z^{cw})$   $i = a, m, l$ , where  $z^{cw}$  = consumer worker characteristics. Optimal choices depend on the prices of the goods of the goods consumed, wage rate, total time available and the characteristics of the family members who are the consumers and workers (gender and age).

Agricultural households in developing countries are characterized by high poverty levels, large proportion of their production kept for subsistence needs and selling surplus to the market to meet basic households needs. Production, consumption and reproduction decisions are integrated. Not all products and factors of production are tradable because of high transaction costs, shallow markets, and risks and uncertainty about weather conditions which drive purchase prices up and selling prices low. Limited access to credit is a frequent cause of market failure, as the household cannot satisfy an annual cash income constraint, with expenditure greater than revenue at certain periods of the year. The household faces a price band, where the purchase

price is higher than the selling price. Production and consumption decisions are no longer taken in response to exogenous prices. Prices ( $p^*$ ) are endogenised, being determined by the household's demand and supply conditions.

When markets for some inputs and outputs are missing, market prices can no longer support a separation of production and consumption decisions. Consumption decisions affect production decisions as production depends on the price of consumer goods and household preferences. The quantity produced for a non-tradable commodity corresponds to an unobservable internal shadow price, the decision price  $\bar{p}_i$ , at which supply equals demand. The household approach is followed, where the problem is to maximize utility  $u = u(c, z^h)$ , subject to a cash constraint:  $\sum p_i(q_i + E - c_i) + T \geq 0$ ; credit constraint:  $\sum p_i(q_i + E - c_i) + K \geq 0$ ; production technology:  $g(q, z^q) = 0$ ; exogenous effective prices for tradables:  $p_i = \bar{p}_i \quad i \in T$ ; equilibrium condition for nontradables  $q_i + E_i = C_i \quad i \in NT$ , where  $z^h$  = household characteristics,  $K$  = access to credit,  $S$  = remittances, and  $\bar{p}$  = exogenous effective prices.

Reduced form of the model: supply and factor demand  $q_i = q_i(p_i^*, z^q)$  and profit  $\pi^* = \sum p_i^* q_i$ . Consumption  $c = c(p^*, y^*, z^h)$ . Production and consumption decisions are made depending on the subjective equilibrium prices  $p^*$ , decision income  $y^*$ , household characteristics,  $z^h$  and farm characteristics  $z^q$ .  $p^*$  and  $q^*$  themselves are dependent on exogenous prices  $\bar{p}$ , household and farm characteristics, exogenous income  $S$ , and access to credit and can be eliminated to give reduced form equations  $q = q(\bar{p}, z^q, z^h, S, K)$ . The distinguishing feature between the household model and the pure producer model is that in the household model, both production and consumption decisions depend on the household characteristics  $z^h$  (Sadoulet and de Janvry, 1995). Demographic variables have been used in several studies to test for separability property,

with some rejecting the non-separation condition while others rejected the separation condition especially in Africa (Lopez, 1984; Pitt and Rosenzweig, 1986; Benjamin, 1992;). Moreover, it is not uncommon for supply response studies in developing countries to come up with highly inconsistent and low supply elasticities (de Janvry and Sadoulet, 1992; Goetz, 1992).

We test the hypothesis that household characteristics (gender, age and household composition) influence production decisions for cooking banana in Uganda. Nonfarm income and access to credit are hypothesized to influence cooking banana production differently in two production regions, high and low altitude. In the low altitude areas, nonfarm income and credit access relaxes liquidity constraint in favor of annual food crops (maize, sweet potato and cassava) and reducing farmers' dependency on bananas for regular income. In the high altitude region, the effect of nonfarm income and credit on banana production is likely to be two fold, (1) an increase in banana production resulting from increased investment in purchased inputs and hired labour and (2) a negative output response resulting from withdraw of family from farm to nonfarm activities and failure to substitute family labour with hired labour because of high transaction costs involved.

## **EMPIRICAL ESTIMATION**

### **The data**

The study is based on data drawn from a sample of 660 households of which 532 households were usable. The sample was selected randomly from three different regions, namely eastern, central and southwestern Uganda. The domain was purposively selected to represent major banana production systems in Uganda. Stratification of the domain was done first by elevation and then by exposure to new improved banana varieties (hybrids). Elevation

was used in the stratification as it is highly correlated with differences in farm plot biophysical characteristics such as soil fertility, incidence of pests and disease, and climatic conditions (temperature and rainfall). Exposure captures the village level effect on household decision-making of previous technology releases. Two elevation levels were used with recommendation from biophysical scientists: high elevation (areas above 1200 masl) and low elevation (areas below 1200 masl). The primary sampling unit was the subcounty. All the subcounties in the domain were mapped into 4 strata: 1) low elevation, with exposure; 2) low elevation without exposure; 3) high elevation, with exposure, and 4) high elevation, without exposure. Subcounties were drawn using systematic random sampling from a list frame with a random start. The final sampling frame consisted of 27 subcounties of which 3 were purposively selected (Ntungamo, Bamunanika, and Kisekka) to complement soil analyses. The three subcounties represent three production levels: 1) Ntungamo subcounty representing areas high production and with no eminent signs of decline, 2) Kisekka subcounty representing high production with signs of yield decline, and 3) Luwero subcounty representing areas with serious decline in yield and production.

The secondary sampling unit was the village. From each primary sampling unit, one village was randomly selected except in Ntungamo, Kisekka and Luwero from where we selected three villages each. From each secondary sampling unit, 20 households were selected randomly from a list provided by local council chairman.

The units of observations were village, household and plot. Village level data included elevation, location, wage rates and prices. Household level data included demographic characteristics, production, income and access to credit. Plot level data included crop production

characteristics, soil fertility and moisture levels, inputs and outputs. The data is summarized in Tables 1 and 2.

The household was assumed to be the lowest decision making unit regarding production and consumption. It was taken to consist of members living together and eating from the same pot, with decisions made by the household head and/or the spouse. Thus the characteristics of the household head and spouse (age and education) were included in the model as independent variables affecting production and consumption decisions. There are cases where some households shared resources with other households or received support in terms of food and income (e.g. by a parent). Such benefits were considered as gifts (exogenous income) to the beneficiaries.

### **Model specification**

The null hypothesis is of separation, where production decisions are made independent of consumption and consumption dependent on the profit from production, wage income and non-labour income. The first order condition for farm labour is:  $p_a \frac{\partial q}{\partial l} = w$ . Where  $P_a$  and  $w$  are exogenous banana output farm gate price and farm wage rate respectively. The household chooses labour  $l$  or produces output  $q$ , such that the marginal revenue equals the market wage. Holding  $l$  constant, an increase in wage rate results to a lower level of farm labour use while an increase in output price and/or labour productivity would result to more labour being used on farm. The other

condition from the utility maximization problem is:  $\frac{U'_q}{U'_{l_c}} = -\frac{P_a}{w}$  implying that the marginal rate of substitution between home time (leisure),  $l_c$ , and consumption of good,  $a$ , is proportional to the ratio of the consumption good price to the farm wage rate. An increase in the consumption good price would result in an increase in consumption of home time and a reduction in the

consumption of the good while an increase in farm wage rate would result in an increase in consumption of the good and a reduction in home time, provided output of the good constitutes a large proportion of the farm's output.

The alternative hypothesis is that where decision prices  $p_a$  and  $w$  are endogenised, being influenced by household demographic composition and size. The variable to be explained is  $l$ , total hours used per year in cooking banana production, which consists of both family and hired labour. In addition to farm assets (farm size, liquid assets) and exogenous income (remittances and gifts), we add demographic variables (household size and composition) to the model as independent variables to test for separability. If the separation condition is true, household size and composition should not affect amount of labour used in banana production. Rejection of the null hypothesis would imply inefficiency in the production system, which calls for intervention either in the labour markets and/or the product market. Nonfarm employment income (including income from self employment) and non crop farm income (income from livestock) are included among the independent variables as well as access to credit to assess the influence of liquidity constraint on labour demand decisions. Negative and/or non-significant effects of income from nonfarm activities and/or credit access on cooking banana output would be evidence for banana production decisions not to be credit constrained. Alternatively, significant negative effects of income from non-farm self-employment on labour demand for banana production would imply higher opportunity costs for banana production in the non-farm sector. The farmers would be better off employing their resources (especially family labour) in the better paying nonfarm activities.



We estimate a production function to analyse output response to labour input, human capital and farm production characteristics in the low and high altitude areas. Labour input is disaggregated according to labour used in weeding, soil loosening, erosion control, crop sanitation, animal manure application and mulch and crop residue application. Crop sanitation includes deleafing, sheaths removal, pruning and removing and splitting post-harvest residues (e.g. corms and pseudostem stamps). Labour input is also disaggregated by gender and age. Proxies used for human capital include household head age and wife age, representing banana production experience, and education levels of the household head and his wife. We include altitude variable for the overall sample, as a measure the environment effects (differences in soil fertility, moisture levels and disease and pest pressure).

We use a reduced-form modeling approach to estimate labour demand in banana production. The model is estimated econometrically using a double log functional form to analyze the determinants of farmers' investment in banana production. The model takes the form:  $\log l = \alpha + \log p_a + \log w + \sum_i \beta_i \log A_i + \sum_j \gamma_j \log S_j + \log K + \sum_{\Omega} \delta_{\Omega} \log T_{\Omega} + \log E + \sum_m \eta_m f_m$  where  $p_a$  and  $w$  are output farm gate price and farm gate wage rate respectively while  $A_i$  = farm and liquidity assets (farm size, cultivated area, pasture, tree area, fallow, non crop farm income and nonfarm income).  $S_j$  = exogenous income (remittances and gifts) and  $K$  = amount of credit in U.Shs obtained within the previous six months. Other variables included in the model are  $T_{\Omega}$  = measures of transactions costs (distance to paved roads) and access to new cultivars and production information,  $E$  = altitude (1= above 1200m asl), as a measure of environmental effects, and  $f_m$  = household characteristics (family size by gender and age brackets of < 5 years, 5-14 years, 15-65 years and > 65 years).  $\eta$  measures the joint influence of household characteristics on amount of labour used in cooking banana production  $l$ . The null hypothesis is

$\eta = 0$  (the household characteristics have no influence on output  $y$  and the separation condition is accepted, otherwise it is rejected). We test this hypothesis using an F-test where:

$$F_{(m, n-k)} = \frac{(RSS_* - RSS)/m}{RSS/(n-k)}, \quad RSS_* = \text{residual sum of squares (RSS) from the restricted model}$$

obtained by excluding the demographic variables from the regression,  $m$  = number of restrictions (number of demographic variables in the model). The unrestricted RSS is obtained by regressing on all the variables with  $n$  = number of observations and  $k$  = number of parameters estimated. If calculated  $F$  is higher than the theoretical  $F$ , the null hypothesis is rejected.

We test for parameter constancy across the two areas, low and high altitude, using a

Chow test where: 
$$F_{(n_2, n_1-k)} = \frac{(RSS_* - RSS)/n_2}{RSS/(n_1-k)}, \quad RSS_* = \text{restricted RSS obtained by fitting the}$$

regression on to all sample observations while  $RSS$  = unrestricted RSS obtained by fitting the regression to  $n_1$  observations. The null hypothesis of parameter constancy is rejected if  $F$  exceeds a preselected critical value, implying the parameter estimates for one of the regions cannot explain variation for the whole sample.

## RESULTS AND DISCUSSION

### Production function estimates

Results for output response to production inputs are presented in Table 3. In low altitude areas, cooking banana output responded positively to age of plantation, crop sanitation labour, and male labour, and negatively to fallow area and education level of household head. In high altitude areas, output response was positive to crop sanitation labour, area cultivated and natural pasture while plantation age had no effect on output. Plotting predicated output and plantation

age depicted a positive trend for output in low altitude areas and none for output in high elevation areas, implying that age of banana plantation is a factor only in the low altitude areas (Figures 1 and 2).

The positive effect of plantation age on output in low altitude areas could be a result of positive relationship between years spent growing bananas and experience acquired during the process. Farmers with older banana plantations could have accumulated better experience and ability to manage pests and diseases in the low altitude areas, thus the higher output levels in older banana plots.

Suppression of pest and diseases is a possible explanation for the positive and significant effect of labour used for crop sanitation on banana output. Another possible explanation is the accumulation of crop residues enabling the plantation to have self-mulch necessary for moisture and nutrient retention. The biomass that accumulates overtime might be one of the reasons why households with older plantations produce higher output. Output response to crop sanitation labour was higher in high altitude than low altitude areas mostly likely because of better environment conditions (e.g. soil fertility). Non-significant results obtained for labour used in weeding could be a result of non-compliance with recommended weeding regime. Banana plots with older and densely populated weeds mostly likely require the same amount of labour to weed as the most frequently weeded plots, taking into consideration the frequency and amount of labour used each time, thus the non-significant results obtained for weed control. The same applies to soil loosening, erosion bands, manure application and mulch and crop residue application, which had not significant effect on output most likely because the levels of application are below recommended rates and/or timing of application is poor. However, crop sanitation labour still remains the most important activity in banana production. It is a strong

explanatory variable for banana production, which implies that pests and diseases are major determinants of cooking banana output.

Male labour input had significant effect on output for the low altitude and overall sample but not for the high altitude areas. This result implies that there is differentiation in gender roles and preferences, and most likely the tasks done by men contribute more to output than those performed by women in the low altitude areas.

There was a significant effect of area cultivated on cooking banana output in the high altitude but not in the low altitude areas. This is might be a result of differences in household preferences, with households in low altitude areas preferring to grow bananas just for their home consumption, thus the amount grown is limited by subsistence needs and preferences. In high altitude areas, the positive effect of area cultivated on banana output is an indication that cooking banana production is beyond satisfying subsistence needs. Higher output response to labour input in high altitude area encourages farmers to produce for the market even at a relatively lower farm gate prices.

Area under natural pasture had a positive and significant effect on banana output in both low and high altitude while the effect of area under fallow was negative and significant but only for the low altitude areas. This implies that bananas integrates better in the livestock system and benefits from the nutrients from the cattle manure. Also farmers who have access to pasture are less likely to intercrop their bananas with other crops, which would contribute to yield reduction for cooking bananas. The negative and significant result for fallow in the low altitude areas implies that farmers in these areas rely more on annual crops than bananas.

Effect of education level of household head was negative and significant for low altitude areas implying that educated farmers allocate less management to bananas. Thus education

influences decision making towards more of earning cash income rather than meeting household consumption preferences through subsistence production.

Output response to elevation was positive and significant implying better environment factors (better soils and less pests and disease pressure) compared to low altitude areas. Adjusted R-squared is rather low for low altitude compared to high altitude implying a higher random effect and/or missing variables.

### **Labour demand estimates**

Labour input use in cooking banana was not responsive to output prices in both low and high altitude areas. Bananas being a perennial crop, output supply (labour use) might not respond to the prevailing prices because the banana plots are already established. Another implication is that the effects of the environment could be too strong to be offset by higher prices. The labour use response to farm wage rate was as expected, being negative and significant for the low altitude areas but not the high altitude areas. The negative effect of farm wage rate in low altitude areas implies low farm employment at higher wage rates. The high wage rate and low farm productivities in the low altitude areas combine to drive away labour from agricultural production to nonfarm employment, specifically to self-employment and migration to nearby towns. This leaves crop production to depend mainly on family labour and largely subsistence in nature. The significant response to wage rate for low elevation areas was expected as the labour market is more developed and households have more opportunities for nonfarm employment.

Labour demand was significant and positively related to cultivated area in the high altitude areas but not in the low altitude areas. This implies that output supply is positively related to cultivated area in the high altitude areas whereas supply of cooking bananas is not

affected by access to cultivated area in the low altitude areas, where production is largely subsistent. Farm area under forest was positively related to labour in low altitude areas and the relationship between tree share in cooking banana and labour was positive for both low and high altitudes. Farmers believe that trees have a big role to play in soil and moisture conservation. Leaving land under fallow, for a period long enough for the forest to regain the land, had always been used as a method of improving soil productivity. Long fallow periods and forest regeneration have been associated with less intensification and use of traditional methods of cultivation relying on external inputs and more of labour input (Boserup, 1965). In bananas, trees are mainly grown to provide shade and prevent soils moisture loss. However, they could be strong competitors with bananas for soil moisture and nutrients.

Income from nonfarm self-employment was negatively related to labour used in bananas in the low altitude areas. Among the variables hypothesized to relax farmers' liquidity constraint, nonfarm self-employment was the only one that significantly influenced labour use in cooking banana production and only in the low elevation areas. This implies that family labour is withdrawn from banana production to the nonfarm activities, leading less labour allocation to production of cooking bananas. Also income from nonfarm employment could be enabling the farmers to take on more profitable but risky crop enterprises in the region.

Distance to paved roads was negatively related to labour used in banana production, being significant for both low and high altitude. Farmers far away from paved roads could be facing high transaction costs in terms market search, labour recruitment costs, and information asymmetries, which affect their supply decisions with respect to banana production.

Labour use response was positive to most demographic variables except gender of household head. Family size had no significant effect on labour used in cooking banana

production in the low elevation, implying that cooking banana production cannot support large families and farmers have to look to other crops, preferably cassava and sweet potatoes, to fulfill their household consumption requirements. However, the effect was positive and significant for high altitude areas, implying that consumption considerations play a role in resource allocation decisions. Effect of the number of persons in the age bracket 5 – 19 on labour use in banana production positive and significant in low altitude areas. This result implies presence of different roles done by different gender and the tasks done by persons in the 5-19 years category contribute more to cooking banana output. Age of wife positively influenced labour use in banana production in the high elevation areas while the effect of wife education on labour use was positive in low altitude areas. In high altitude areas, where production is both for home consumption and sale, young women (spouses) contribute less to decision making for banana production. The result for education level of wives in low altitude areas shows that education of women improves resource allocation decisions in favor of food production. The effect of gender of household head on labour used was negative but only significant for the low altitude areas. Female-headed households have limited access to resources and most likely allocate them to crops that most satisfy the households' food requirements. The driving factor in resource allocation decisions by these households is most likely to be quantity rather than preferences (taste), and thus decisions are made in favor of crops that have higher productivities in relation to labour input and land. The null hypothesis for the test of joint influence of household characteristics on labour use was rejected in all cases (overall sample, high elevation and low elevation) implying that the separation property is rejected. Therefore, production and consumption decisions are done concurrently as regards cooking banana production, confirming earlier studies conducted elsewhere in Africa (Goetz, 1992).

The results for effect of exposure to new cultivars and/or management practices on labour use in cooking banana were unexpectedly negative and significant for all cases (low altitude, high altitude and overall sample). Altitude had a significant influence on labour used in cooking banana production, confirming the hypothesis that differences in biophysical constraints do influence farmers' production decisions, in particular output prices (Ali, 1995). The F-test showed parameter estimates for altitude areas not to be different from the overall sample implying high variability in production characteristics in the low altitude areas. The F-test for high altitude areas showed that production characteristics in these areas are quite different from the rest of the sample.

## **CONCLUSIONS**

Cooking bananas is a key staple food crop in Uganda, being mainly produced for home consumption in low elevation areas and both consumption and sale in the high elevation areas. Market for cooking bananas is in main cities, which are mainly located within the low altitude areas. Differences in biophysical constraints, as determined by elevation, significantly influenced farmers' response to wage rate. Farmers in the low elevation areas are at a disadvantaged position in terms of returns to labour and other variable inputs. Farm wage rate was more significant in the low elevation areas because of the close proximity to cities, which offer different opportunities prerequisite for the development of the wage labour market. Investment in technology development and dissemination seems to be a more plausible option for improving banana production in the region than relying on price instruments. Distance to paved roads negatively affected labour used in banana production. Demographic characteristics and household composition significantly influenced labour use in cooking banana, which



invalidates the separation property. In particular, gender of household head, family size, male persons in the age bracket 5 to 19 years, and age and education level of wife significantly influenced labour use in banana production. Investment in human capital, especially women empowerment, and providing an enabling environment for easy access to input markets, market information and crop production technologies, have positive implications for agricultural development and improving food security.

### **Acknowledgment**

The Rockefeller Foundation, through a student grant to Uganda National Banana Research Programme (NBRP) funded the study. Most data is from the collaborative project between IFPRI and NBRP funded by USAID. Collaboration with IFPRI staff, specifically Melinda Smale, is highly appreciated. The Authors are grateful to Mulumba Yusuf, Tumusime Wycliffe and Natukunda Annette for data entry and processing. We thank the enumerators who tirelessly conducted farmer interviews, not forgetting the farmers who gave in their time for the interviews.

### **REFERENCES**

- Ali, A.M.S. 1995. "Population pressure, environmental constraints and agricultural change in Bangladesh: examples from three agroecosystems." *Agriculture, Ecosystems and Environment* 55:95-109.
- Baland, J.M. and J.Ph. Platteau. 1996. *Halting degradation of natural resources*. New York: Oxford University Press.
- Barret, C.B. 1997. "Food marketing liberalisation and trade entry: evidence from Madagascar." *World Development* 25:763-777.
- Benjamin, D. 1992. Household composition, labour markets, and labour demand: testing for separation in agricultural household models, *Econometrica*, 60: 287-322.
- Binswanger, H. and M.R. Rosenzweig. 1986. "Behavioural and material determinants of production relations in agriculture." *Journal of Development Studies* 22:503-539.
- Boserup, E. 1965. *The conditions of agricultural growth: the economics of agrarian change under population pressure*. London: Allen and Unwin.
- Brush, S. and B.L. Turner II. 1987. "The nature of farming systems and views of their change." in *Comparative Farming Systems*, edited by B. L. Turner II and S. Brush. New York: Guilford Press.
- Carter, M.R. 1988. "Equilibrium credit rationing of small farm agriculture." *Journal of Development Economics* 28:83-103.
- Heltberg, R. 1998. "Rural market imperfections and the farm size-productivity relationship: evidence from Pakistan." *World Development* 26:1807-1826.

- Goetz, S. 1992. A selectivity model of household food marketing behaviour in Sub-Saharan Africa. *American Journal of Agricultural Economics*, 74: 444-452.
- Gold, C.S., E.B. Karamura, A. Kiggundu, F. Bagamba and A.M.K Abera. 1999. "Geographical shifts in highland banana production in Uganda." *The International Journal of Sustainable Development and World Ecology* 6:45-59.
- Graziano, Da Siva, J. and M. Del Grossi. 2001. "Rural nonfarm employment in Brazil: patterns and evolution." *World Development* 29:443-453.
- INIBAP. 1986. "A preliminary study of the needs for banana research in Eastern Africa." Pp. 98. Montpellier: INIBAP.
- Jacoby, H. 1993. Shadow wages and peasant family labour supply: an econometric application to the Peruvian Sierra, *Review of Economic Studies*, 60:
- Karamura, D.A. 1998. "Numerical taxonomic studies of the east African Highland bananas (Musa AAA-East Africa) in Uganda." Pp. 344. Reading, UK: University of Reading.
- Lopez, Ramon. 1984. Estimating labour supply and production decisions of self-employed farm producers. *European Economic Review* 24: 61-82.
- Lynam, J.K. 2000. Market development and production potential for banana and plantain. In K. Craenen, R. Ortiz, E.B. Karamura and D.R. Vuylsteke (Eds.). *Proc. Int. Symp. On Banana and Plantain for Africa. Acta Hort. 540, ISHS: 39-53.*
- Pender, J., F. Place and S. Ehui. 1999. "Strategies for sustainable agricultural development in the East African highlands." Washington, D.C: IFPRI.
- Pender, J., S.J. Scherr and G. Duron. 2001. "Pathways of development in the hillside areas of Honduras: causes and implications for agricultural production, poverty and sustainable Resource use." Pp. 171-195 in *Tradeoffs or Synergies*, edited by D. R. Lee and C. B. Barret: CAB International.
- Pingali, P.L., Y. Bigot and H. Binswanger. 1987. *Agricultural mechanisation and the evolution of farming systems in SubSaharan Africa*. Baltimore: John Hopkins University Press.
- Pitt, M., and Rosenzweig, M. 1986. Agricultural prices, food consumption and the health and productivity of Indonesian farmers, in I. Singh, L. Squire and J. Strauss (eds.), *Agricultural Household Models: Extensions, Applications and Policy*, Baltimore and London: The Johns Hopkins University Press.
- Place, F. and P. Hazell. 1993. "Productivity effects of indigenous land tenure systems in SubSaharan Africa." *American Journal of Agricultural Economics* 75:10-19.
- Ruttan, V.W. 1984. "Induced innovations and agricultural development." in *Agricultural Sustainability in Changing World Order*, edited by G. K. Douglas. Boulder, co: Westview Press.
- Sadoulet, E. and A. de Janvry. 1995. *Quantitative development policy analysis*. Baltimore, USA: The Johns Hopkins University Press.
- Schultz, T. 1964. *Transforming traditional agriculture*. New Haven: Yale University.
- Tiffen, M. 1988. "Demographic growth and sustainable land use." Pp. 1333-1347 in *Towards Sustainable Land Use: Furthering Co-operation between People and institutions*, vol. 2, edited by H.-P. e. a. Blume. Reiskirchen: Catena.
- Reardon, Thomas and et al. 1997. "Promoting sustainable intensification and productivity growth in Sahel agriculture after macroeconomic policy reform." *Food Policy* 22:317-27.

Reardon, T., C. Barret, V Kelly and K. Savadogo. 1999. "Policy reforms and sustainable agricultural intensification in Africa." *Development Policy Review* 17:375-395.

Reardon, Thomas, Julio A. Berdegue and German Escobar. 2001. "Rural nonfarm employment and incomes in Latin America: overview and policy implications." *World Development* 29:395-409.

UNHS. 1994. "Uganda National Household Survey, 1993/94."

## TABLES

Table 1. Farm production characteristics

	High altitude		Low altitude	
	Mean	SD	Mean	SD
<b>Farm characteristics</b>				
Farm size (acres)	2.89	5.69	4.30	8.99
Natural pasture	0.75	3.80	1.17	8.31
Forested	0.06	0.24	0.17	0.97
Swamp	0.07	0.40	0.10	0.36
Fallow	0.09	0.45	0.38	0.85
Cropped land (acres)	1.74	1.62	2.17	2.11
Bananas (plot area <sup>a</sup> )	1.01	0.93	0.92	0.98
Bananas (crop area <sup>b</sup> )	0.85	0.77	0.64	0.78
Highland cooking bananas <sup>c</sup>	0.78	0.71	0.49	0.61
Tree share in cooking bananas (acres)	0.00	0.01	0.03	0.05
Highland cooking bananas <sup>d</sup>	0.78		0.46	
Age banana plantation	41.8	27.3	12.7	14.5
Number mats highland cooking bananas	326.9	289.4	161.7	216.8
Number mats non-cooking bananas	26.8	48.9	58.7	173.9
<b>Labour used (hours/year)</b>				
Total	1202.5	805.5	567.7	613.7
Male labour	683.7	520.0	199.9	294.6
Female labour	331.8	321.9	261.4	311.4
Child labour	187.1	368.1	106.4	215.5
Crop sanitation	610.1	409.3	220.9	229.6
Weeding	398.3	413.3	185.3	209.6
Mulch and crop residues	100.2	158.2	67.2	109.7
Manure application	41.6	117.1	18.1	60.1
Soil loosening	33.2	75.8	38.1	79.8
Soil erosion control	5.1	11.9	5.3	25.1
<b>Infrastructure</b>				
Distance to paved roads (km)	10.4	13.1	15.5	21.2
<b>Cooking banana productivity (tones)</b>				
Total production	5.89	6.85	1.89	3.00
Annual home consumption	3.92	3.93	1.38	1.76
Annual sales	1.97	5.41	0.55	3.32
Annual purchase	0.00	0.00	0.04	0.20
Mean bunch weight peak production (kg)	17.9	5.43	12.8	4.88
Mean bunch weight slack production (kg)	15.3	5.64	11.0	4.22
Farm gate price (U.Shs per kg)	87.0	31.6	145.7	57.4
Farm wage rate (U.Shs per day)	961	168	1703	698

*SD = standard deviation*

Table 2. Household characteristics for high and low elevation in study areas

	High elevation		Low elevation	
	Mean	SD	Mean	SD
<b>Nonfarm income (000' U.Shs)</b>				
Non-crop farm income	52.4	147.2	277.1	2499.5
Non-agricultural wage employment	83.9	347.4	123.4	649.0
Self-nonfarm employment	123.0	482.5	317.3	1388.3
Household size	6.03	2.48	5.94	2.80
Number persons 15-64 years	2.97	1.77	2.73	1.64
Number persons 5-14 years	2.03	1.58	2.11	1.82
Female persons 5-19 years	1.52	1.41	1.37	1.41
Male persons 5-19 years	1.31	1.31	1.46	1.46
Female persons 20-64 years	1.14	0.75	1.09	0.68
Male persons 20-64 years	1.11	0.83	0.96	0.73
Age household head (years)	43.5	14.3	45.9	16.8
Education household head (years)	4.95	4.00	5.63	4.22
Age wife (years)	28.4	17.4	24.5	18.2
Education level wife (years)	3.27	3.64	3.35	3.71
Gender household head (female = 0)	0.84	0.37	0.78	0.41

*SD = standard deviation*

Table 3. Production function estimates for highland cooking bananas, Uganda

variables	Low altitude	High altitude	Overall sample
	<b>Coefficients</b>		
Intercept	1.387 (4.336)***	2.611 (7.763)***	1.551 (12.613)***
Log banana plantation longevity (years)	0.285 (2.604)***	0.11 (0.894)	0.260 (3.057)***
Log labour soil loosening	-0.080 (-1.249)		-0.05 (-1.071)
Log labour erosion bands	0.101 (1.25)		0.066 (1.105)
Log labour crop sanitation	0.257 (3.392)***	2.96 (3.247)***	0.321 (5.313)***
Log crop residue and mulch application	0.091 (1.20)	-0.034 (-0.998)	0.057 (1.086)
Log male labour	0.090 (1.885)*		0.073 (1.892)*
Log female labour	0.090 (1.430)		0.050 (1.097)
Log area under crops (acres)	0.253 (1.477)	0.07 (4.051)***	2.545 (3.32)***
Log natural pasture (acres)	0.422 (2.621)***	0.215 (1.663)*	0.408 (3.32)***
Log fallow (acres)	-0.422 (-1.813)*		-0.353 (-1.772)*
log tree share	-1.598 (-1.043)		-1.562 (-1.165)
Education household head (years)	-0.020 (-1.998)**	0.010 (1.155)	-0.009 (-1.364)
Education wife (years)	0.013 (1.23)	-0.013 (-1.387)	
Age household head	0.09 (0.653)	-0.012 (-1.042)	
Age household head squared	-0.000007 (-0.560)	0.0001 (0.878)	0.000004 (0.208)
Exposure to banana technologies (1=exposed)	0.098 (1.233)		0.15 (2.494)**
Altitude			0.23 (2.697)***
R-squared	0.321	0.448	0.433
Adjusted R-squared	0.292	0.398	0.417
F-Parameter constancy <sup>a</sup>	0.297		

<sup>a</sup> *F* test for constancy of parameters across sub samples,  $F(n_2, n_1-16)$   
*t*-values in parentheses

Table 4. OLS estimates for labour demand in highland cooking banana production, Uganda

Parameter	Low altitude	High altitude	Overall sample
	Coefficients		
Intercept	5.804 (5.875)***	3.398 (2.672)***	5.940 (7.209)***
Log price cooking bananas	0.080 (0.309)	-0.004 (-0.022)	-0.068 (-0.347)
Log farm wage rate	-1.195 (-4.057)***	-0.244 (-0.590)	-1.136 (-4.634)***
Log area cultivated (acres)		0.791 (5.969)***	0.241 (1.716)*
Log natural pasture (acres)		-0.112 (-1.099)	
Log forest (acres)	0.674 (2.210)**		0.620 (2.389)**
Tree share (acres)	2.512 (3.959)***	2.503 (4.213)***	2.455 (4.14)***
Log income non-farm self employment	-0.029 (-1.805)*		-0.033 (-2.577)***
Log distance to paved roads (km)	-0.229 (-2.381)**	-0.314 (-2.117)**	-2.66 (-3.440)***
Log age plantation (years)	0.465 (3.959)***	0.430 (4.83)***	0.376 (4.052)***
Family size		0.019 (1.821)*	
Number persons 65+ years		-0.056 (-1.148)	
Number male persons 5-19 years	0.056 (2.132)**		0.049 (2.287)**
Age wife (years)		0.004 (2.576)**	
Education wife (years)	0.038 (3.260)***		0.027 (3.010)***
Gender head of household (1=male)	-0.202 (-1.884)*		-0.121 (-1.454)
Exposure to banana technologies <sup>a</sup> (1=exposed, 0=not exposed)	-0.423 (-4.956)***	-0.364 (-2.856)***	-0.411 (-6.137)***
Altitude (1=above 1200m above sea level)			0.204 (2.179)**
R-squared	0.192	0.478	0.283
Adjusted R-squared	0.169	0.431	0.265
F Demographic variables <sup>b</sup>		7.841	4.681
F Parameter constancy <sup>c</sup>	0.21	10.77	

<sup>a</sup> households within villages that had been exposed new banana cultivars and/or management practices by researchers

<sup>b</sup> F test for exclusion of household demographic variables  $F(m, n-k)$ .

<sup>c</sup> F test for parameter constancy over the regions: low and high altitude,  $F(n_2, n_1-k)$ .  
t-values in parentheses

## Captions

**Figure 1.** Relationship between predicted log output and log plantation longevity for cooking bananas in low altitude areas

**Figure 2.** Relationship between predicted log output and log plantation longevity for cooking bananas in high altitude areas



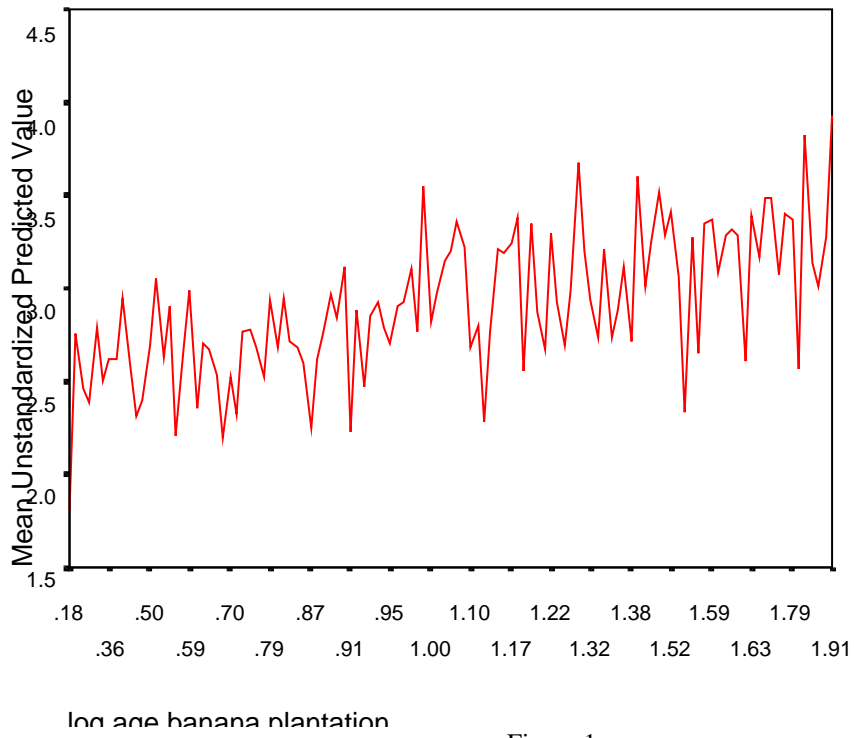


Figure 1

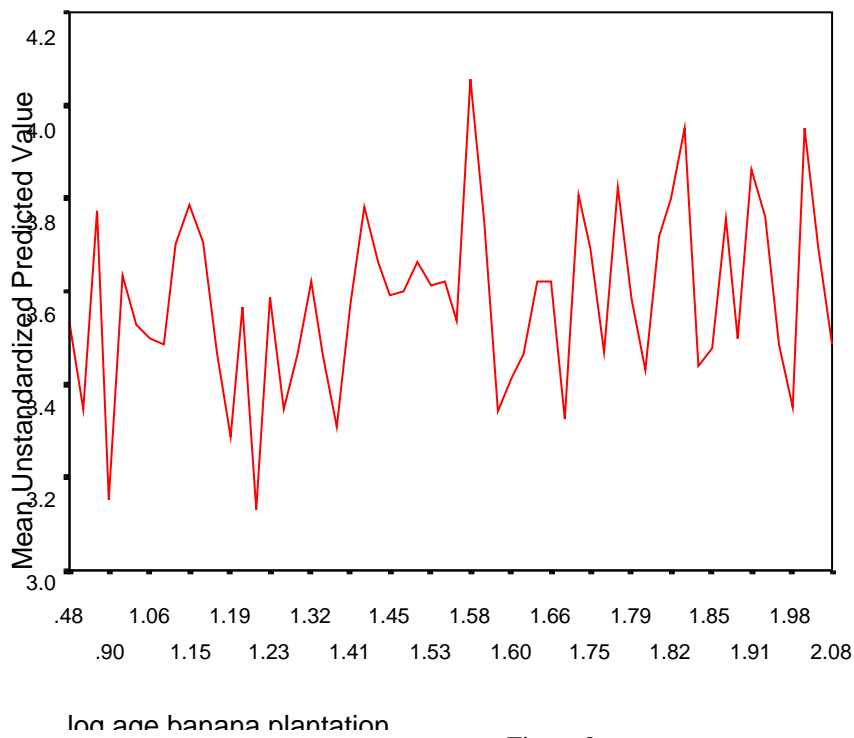


Figure 2