Potato Production and Supply by Smallholder Farmers in Guinea: An Economic Analysis

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Authors' contributions

This work was carried out in collaboration between all authors. Author ET designed the study, conducted the field survey, performed the statistical analyses and wrote the protocol. Authors HK and MI designed the study and supervised the work. Authors ME and BSB managed the literature searches and edited the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The purpose of the current study was to assess the determinants of the quantity of potato produced and marketed by smallholder farmers in Guinea. Potato has emerged as an attractive cash crop due to its income-generating potential and is one of the main sources of income for the majority of the resource-poor smallholder farmers. Thus increasing production and improving marketing efficiency has the potential for raising incomes of the farming households. Using a multi-stage sampling technique, data was collected from a sample of 90 potato producers in Middle Guinea. Results of the Cobb Douglas production function showed that potato area, improved seed use and fertilizer, positively influenced the potato output, while production losses are negatively associated with the potato output. A supply function used to investigate factors influencing the quantity of potato

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marketed revealed that quantity produced, price of potato and share of sales four weeks after harvest were positively associated with quantity of potato supplied to the market, whereas quantities retained for seed, food and gifts, and post-harvest losses have negative effects on the quantity of potato marketed. Results also revealed that none of the relevant production inputs used by the sample farmers were efficiently allocated and utilized. Constraints to potato production and supply include lack of funds, poor irrigation, pest and disease, the high cost of transportation, lack of storage facilities among others. Findings, therefore, suggest that government and development stakeholders should encourage and support farmer organizations, develop agricultural and marketing infrastructures, so as to boost agricultural production and farmers' market access.

1. INTRODUCTION

Potato is the fourth most important food crop in the world after wheat, rice, and maize. Because of climate change, the reduction of arable land, increasing population, and frequent occurrence of natural disasters, food security has become a crucial issue. To face this situation, increased food supply has become a priority in the world's development agenda. Due to the recent surge in the global food prices, several international organizations have been giving emphasis to the potato as a key part of world food production. Many countries and international development agencies give due concern to the intensification and commercialization of smallholder agriculture as a means of achieving poverty reduction; and thus they have reflected it in their official policies [1]. Until recently, in many Developing and Least Developed Countries, potato was relatively unknown and mostly regarded as a subsistence crop. However, today the market is expanding rapidly as potatoes are increasingly popular as a source of affordable food for growing urban populations. According to FAO statistics [2], potato production in developing countries has increased by 94.6% over the last 15 years. And out of the four major food crops (rice, wheat, potato and maize), potato has the best potential for yield increases. In terms of nutritional value, adaptability to diverse environments and yield potential, the potato is a preferred crop, especially in developing countries. Many of the poorest producers in these countries and most undernourished households depend on potatoes as primary or secondary sources of food and nutrition. In addition, a more affluent middleclass has developed a preference for potatoes in processed forms such as fries and chips. This growing domestic market presents a valuable opportunity for smallholder farmers and provides a path out of subsistence farming and poverty with little risk exposure to farmers.

Farmers' market access is a vital component of market participation. A smallholder farmer can access the market either by selling to a buyer at the farm gate or physically transporting the produce to the market place using available means. Commercializing smallholder agriculture is an indispensable pathway towards economic growth and development for most developing countries relying on the agriculture [3-5]. Moreover, commercialization acts as a go-between input and output sides of a market. Although the net welfare gain from agricultural commercialization at the household level is universally accepted, there is no common standard for measuring the degree of household commercialization. Some literature has considered different types of ratios such as marketed outputs or inputs to the total value of agricultural production or total household income [3,6]. Understanding the functioning of input and output marketing is essential to the improvement of farm productivity and smallholders' agricultural commercialization.

In Guinea, the agricultural production is as elsewhere in other developing economies dominated by the smallholder farmers. It accounts for about 25% of the Gross Domestic Product [7]. More than 85% of Guinea's population depends on subsistence agriculture for food production and the sector remains the main source of income and livelihood for the vast majority of the rural and peri-urban communities. Most of the farmers cultivate food staples such as rice, maize, potato, vegetable food crops, etc. for own consumption and commercialization. Many of the producers of the potato in Guinea are smallholders who cultivate less than one hectare and the majority are subsistence farmers with low productivity and yields. Barret, [8] argued that farm households especially subsistence ones must have access to productive technologies and adequate private

and public goods in order to produce a marketable surplus. Yet investment in private assets, improved technologies and public goods requires that households earn enough that they can save and invest. Kumar [9] in a study on the adoption of hybrid maize in Zambia argues that an increase in maize supply by smallholder farmers can be attributed to their access to hybrid maize seeds as well as other agricultural inputs. Potato as one of the main cash crop grown in Guinea is an essential source of income for the majority of smallholder farmers with about 18,000 tons of annual production entirely produced in Middle Guinea. However, in addition to the low yield, its production and market access, as for many other cash crops, face numerous constraints that limit productivity and income earning capability of producers.

There are a number of factors that affect potato production and agricultural productivity in general in Guinea including rainfed agriculture, poor farming technology and limited inputs among others. In addition, a high proportion of the agricultural commodities is sold in the form of raw materials with insignificant value addition. Smallholder farmers are faced with many constraints, some of these include low uptake of improved farm inputs, weak links to markets, high transportation costs, small and weak farmer organizations, lack of information on markets and prices. As reported by [10], high transaction costs are one of the main reasons for smallholder farmers' failure to participate in markets and supply adequate quantity of produce. Several initiatives by governmental as well as non-state actors are in place to promote intensification and commercialization of smallholder farming. One of the organizations spearheading the commercialization of smallholder farming in Guinea is the National Confederation of Farmer Organizations (CNOP-G), a farmer-based organization that aims to deliver adequate services to smallholder farmers so as to improve their production and incomes.

There is largely a consensus that potato production and commercialization is crucial and has differential impacts on rural farm households in Guinea. However, the relatively poor output realized by farmers and the poor performance of the agricultural sector may be an indication that little emphasis is placed on the crop and that resources needed in the production are not being used at their optimal levels. This situation affects the conditions of commodity production and

supply, calling for an assessment of the potato production and marketing. The current research aims at analyzing the factors influencing potato production and supply to the market by smallholder farmers in Guinea in view of bridging the knowledge gap in the literature.

1.1 Potato Production in Guinea

Agricultural activities in Guinea have long been focused on traditional food production, focusing on crops such as rice, cassava, maize, yams, potatoes, fonio, peanuts, mangoes and pineapples. Maize, rice and cassava are the three most important food crops in Guinea, rice being the predominant and major staple food in the diet of both urban and rural households. However, its domestic production has never been able to meet the increasing national demand, leading to serious concerns about food security. These food deficits repeatedly ruin the efforts made by more than 85% of the population whose livelihood depends solely on agriculture. From this point of view, potato has emerged as an important food crop, taking a leading role in the crop production system in Guinea, while increasing food diversity and providing income.

Potatoes were first introduced in Guinea during the early 1920 s and have shown excellent results in the central plateau of the Fouta-Djallon where the average annual temperature is 23ºC, with lows reaching 4ºC in certain areas. This region has a tropical climate with two humid seasons accompanied by 1,500-2,000 mm of rain for six months of the year. Potatoes were brought into the region during colonial times and have remained, although the seeds have degenerated and the size of the potatoes has diminished. According to [2], potato production stands at 10,800 tons from 1,750 ha, with an average national yield of about 6.2 t/ha. This is low compared with the 25 t/ha that can be attained by farmers under organized production systems [11]. In Guinea, potato production is concentrated in the Fouta Djallon highlands. The Table below shows the characteristics of the major production areas.

As depicted in Table 1, the major production areas are in the Fouta Djallon highlands and around Mamou prefecture. Areas within the Fouta Djallon where potato production is expanding and where further development of the crop is viable include Dalaba, Labé, Mali, and Tougué.

Although data are fragmented and official statistics is of doubtful quality, best estimates indicate that national potato production rose from 500 tons in 1992 to 2,500 tons in 2000, with annual production in the range of 6,000 to 8,000 tons [12]. Production is just sufficient for national consumption, with only a few hundred tons shipped into neighboring countries by informal traders.

Post-harvest losses are excessive due to inadequate harvesting techniques, combined with improper storage, packaging, and transport. The unavailability of export quality boxes and other packing material inhibits exports. The profitability of the crop is affected by the lack of proper storage facilities, including cold storage facilities that would permit the potato to be stored for longer periods of time to capitalize on higher off-season prices.

There are two major producer organizations in Guinea: the Fédération des Paysans du Fouta Djallon (FPFD), and the Union des Groupements Agricoles de Soumbalako (UGAS). A small percentage of potato producers such as Dansoko and Agrobusiness work independently, with no affiliation with either producer organization. Their main difficulty is in obtaining good quality seed and farm inputs.

Few formal exports have been reported, although undoubtedly informal cross-border trade in potato occurs between Guinea and neighboring countries. It is notable that a vibrant, although small, industry has evolved in the regions around Labé and Dalaba for the production and sale of potato seeds. Historically, first-crop seed potatoes in Guinea have been imported from northern Europe at a high cost. The ability to produce certified seed potato in Guinea would undoubtedly have a favorable impact on the potato agro-industry.

Table 1. Potato production zones in Guinea

	Production zones	Characteristics
Main zones	Timbi Madina (Pita)	The Timbi-Madina area is the most important potato production zone with a huge potential. Altitude varies between 900 and 1,200 m with about 30,000 ha of plains and bas-fonds, favorable to potato production. With 70 ha and 35 ha of irrigated plains and bas-fonds respectively, the zone produces 75% of the total potato production. Although the water system is irregular in this region, it offers important possibilities for potato production. The total cultivated area is estimated at 32,000 ha and the average yields of about 3-5 t/ha [13].
	Soumbalako (Mamou)	The Soumbalako zone in Mamou prefecture is the second largest production area, with 246 ha of irrigated land and 30 ha used for potato production; the presence of the Bafing River in the area gives potential for expanding production. Altitude varies between 400 and 800 m and production quantities estimated to 500-560 tons, yearly.
Expansion zones	Dalaba	Dalaba is a lesser mountainous area with altitude averaging 800 m. The area benefits from 1,500 to 2,500 mm of rain every year and there has been growing interest in the cultivation of potato in this area.
	Mali	The Mali zone is a mountainous area with 800 m to over 1,000 m altitude. The favorable agro ecological conditions in this zone give it a huge potential for potato production.
	Tougue	Tougue (in Fatako sub-prefecture), this zone has vast plains for potato production and altitude varies between 400 m to over 800m. Potato is produced in the area during dry season and offseason.
	Labe	Altitude in Labe prefecture varies between 800 m and 1,000 m and the huge water system in the area is a considerable asset for potato production. The irrigated farm lands of Sagara, Labedheppere and Kalan are of a great potential for potato production.

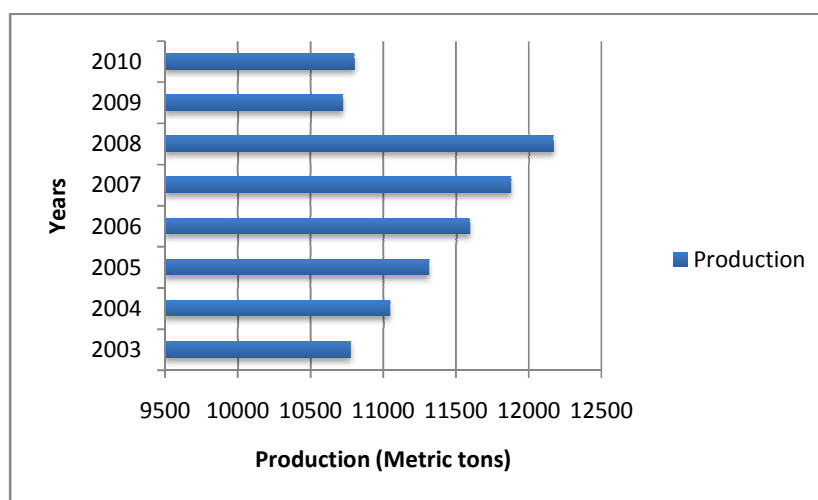*Source: Author's compilation (Field survey, 2012)*

Fig. 1. Potato production in Guinea, 2003-2010, (FAO stat, 2010)

2. MATERIALS AND RESEARCH METHODOLOGY

2.1 Study Area and Sampling Procedure

The study was carried out in three major potato producing districts in the Fouta Djallon highlands, namely Timbi Madina, Timbi Touny (both in Pita prefecture) and Hafia (Labe prefecture). These districts were purposively selected because they are the leading potato producing areas with identifiable potato producers both members of farmer groups and non-members. The study adopted a random sampling technique to select 60 registered farmers of the Fouta Djallon Farmers' Federation (FPFD) from a complete list in each area as well as 30 independent potato producers. However, due to low reliability, data from five farmers were not considered for the empirical analysis. Primary data were collected by administering a well-structured questionnaire to individual farmers. The interviews with farmers and key informants captured data on the farm economy, potato production and marketing as well as the socio economic characteristics of the farm household.

Secondary information was obtained from literature review and reports from the Ministry of Agriculture and the Guinea National Confederation of Farmers' Organizations (CNOP-G) among other sources.

Data for this study was subject to different types of analyses with the aid of Statistical Package for the Social Sciences (SPSS 19), STATA 12 and Microsoft Excel package.

2.2 Econometric Model Estimation

For the purpose of this study, we employed the production function framework. Specifically, the study uses a Cobb Douglas functional form to investigate factors influencing potato production, while a supply function was used to investigate factors influencing the quantity of potato marketed. The Cobb Douglas functional form for the production function is specified below:

$$\ln Q_{pi} = \theta_0 + \sum_{j=1}^{J} \alpha_j \ln Z_{ij} + \sum_{k=1}^{K} \beta_k D_{ik} + \varepsilon \qquad (1)$$

Where the subscript i, indicates the ith household in the sample (i=1,....,85); ln is the natural logarithm; α_j and β_k are parameters to be estimated (J=1,....,5; K=1,....3) and represent the elasticity of output with respect to each ith input. Q_p= quantity of potato produced (kg) by the ith farmer; θ= constant; Z_1= age of the farmer (years); Z_2= potato area (ha); Z_3= quantity of improved potato seed used (kg); Z_4= labor hired (man-days/ha); Z_5= quantity of fertilizer used (kg); D_1=gender of the household head (dummy:1=male; 0=female); D_2= access to extension service (dummy:1=yes; 0=no); D_3= respondent's estimate of production loss (dummy:1=high; 0=low)) and ε = error term.

The functional form for the supply function is presented below:

$$\ln Q_{\pi i} = \delta_0 + \sum_{j=1}^{J} \delta_j X_{ij} + \sum_{k=1}^{K} \beta_k D_{ik} + \varepsilon \qquad (2)$$

Where the subscript i, indicates the ith household in the sample (i=1,....,85); α_j and β_k are parameters to be estimated (J=1,....,8; K=1). Q_Π = quantity of potato marketed (kg); X_1= family size (persons); X_2= respondent's education level (years); X_3= quantity of potato produced (kg); X_4= distance to market (Km); X_5= potato price (Fg/kg); X_6= quantity of potato retained for seed (kg); X_7= quantity of potato kept for food and gifts (kg); X_8= estimate of potato sold four weeks after harvest (%); D_s= estimate of production loss (dummy:1=high; 0=low); and ε=error term.

Estimation of the model outlined in the above equations followed a series of regression diagnostics. Collinearity diagnostics tests were done using a simple regression matrix of the variables. Variance Inflation Factor (VIF) was used to check for tolerance level of multicollinearity. The average VIF of less than 10 implies that the variables in the model had no serious multicollinearity [14]. In addition, heteroskedasticity was checked using Breusch-Pagan/ Cook-Weisberg tests [15].

The Cobb-Douglas functional form enabled to determine the extent of resource use efficiency in potato production in the study area. The production function analysis gives the physical or technical relationship between inputs and output in any production scheme or process [16,17]. To evaluate the extent to which potato farmers in the study area are employing their resources into efficient use, the study also adopts the marginal value product (MVP) and the marginal factor cost (MFC) approach to measure the ability of farmers in achieving the best combination of different inputs to produce a given level of output considering the relative price of these inputs.

Following [18-20], the efficiency of resource used in potato production was determined by the ratio of the Marginal Value Product (MVP) to Marginal Factor Cost (MFC) using the formula below.

$$r = \frac{MVP}{MFC} \qquad (3)$$

Where r = Efficiency ratio; MVP = Marginal Value Product; MFC = Marginal Factor Cost.

The marginal value product (MVP) of each input was estimated as a product of the marginal physical product (MPP) of each production input and the unit price of output.

$$MVP = MPP_{Xi}.P_y \qquad (4)$$

Where MPP_{Xi} =Marginal Physical Product with reference to resource Xi; P_y=Unit price of output. And the marginal physical product (MPP) was determined using the formula:

$$MPP_{Xi} = \text{bi} \frac{\bar{Y}}{\overline{Xi}} \qquad (5)$$

Where $\bar{Y}$ = Geometric mean value of output; $\overline{Xi}$ = Geometric mean value of the ith input considered; bi = Elasticity coefficient of the ith independent variable.

The prevailing market price of input was used as the Marginal Factor Cost (MFC):

$$MFC = P_{Xi} \qquad (6)$$

Where P_{Xi} = Unit price of input Xi.

The decision rule for the efficiency analysis was as: i. $r = 1$, implies that resources are used efficiently by potato farmers in the study area, thus an optimum utilization. ii. $r > 1$, implies resource is underutilized and increasing the rate of use of that resource will help increase productivity. iii. $r < 1$, implies resource is excessively used or over utilized hence reducing the rate of use of that resource will help improve productivity.

3. RESULTS AND DISCUSSION

Variables used for the empirical analyses are presented in Table 2. Previous research has shown that agricultural production and market access by farmers are strongly influenced by factors such as the physical conditions of the infrastructures, access to production and marketing equipment [21].

The summary of the variables presented include indicators of household agricultural resource endowment such as the farm size. The majority of farmers cultivate less than 1 ha; the average planted potato area is 0.89 ha. This reveals a pattern that closely mirrors the situation in respect to the overall farm size in Guinea. An increase in farm size may enhance production if the land is effectively utilized which entails application of appropriate farm practices and inputs. Access to extension service is 73%; this is however mainly through farmers groups implying that the majority of farmers have poor access to extension workers to solve their farming problems.

Also included are the household demographic factors, potato production and marketing, variables indicative of farmers' market access conditions. The demographic variables include the gender, age and education of the household head, family size. The market access variables include the distance to the primary market and the estimate of sales four weeks after harvest. With an average family size of 7 persons ensuring availability of labor and farm expansion, the average age of potato farmers in the study area is 50 years old and the majority are female (60%). Family size is a key determinant of farmers' behavioral pattern in production and productivity given the labor-intensive nature of potato farming in the study area. Farm labor used is 199 man-day/ha and large household size would reduce the cost of hired labor. With about only 3 years of education, the literacy level is very low in the study area; only about 35% of farmers are educated, 48% and 50% of the respondents, respectively members and non-members of farmers groups have a primary school education.

The quantity of fertilizer used is 401 kg/ha on average; this variable is expected to be positively related to productivity; a farm unit that is too constrained to afford an adequate amount of fertilizer will most probably experience lower output and ultimately less marketable surplus. The use of improved potato seeds with an average of 508 kg/ha is expected to have the potential of high yields and recovering from adverse effects of drought, pest and diseases. However, access to fertilizer and improved seeds, mainly through membership in farmers groups and other suppliers (traders, money lenders, private companies), is a major constraint to crop production. Difficulty to access farm inputs in general led to farmers retaining important quantity of potato (946 kg/ha) to serve as future seed. More, with production averaging 5,148 kg/ha, 85% of producers sell 75% of output just four weeks after harvest (3,829 kg/ha sold on average), and farmers keep on average 370 kg/ha for consumption and gifts. It is expected that output of potato positively influenced quantity market. The more the quantity of potato produced, the higher would be the share of potato supplied to the market.

Given the poor production and management technology, production loss (post-harvest) estimated at 42%, is a major impediment to potato production across the producing areas. In effect, in Guinea as in many West African countries, farmers store their crops in homes, on the field, in the open. Which is the case in the low-income countries, where pre-harvesting management, processing, storage infrastructure and market facilities are either not available or are inadequate [22]. With regard to the selling price, the average potato price was 4,480 Fg/kg, with the unit price ranging from 2,600 Fg to 7,000 Fg. Better potato price can provide an incentive to farmers for market participation by supplying more quantities. Many producers seek higher market price through their membership in farmer organizations, however, the performance of the latter in paying a higher price to their members remains in question. The majority of farmers are bound to sell their produce to buyers to whom they may have obtained input credit from.

Distance to market is 4.44 km on average and is hypothesized to be negatively related to producers' market access. The further the production area from the market, the less likely would be the farmers' participation. This comes with the logistical problems in terms of the availability of transport facilities, increased transportation costs and the poor access to market information and facilities.

The variables discussed above were tested for their significance and considered for the models. Comparing farmers members of farmers groups and non-members, the respondents' socio economic characteristics are depicted in Table 3.

The socio economic characteristics of the sample farmers both members of farmer groups and non-members are presented in Table 3. More female (60%) are involved in potato production than male. However, the Figure for the two categories of producers, show that 48.3% are female and non-members of farmer groups compared with 66.1% for members. The average age of the members of farmer groups was 53.05 years and 46.59 years for non-members, revealing a significant difference between the two groups. This also suggests that potato farmers in the study area are relatively old; therefore, young farmers need to be encouraged to join farming. The finding corroborates with that of [23], highlighting the necessity for youth to effectively participate in potato farming. Results in Table 3 show that farmers suffer significant crop losses. 28.6% of members of farmer groups and 69% of non-members reported having experienced high crop losses. These are physical losses caused by poor harvest technologies, sorting, handling and transportation among others. Household

characteristics between the two groups of farmers were similar in many aspects. There was no difference in the quantity of potato produced between the two groups of farmers, however, there existed a difference in the quantity sold and retained for seeds. While members of farmer groups kept 1,086 kg/ha for future seed and supplied 4,296 kg/ha to the market, the Figure for non-members shows 676 kg/ha and 2,928 kg/ha respectively for the quantity of potato kept for seed and sold. Table 3 also shows that the majority (94.6%) of members of farmer groups declared to have access to extension service while only 31% of non-members receive extension services. The implication of this that the lack of extension service which is a channel through which agricultural technology and information are passed to farmers, could lead to inefficient use of farm resources, consequently low productivity and threaten food security. As argued by [24], agriculture-specific human capital is important in improving farm yields in a changing environment because it enhances resource allocation abilities of farmers. Agricultural extension service plays a role in linking the different stakeholders involved in input–output marketing and credit supply; this could be the government agency or ministry responsible for promoting the adoption and utilization of new scientific farming practices through educational procedures [25].

3.1 Factors Influencing Potato Production in the Study Area

The factors influencing the amount of potato produced are presented in Table 4.

The results of the Cobb-Douglas production function show that the value of the coefficient of multiple determinations for the total sample is 0.842. This implies that 84.2% of the total variation in the output of potato farmers is explained by the variation in the independent variables included in the model. For variables with positive regression coefficient, this means that a unit increase in any of them holding others constant, will lead to a unit increase in the gross output. The F-value (50.753) was significant at 1% and determines the overall significance of the model. Specifically, the results show that the coefficients of planted potato area, improved seed used and fertilizer used carried positive signs and are significant for both farmers members of farmer organizations and non-members.

The positive and highly significant effect of planted area (p<0.01) implies that there is a direct and positive relationship with the potato output. That is, as farm size increases, holding other variables constant, the output of potato increases consequently. This is a critical variable

Table 2. Summary statistics of demographic and socio-economic variables

Variables	Definition	Mean	Std. Dev
Age	Actual age of household head (years)	50.85	10.937
Gender	Respondent's gender (1=male; 0=female)	0.40	0.493
Education	Number of years in school (years)	2.76	3.860
Family size	Number of household members (persons)	7.34	3.220
Potato area	Planted potato area (ha)	0.89	0.722
Labor used	Total labor hired (man-days/ha)	199	317.219
Fertilizers used	Quantity of fertilizer used (kg/ha)	401	381.28
Potato seed used	Improved potato seed used (kg/ha)	508	437.70
Quantity produced	Total output of potato (kg/ha)	4,224	5,802.867
Distance to market	Distance to the nearest market (km)	4.44	2.318
Potato price	Market price of potato (Fg/kg)	4,480	860.814
Quantity sold	Total quantity of potato marketed (kg/ha)	3,829	2,917.361
Future seed	Amount of potato kept as future seed (kg/ha)	946	997.130
Food and gift	Quantity for consumption and gift (kg/ha)	370	417.746
Sales in 4 weeks	Sales 4 weeks after harvest (percent)	75	28.914
Production losses	Estimate of output loss (1=high; 0=low)	0.42	0.497
Extension access	Access to extension service (1=yes; 0=no)	0.73	0.447

Source: Author's Field survey (2012)

upon which output in potato farming depends in the study area. Thus, farmers who allocated more of their land for potato would realize more potato production under good management. Findings from our study in the area had revealed that the effective utilization of farmland enhanced production and consequently marketable surplus and thus increase farm income [26]. This is consistent with results from a study by [27] suggesting that productivity would be higher if more land is brought under potato cultivation. Yusuf et al. [28] in a study on sweet potato production reported that increase in farm size means more inputs would be utilized and consequently more output would be expected.

Table 3. Socio-economic characteristics of respondents

Continuous variables		Group members	Non members	t-statistic	p-value
Age		53.05	46.59	2.678	0.009***
Education		2.54	3.21	-0.758	0.450
Family size		7.57	6.90	0.915	0.363
Potato area		0.92	0.83	0.527	0.600
Labor used		210.67	176.97	0.463	0.645
Improved seeds used		553.336	420.688	1.331	0.187
Fertilizer used		436.802	333.254	1.190	0.237
Quantity produced		4,733	3,243	1.124	0.264
Distance to market		4.49	4.35	0.269	0.789
Potato price		4,557	4,332	1.144	0.256
Quantity sold		4,296	2,928	2.091	0.040*
Future seeds		1,086	676	1.826	0.071*
Food and gift		360	388	-0.294	0.769
Sales in 4 weeks		73.93	77.24	-0.499	0.619
Categorical variables		%	%	X^2 statistic	p-value
Gender	Male	33.9	51.7	2.521	0.161
	Female	66.1	48.3		
Extension	yes	94.6	31	39.166	0.000***
service	no	5.4	69		
Production	High	28.6	69	12.769	0.000***
losses	Low	71.4	31		

***, indicates significance level at 1%; Source: Author's survey (2012)

Table 4. Determinants of the quantity of potato produced by farmers

Variables	Members		Non-members		Total sample	
	Coefficients	Std. error	Coefficients	Std. error	Coefficients	Std. error
Constant	1.462	0.491	0.859	1.186	1.412	0.432
Age	0.217	0.284	0.668	0.596	0.346	0.244
Gender	-0.001	0.057	-0.048	0.104	-0.010	0.047
Potato area	1.046***	0.069	1.043***	0.127	1.037***	0.061
Improved seeds	0.353***	0.090	0.259***	0.080	0.249***	0.048
Labor hired	0.033	0.031	0.045	0.063	0.044	0.026
Fertilizer used	0.314***	0.100	0.385*	0.176	0.386***	0.073
Extension service	0.136	0.118	0.111	0.127	0.032	0.057
Production losses	-0.177***	0.057	-0.079	0.102	-0.119**	0.047
R-square		0.863		0.830		0.842
Adjusted R square		0.840		0.762		0.826
F		36.971***		12.209***		50.753***

Note: ***, **, * significance at 1%, 5% and 10% respectively; VIF= 1.71; $F_{(8, 84)}$ = 50.753; chi2= 0.25; Prob > chi2 = 0.6204; Source: Author's Field survey (2012)

High crop yields can usually be attributed to the improvements in plant varieties. In the study area, farmers plant both their own saved potato seeds and improved seeds accessed through informal systems (traders, money lenders, etc.) or through their organizations. The results show that for both farmers members of farmer organizations and non-members, improved seeds have positive and significant effects on potato output. Keeping all other factors constant, a one percent increase in improved seeds used resulted in about 0.25% increase in potato output at one percent significant level; figures for this variable show an increase of 0.353% and 0.259% for a unit increase in improved seeds respectively for members and non-members. The results corroborate with the findings of [29] study, on implementing the bean seed strategy in Malawi, where it was found that farmers using improved seeds often realize higher outputs than those using indigenous seeds. Maruod et al. [30] in exploring the potential for improvement in agricultural production and productivity reported that improved seeds have a positive impact on small farmers' productivity, income and livelihood. Farmers using improved seeds often realize higher potato yields and thus are more likely to increase outputs and market surplus. Improved potato seeds have high yields and producers would benefit from planting them. However, access to improved potato seeds is still a major challenge to a number of smallholder producers leading to low production levels in the study area.

With a statistically significant level at 1% and 10% respectively for members and non-members, the coefficient of fertilizer use was overall, positive and highly significant (p<0.01) implying that the quantity of fertilizer applied was directly related to potato output. A one percent increase in fertilizer used resulted in about 0.39% increase in potato production, showing that the amount of fertilizer used had a positive effect on the quantity of potato produced. Fertilizer input is a significant and important variable that affect potato production [23]. Wang'ombe et al. [31] established that with recommended application regimes, fertilizer used can have a great impact on potato yields and productivity. Thus, besides the improved nature of seeds used, potato production can be greatly enhanced by practices such as fertilizer application. Although 66% of our sample respondents were members of farmers' group, the role and effectiveness of collective action in mitigating the numerous challenges facing farmers are still critical.

Production losses resulting from the poor production technique, pest and disease, poor weather condition, negatively influence potato production (p<0.01). Results show that potato output decreases by 0.12% for one percent increase in production losses. Producers in the study area both members and non-members, prioritized these losses as key constraints to achieving high potato output; thus farmers who realize less production losses would have a relatively higher output of potato. This suggests that measures to reduce production losses would equally contribute to an increase in the quantity of potato produced.

Although the age of the farmers and the labor hired have no significant influence on the quantity of potato produced, both variables show a positive relationship with the potato output. The lack of productive assets being a common problem to all farmers in the research area, most potato producers rely on human labor to produce potato. Young farmers contribute more and are more productive given the labor-intensive nature of potato farming.

The estimated coefficients of the relevant independent variables were used to compute the marginal value products (MVP) and their corresponding marginal factor costs (MFC). The ratio of the MVP to MFC was then used to determine the resources use efficiency as shown in equation (3). Table 5 presents the results of the resource use in potato production in the study area. As depicted in the table, for the total sample farmers, fertilizer has the highest MPP; hence a unit increase in fertilizer is estimated to increase output by 0.54 kg per ha. An increase in one unit of laborer per day is estimated to increase potato output by 0.08 kg per ha. Furthermore, an increase of one unit of seeds is estimated to increase the total output by 0.34 kg per ha. However, evaluating the efficiency of these inputs, the results indicate that all the resources were inefficiently utilized; comparison of the ratio of MVP to MFC shows resulting ratios to be less than unity for seed, fertilizer and labor. The results revealed that for both members of farmer organizations and non-members, potato seeds, labor and fertilizer were used above the economic optimum level, implying that these inputs were been over utilized as indicated by their respective efficiency ratio. Increasing the quantity of seeds, labor and fertilizer usage would decrease potato output and thus profit level. The sub-optimal resource allocation in potato production can be attributed to different

Table 5. Marginal value product and efficiency of resource use

Inputs	Members			Non-members			Total sample		
	Seed	**Labor**	**fertilizer**	**Seed**	**Labor**	**fertilizer**	**Seed**	**Labor**	**fertilizer**
MPP	0.471	0.062	0.439	0.357	0.092	0.527	0.336	0.084	0.536
MVP	2,149	281	2,002	1,548	399	2,285	1,506	379	2,403
MFC	9,095	8,170	4,476	9,690	8,569	5,128	9,298	8,306	4698
Eff.	0.236	0.034	0.447	0.160	0.047	0.446	0.162	0.046	0.512

Source: Author's Field survey (2012)

factors. Potato production being a labor intensive activity in the study area, family labor is a readily available pool of labor to draw from whenever needed, thus there is a tendency of over utilizing labor. This result supports the findings of [32] who found that the surplus family labor available to the smallscale sorghum farmers led to the over utilization of labor. The majority of farmers in the study area rely on own stocks of potato seeds of comparatively low yield; this is accentuated by the poor storage conditions of the potato kept for seeds due to the lack of adequate storage facilities. In addition, the lack of a viable functional system of agricultural practices through farmer education in general in Guinea has a negative impact on the technical knowledge of potato producers. This situation may have contributed to the over utilization of inputs (seeds and fertilizer) in the potato farms. Comparable results of the over utilization of production resources such as seeds have been reported by [33]. For potato producers in the study area to achieve levels of optimal resource allocation, inputs such as seeds and fertilizer may have to be reduced. This will, with improved technical and managerial ability of the farmers, increase potato output and consequently incomes from the potato farming business.

3.2 Factors Influencing Potato Supply to the Market in the Study Area

Table 6 presents the determinants of the quantity of potato supplied to the market by farmers. The results show that education has a significant and negative effect (p<0.05) on the quantity of potato supplied to the market. This shows the tendency of educated farmers not to sell their potato output. Possible explanations to this could be that educated farmers in the study area are aware of the fact that during harvest periods, farmers face lower prices as they increase supply of potato.

The total output of potato, for both members and non-members, positively influenced potato marketed. A unit increase in the quantity of potato produced resulted in about 24% increase in the quantity of potato marketed for the total sample. This is confirms the findings of [34] who noted that farmers who realize higher output will supply larger proportions to the market. The results also confirm findings of [35] that quantity of potato produced positively affected quantity sold.

Post-harvest losses are negatively associated with the quantity of potato marketed (p<0.05). As revealed during the field survey, the poor storage conditions and the predominant transportation means (carrying on the head, bicycles, wheelbarrows), are a major impediment to potato marketing in the study area. In a study on market supply response of cassava, [36] found that losses have a negative impact on marketed surplus.

Potato stored for future seeds negatively affected the quantity of potato supplied to the market (p<0.01). Figures are the same for both member farmers and non-members. Farmers in the study area, in general, are resource-poor; the majority of them therefore, retain significant quantities of their crop output for future seeds. Producers who retain less quantities of potato for seeds are able to supply more to the market. Potato retained for seeds and stored traditionally, have low yields as result of poor conservation and diseases, which is an important impediment to crop productivity. The quantity of potato kept for food and gift is also negatively associated with quantity marketed (p<0.05) and might be due to the size of farm household. This implies that the lower the quantity kept by households for consumption and gifts, the higher the quantity of potato available to the market for sale. The economic implication could be that the larger the household size, the higher the quantity kept for food and the lower the quantity supplied to the market.

Although not significant, distance to market has a negative coefficient, suggesting that distance to the market channels could affect potato marketing. Potato price on the contrary positively affects quantity marketed (p<0.1). It acts as an

incentive to members of farmer organizations, thereby highlighting efforts of the latter to pay higher prices to its membership. Better output price and market information are the key incentive for increased sales [37].

The share of potato sold four weeks after harvest is positively related to quantity marketed (p<0.1). Several reasons could explain this. 85% of the surveyed farmers sell their crop output within four weeks after harvest; the lack of storage facilities, the seasonal price instability, the need for immediate cash could have triggered this. As observed during our field investigations, farmers are bound to sell their product to market participants (local collector, money lenders, wholesale agents) from whom they may have obtained credits.

3.3 Production and Marketing Constraints

The major potato production and marketing constraints are presented in Table 7. Across all the surveyed districts, pest and diseases were regarded as the main constraint to potato production, especially for members of farmer organizations. Pest and diseases have been reported to cause losses ranging from 5 to 30%. This could be attributed to the lack of appropriate management practices and research in the

sector leading to higher vulnerability of potato to diseases mainly during the cropping and storage period. Maldonado et al. [38], found that diseases were one of the most important limiting factors to expanded potato production and use. The poor irrigation was singled out by 48.2% of the total farmers as the next major constraint in importance. An essential point observed during our field survey was the farm irrigation system. For the majority of farmers in the study area, irrigation is poor or non-existent. Potato production is also handicapped by the lack of funds (agricultural credits) to face the high cost of inputs. Kaguongo et al. [39] reported that high cost of inputs especially seeds, fungicides and fertilizers greatly limit the production of potatoes in Kenya. Similarly, [40] established that the lack of credits facilities and improved practices are limiting factors to potato production, contributing to low outputs.

Climate-related factors (drought, wildfire, flooding) and labor shortage were also listed as constraints in potato production. Household related factors were considered by 16.5% of the total sample farmers as a factor that seriously hampered potato production. The unavailability of the head of the household or an active family labor could hinder the household's farming business.

Table 6. Factors influencing quantity of potato marketed by farmers

Variables	Members		Non-members		Total sample	
	Coefficients	Std. error	Coefficients	Std. error	Coefficients	Std. error
Constant	4,989.239	2,094.222	811.453	1,582.481	2,720.323	1,430.919
Family size	-37.145	89.551	-129.137	87.757	-57.204	65.223
Education	-207.109**	89.375	-48.993	50.654	-143.750**	53.083
Quantity produced	0.255***	0.048	0.155**	0.057	0.247***	0.037
Distance to market	-148.851	124.967	-6.157	104.299	-74.889	89.298
Production losses	-975.515	635.318	-393.975	524.382	-1,020.913**	409.750
Potato price	0.662*	0.342	0.296	0.228	0.250	0.231
Future seeds	-0.992***	0.288	-1.255***	0.382	-0.978***	0.220
Food and gift	-2.508***	0.802	-2.521***	0.484	-2.468**	0.516
Sales in 4 weeks	12.070	9.908	-1.949	10.124	12.428*	7.192
R-square	0.676		0.821		0.682	
Adjusted R square	0.613		0.736		0.644	
F		10.67***		9.71***	(9, 75)	17.90***

*Note: ***, **, * significance at 1%, 5% and 10% respectively; Source: Author's Field survey (2012)*

Table 7. Production and marketing constraints

Constraints	Members		Non-members		Total sample	
	Freq.	Rank	Freq.	Rank	Freq.	Rank
Production						
Pest and disease	32 (57.1)	1	17 (58.6)	3	49 (57.6)	1
Climate-related factors	20 (35.7)	4	14 (48.3)	4	34 (40)	4
Lack of funds	14 (25)	3	25 (86.2)	1	39 (45.9)	3
Household related factors	10 (17.9)	6	4 (13.8)	5	14 (16.5)	6
Poor irrigation	22 (39.3)	2	19 (65.5)	2	41 (48.2)	2
Labor shortage	11 (19.6)	5	4 (13.8)	5	15 (17.6)	5
Marketing						
High cost of transportation	7 (12.5)	5	10 (34.5)	4	17 (20)	5
Low potato price	27 (48.2)	2	21 (72.4)	1	48 (56.5)	1
High market taxes	3 (5.4)	6	3 (10.3)	7	6 (7.1)	7
Poor transport infrastructure	21 (37.5)	3	11 (37.9)	3	32 (37.6)	3
Trade restrictions	34 (60.7)	1	9 (31)	5	43 (50.6)	2
Lack of price information	1 (1.8)	7	6 (20.7)	6	7 (8.2)	6
Lack of storage facilities	7 (12.5)	5	12 (41.4)	2	19 (22.4)	4

Note: Numbers in parentheses indicate the percentage; Source: Author's Field survey (2012)

In marketing, low potato price was regarded as the major bottleneck and 56.5% of the farmers ranked it as the main limiting factor in potato marketing. Hussain et al. [41] reported that lower potato price was the major problem faced by farmers in the marketing of potato. Restriction on trade imposed by the government was another crucial problem in potato marketing and this was particularly important for farmers members of farmer organizations (60.7%). Additionally, the poor quality of the transport infrastructures was reflected by the high cost of transportation. Transport of potato to the market is expensive due to poor road infrastructure in producing areas [42,41]. This situation reflects the state of agricultural infrastructures in general in Guinea; transport infrastructure, particularly roads, are in poor conditions and underdeveloped; the provision of transportation services is insufficient; and the other types of infrastructure supporting agricultural markets (e.g., for storage and processing) are also underdeveloped. Problems related to storage facilities are also noteworthy; 41.4% of non-members listed the lack of adequate storage facilities to be the next most important constraint in potato marketing. This hinders farmers' marketing capacities as the majority of them are obliged to sell their produce despite the unfavorable price they are offered. The high market taxes and the lack of information on the market price of potato were also regarded as limiting factors in potato marketing by 7.1% and 8.2% of the surveyed farmers respectively. The latter was mostly important for non-members (20.7%) who usually get information on crop output and inputs prices

from various market participants (rural collectors, wholesale traders etc.) participating at different stages of potato supply chain.

4. CONCLUSION AND RECOMMENDATION

This study focused on the economic analysis of potato production in three districts of the Fouta Djallon highlands. Specifically, the study identified the factors affecting the quantity of potato produced and supply to the market as well as the resource use efficiency. The results showed that potato area, the use of improved seeds, fertilizer, and production losses significantly influenced potato output; while education, the quantity of potato produced, quantities retained for seed, food and gifts, potato price and the share of potato sold four weeks after harvest, influenced the amount of potato marketed. The results also showed that farm resources were not efficiently utilized for potato production. Potato seeds, labor and fertilizer were all over-utilized, showing that none of the production inputs were optimally allocated and utilized. This was particularly attributed to farmers' limited knowledge and lack of technical skills, suggesting that farmers should be educated through extension services.

Findings from the current study suggest that to enhance production, farmers should expand extent of land under potato cultivation within their existing farmland. To fully tap the potential of increased potato production and marketing, improvement in the level of farm however

requires an understanding of the technical constraints in the use and allocation of resources such as fertilizer, seeds and labor. To benefit from better potato price and strengthen their bargaining power, producers are encouraged to actively participate in farmers groups. As an important institutional vehicle, farmer organizations should be encouraged and given appropriate support. Membership in farmers' group is likely to increase producers' income earning capabilities due to skills and joint learning among them as opposed to individual producers. Government and development organizations should work closely with farmers' groups as they are portrayed as the most effective outlets for inputs and output markets for smallholder farmers in Guinea. In addition, to realize higher incomes and productivity from potato production, the adoption of new agricultural technologies, improved agricultural and market infrastructures are indispensable and should be made affordable to the vast majority of resource-poor farmers. Results finally suggest the need to formulate policies aimed at efficiently addressing producers' production and marketing constraints and needs so as to boost agricultural production and farmers' access to markets in Guinea.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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