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Full Length Research Paper

Determinants of credit access by smallholder farmers in North-East Benin

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Financing agriculture is a key issue in rural development. Despite the efforts of the government to make credit services available and affordable in most of the rural areas, access to credit among smallholder farmers remains low. This paper analyzes the determinants of credit access by farmers in the North East, Benin. Primary data were collected from one hundred and twenty respondents randomly selected and interviewed through structured questionnaire. A Logit model was specified to identify the relationships between access to credit and selected farmers' socio-economic characteristics. Following this, the marginal effects of the selected farmers' socio-economic characteristics on the probability to access credit were estimated. The analysis revealed that access to credit among smallholder farmers is determined by the number of years of schooling, literacy, membership, guarantor, collateral and interest rate. For each additional year of schooling, the likelihood of access to credit was found to increase by 3.9% while literacy in the local language was found to increase the likelihood by 10.9%. Membership of farmers' cooperatives was found to increase the likelihood of access to credit by 31% while having a guarantor increases this likelihood by 18.9%. However, the availability of collateral decreases the likelihood of credit access by 12.4% while credit with high interest rates decreases it by 11.7%. Thus, to improve rural farmers' access to credit, governments and non-governmental organizations should promote education, literacy and cooperative membership among farmers. Moreover, financial institutions should also play a key role by keeping interest rates for loans at a low level.

Key words: Smallholder farmers, credit, determinants, logit, Benin.

INTRODUCTION

Agriculture plays a fundamental role in the economy of many countries in the world, particularly in developing countries where most of the population depends on agriculture-based activities for their livelihoods. In Benin, agriculture contributes to about 35.9% of the country's gross domestic product (GDP) and employs up to two thirds of the active population (RPSA, 2014; FMI, 2012). Despite this prominent role, smallholder farmers are still predominant with low levels of productivity which could impede the progress of the country due to its estimated population growth of 3.5% (INSAE, 2015). One of the factors driving this situation is limited access of smallholder farmers to appropriate means.

Agricultural credit has been reported as an effective tool for sustainable agricultural development in several places in the world. It is the case of the study of Girabi and Mwakaje (2013) in Tanzania for example who found that agricultural credit has a positive impact on smallholder farmers' productivity as it enables them to access inputs such as fertilizers, improved seeds and to hire labor when needed. Similar observations have been made in Brazil by Feijo (2001) who also found that there was a positive effect on the lives of farmers who have access to credit facilities, based on the measurement of productive growth of their main crops. In Malawi, Zeller et al. (1998) concluded that membership to credit programs had a sizable effect on agricultural income while in Pakistan, Mahmood et al. (2013) also observed that, in the livestock sector, credit availability increased family income per month by 181%. In Bolivia, McNelly and Christopher (1999) found that incomes were increased where access to credit and the education levels of mothers were higher. These studies have shown how access to credit can be a powerful tool to increase farmers' productivity and wellbeing. Indeed, agricultural credit enhances productivity and improves standards of living by breaking the vicious cycle of poverty that small-scale farmers are prone to (Ololade and Olagunju, 2013; Akudugu, 2012).

However, despite this positive effect of agricultural credit in improving farms productivity as well as farmers' wellbeing in general, in many places in the developing world, access to credit is still low. It is the case in Benin where access to credit is particularly limited among farmers (Sossou et al., 2014; Sossa, 2011) with little known on the reasons of this situation. Drawing from these facts, this study has been initiated to investigate the determinants of access to credit in the North East of Benin to help policy makers formulate proper policies that will consider the positive factors and mitigate the negative factors.

MATERIALS AND METHODS

Study area

This study was conducted in the district of Nikki in the North East of Benin (Figure 1). Benin is located in West Africa with a population estimated at 10.88 million in 2015. Its latitude ranges from 6°30′ N to 12°30′ N and its longitude from 1° E to 3°40′ E. Nikki district in the region was selected for three main reasons: (1) firstly because of its prominent contribution to food crop farming in the region, and in the country, (2) secondly because the United Nation Development Program implemented a pilot credit program for smallholder farmers in this region from 2009 to 2014; (3) thirdly because of the diversity of its population which includes all the sociocultural groups of the North East region of the country.

Data source and sampling procedures

In total, 120 respondents were randomly selected and interviewed for the study. Primary data on the features of the credit scheme (e.g. interest rate) and socio-economic characteristics of farmers (e.g. education, literacy, etc.) were collected by a household survey conducted through structured questionnaires. Table 1 shows the distribution of the sample size.

Both descriptive statistics and econometric methods were used to analyze the primary data. Descriptive statistics helped to describe the respondents' socio-economic characteristics whereas the determinants of credit access among the farmers were assessed, using the binomial logit regression model. The marginal effects of the explanatory variables have been estimated using the delta method in Stata 11, software.

Method of analysis

For binary dependent variable, Logit or Probit regression model can be used as regression model to identify the relationship between the dependent variable and the set of explanatory variables (Hoetker, 2007; Erdem, 2009; Fox, 2010). Although, the two models yield similar results, the advantages of the logit regression model are its heteroskedasticity consistency, the simplicity of the method, and the easiness it offers for the results interpretation (Erdem, 2009).

Accordingly, the Binomial Logit regression model was used in this study to determine factors affecting farmers access to credit in Benin. The model is based on the following specification:

$$Y = f(X) \quad (1)$$

In this equation, Y is the dependent variable which represent farmer's access to credit and X the set of explanatory variables. Y is equal to 1, when a farmer does have access to credit; and 0 otherwise. Following the theoretical considerations, whether the famers have access to credit (or not) could be explained by a set of socio-economic characteristics (farmers' age, sex, household size, educational level, farming experience, membership, marital status and the contact with an extension agent or not), and the features of the credit scheme (credit interest rates, whether or not they have guarantor, collateral or not). Table 2 presents the explanatory variables, their codes and expected nature of relationship on the farmers' decision to have access to credit based on the literature (Ololade and Olagunjun, 2013; Akudugu, 2012; Dzadze et al., 2012; Anyiro and Oriaku, 2011).

Following the previous considerations, let us denote access to credit, socio-economic characteristics, and characteristics of the credit scheme by *ACC*, *SOEC* and *CCR*, respectively. Thus, Equation (2) becomes:

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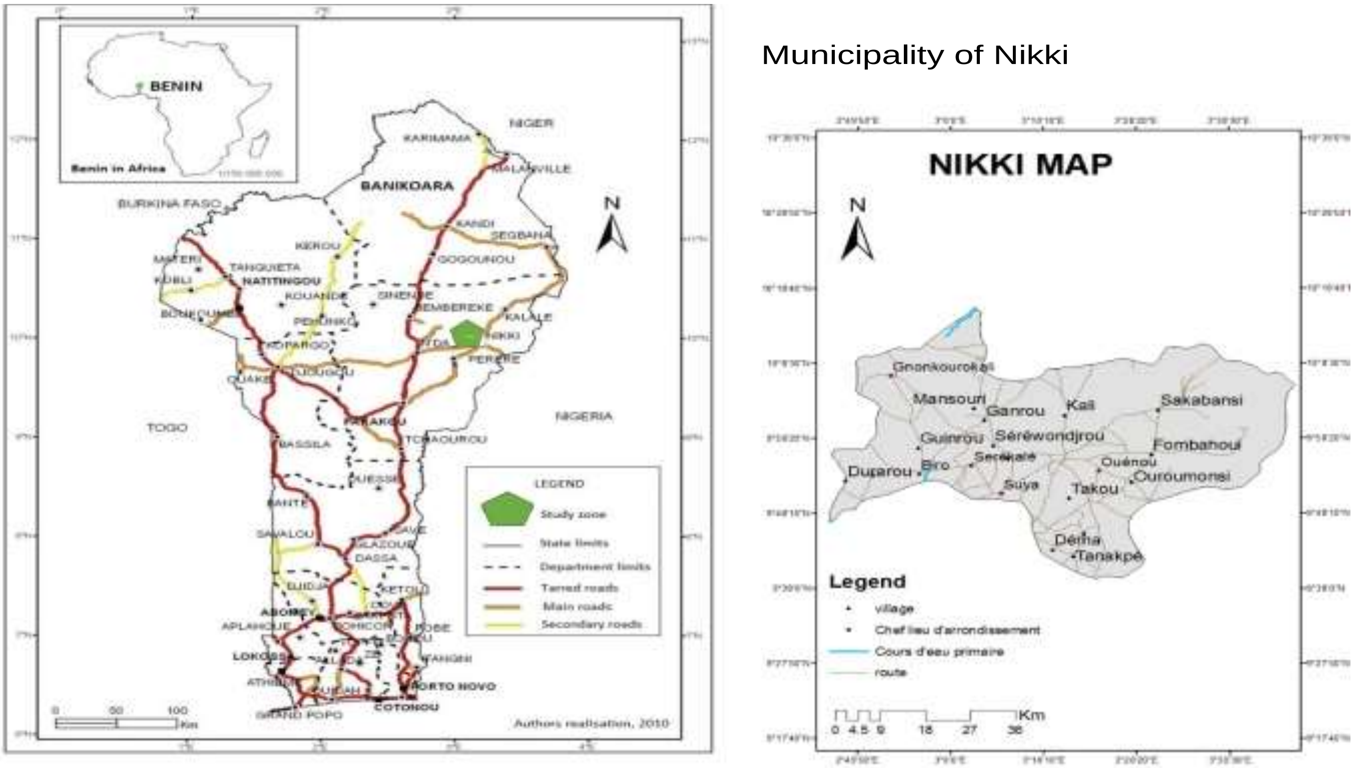

Figure 1. Study zone.

Table 1. Distribution of the respondents in the study area.

Administrative unit (district)	Villages	Sample size
Biro	Biro	30
Nikki	Sakabansi	45
	Nikki Centre	45
Total	3	120

Table 2. Prospective explanatory variables.

Variables types	Variables	Codes	Expected sign
Socio-economic characteristics of farmers	Age (years)	AGE	-
	Sex (1=male; 2=female)	SEX	+
	Marital status (1=married; 2=otherwise)	MAS	+
	Education (years)	EDU	+
	Literacy (1=yes; 0=no)	LIT	+
	Household size (number)	HHZ	-
	Farming experience (years)	EXP	±
	Membership to farmers' associations (1= member; 0=otherwise)	MEM	+
	Extension agent (1=yes; 0=no)	EXT	+
Characteristics of the credit scheme	Guarantor (1=have guarantor; 0=otherwise)	GUA	+
	Collateral (1=have collateral; 0=otherwise)	COL	+
	Interest rate (1=high; 0= low)	INT	-

More explicitly, Equation 3 can be expressed as:

$$ACC_i = \beta_o + \beta_1 AGE_i + \beta_2 SEX_i + \beta_3 MAS_i + \beta_4 EDU_i + \beta_5 LIT_i + \beta_6 HHZ_i + \beta_7 EXP_i + \beta_8 MEM_i + \beta_9 EXT_i + \beta_{10} GUA_i + \beta_{11} COL_i + \beta_{12} INT_i + e_i \quad (3)$$

In Equation 3, β are the coefficients or parameters to be estimated; and e is the error term. The parameters β were estimated by using a maximum likelihood (ML) method through a Logit regression model. Let us set π_k the probability that the k-th farmer has access to credit. It is assumed that π_k follows a standard logistic distribution function depending on independent variables which are the vector of predictors X_i. Accordingly, π_k is expressed as follow:

$$\pi_k = \Pr(Y = 1|X) = \left[1 + e^{-(\beta_0 + \beta_1 X)}\right]^{-1} \quad (4)$$

β_i is a vector of unknown parameters to be estimated. Only the sign of the parameter estimates gives the direction of a change for each of the explanatory variables of the probability of a farmer having access to credit (Y=1). Yet, the parameter estimates from models alone do not hold any economic meaning. To assess the effect of a unit, change of independent variables on the probability of the farmers having access to credit, the marginal effects were estimated. Stata 11 software was used for the data analysis.

RESULTS AND DISCUSSION

Socio economics characteristics of the farmers

Table 3 summarized the descriptive statistics of the respondents' socio-economic characteristics. The table reveals that seventy-six percent (76%) of the respondents were male as compared to 24% female respondents. This could be explained by the fact that, agriculture in most of developing countries is dominated by male farmers (Yegbemey et al., 2014). In addition, male farmers in developing countries have more access to agricultural resources (Kokoye et al., 2017). The average age of the respondents was 40.57 years with eighty-eight percent of farmers (88%) being married.

The descriptive statistics also revealed that the average household size among the farmers is nine (9) members which is higher than the national average household size of seven (7) people (SNCA, 2008). Although, a higher household size (large family) could increase farmers' poverty status (Ololade and Olagunju, 2013), in the study area on the contrary, it is a key source of labor that helps support the respondents in their activities.

Regarding education, local language education is more readily promoted in the study area as compared to formal education. Indeed, fifty-three percent (53%) of the respondents attended local language education against forty-one percent (41%) for formal education. Meanwhile, among those who attained formal education, the average years of schooling is five (05) years. This low level of formal education among smallholder farmers observed in the study area is common in rural areas and confirms the findings of researchers (Dzadze et al., 2012; Olorunsanya et al., 2009).

The average number of years of farming experience of the respondents was 25.48 years, indicating an experienced population in farming activities. Almost all the respondents had agricultural activities as their primary occupation (99%). This indicates that crop farming is the main economic activity of the farmers and the largest employer of labor in the study area. However, forty-three percent (43%) of the farmers had a secondary occupation. Secondary activities are essential for the respondents as they enable them to have an additional income during non-farming periods.

Binomial logit regression analysis

Table 4 presents the estimation results from the Logit model. In addition, several goodness-of-fit measures are reported. The first one is the pseudo-R squared and the second, the Likelihood ratio Chi-square which is an estimation of how well the model classified respondents correctly based on estimated probabilities. The likelihood ratio Chi-square of 79.95 with a p-value of 0.0000 tells us that our model is statistically significant.

Table 4 shows that out of the twelve variables, six were significant for credit access among farmers. These factors are formal education, local language education, membership, guarantor, collateral and interest rate. These factors could be divided in two groups: those with positive effects on the probability of smallholders' farmers having access to credit, which include formal education, local language education, membership and guarantor, and those which have negative effects on this probability collateral and interest rate.

Farmers with formal education have the ability to understand the credit scheme and their terms and conditions (Hananu et al., 2015). This could justify the positive effect of education. This finding corroborates the results of Dzadze et al. (2012), Akudugu (2012), Bakhshoodeh and Karami (2008), Thaicharoen et al. (2004), Etonihu et al. (2013) and Hananu et al. (2015) who observed that being educated favors farmers' access to credit. The positive effect of membership on credit access could be explained by the fact that in the study area, memberships is one of the key requirements for getting credit from credit institutions. This requirement helps the institutions prevent cases of credit default or credit non-repayment among farmers. Mohammed et al. (2013) also examined the influence of farmer based organization (FBO) on access to credit. They found that FBO's social capital homogeneity, network connection, level of trust, collective action and the respect for contract had positive significant effect on access to credit. Hananu et al. (2015) in their study of factors affecting agricultural credit demand in Northern Ghana, revealed that group membership explained that formation of economic and social associations helps to improve credit access given the existence of joint guarantee by associations members. The positive effect of having a guarantor on farmers' access to credit is also consistent with the finding of Kacem and Zouari (2013) who reported the absence of

Table 3. Socio-economic characteristics of survey respondents.

Qualitative variable	Frequency	Percentage
Primary occupation		
Agricultural activities	118	99
Non-Agricultural activities	02	01
Secondary Occupation		
Secondary activities occupant	43	36
No secondary occupant	77	64
Educational Level		
Formal education	49	41
Local language education	64	53
Marital Status		
Married	106	88
Unmarried	14	12
Gender		
Male	91	76
Female	29	24
Quantitative variables	**Mean**	**Standard deviation**
Age	40.57	0.86
Educational level	5.55	0.40
Farming experience	25.48	0.87
Household size	9.37	0.45

Table 4. Logit estimate of the factors affecting access to credit.

Variables	Coefficient	Standard Errors	z	P>|z|
Age	-1.21	1.45	-0.01	0.993
Gender	0.41	0.78	0.53	0.596
Marital status	-0.26	0.36	-0.73	0.467
Education	0.38***	0.14	2.79	0.005
Literacy	1.05*	0.63	1.68	0.094
Household size	0.03	0.09	0.33	0.738
Farming experience	1.21	1.46	0.01	0.993
Membership	2.98***	0.74	4.03	0.000
Extension agent	-0.26	0.68	-0.39	0.698
Guarantor	1.81**	0.80	2.27	0.023
Collateral	-1.19*	0.71	-1.68	0.093
Interest rate	-1.12*	0.58	-1.94	0.052
Constant	15.89	2.18	0.01	0.994
Number of observations		120		
Pseudo R^2		0.50		
LR Chi squared		79.95		

*10% level of significance; ** 5% level of significance; ***1% level of significance.

guarantor as one of the main barriers for rural people access to credit. The negative effect of having collateral on credit access among farmers suggests that the requirement of having collateral might hinder the demand for credit. This could be explained by the fact that farmers who have collateral have more assets and can self-fund

Table 5. Estimated marginal effects of the explanatory variables.

Variables	dy/dx	Delta-method Std. Err.	z	P>|z|
Age	-0.126	15.177	-0.01	0.993
Gender	0.043	0.081	0.53	0.595
Marital status	-0.027	0.037	-0.73	0.463
Education	0.0397	0.013	3.10	0.002
Literacy	0.109	0.062	1.76	0.078
Household size	0.003	0.009	0.33	0.738
Farming experience	0.126	15.177	0.01	0.993
Membership	0.310	0.053	5.82	0.000
Extension agent	-0.028	0.071	-0.39	0.697 -
Guarantor	0.189	0.077	2.44	0.015
Collateral	-0.124	0.071	-1.74	0.082
Interest rate	-0.117	0.057	-2.05	0.040

their production without credit. Therefore, avoid paying interest rate on the credit. According to Okojie et al. (2010), the lack of collateral limit rural women's access to credit from formal institutions. Studies of Ololade and Olagunju (2013) revealed that the requirement of collateral does not have significant effect on farmers' access to credit in Nigeria, Oyo State. The negative effect of interest rate suggests that credit scheme with high interest lower the probability of having access to credit. This result is quite consistent with many studies which found that farmers are reluctant to credit scheme with higher interest rate (Ibrahim and Aliero, 2012; Ololade and Olagunju, 2013).

Table 5 shows the estimated marginal effects of the explanatory variables on the likelihood of farmers having access to credit. This table demonstrates that for every additional year of education, the probability of farmer's having access to credit rises by 3.9%. Being literate in the local language increases the probability of having access to credit by 10.9% while being a member of an association increases the likelihood of having access to credit by 31%. This finding may be explained by the idea that knowing how to read and write in the local language helps farmers to plan their farming activities while being a member of an association enables them to satisfy one of the key loan access requirements of farmer's microfinance institutions in the area. In addition, having a guarantor was found to increase the probability of having access to credit by 18.9%. However, having collateral decreases the likelihood of credit access by 12.4% and credit with high interest rates decreases it by 11.7%. This could be explained by the fact that, in the study area, farmers tend to avoid loans due to concerns over repaying the loan with interest.

CONCLUSIONS AND RECOMMENDATIONS

In this paper, the authors have analyzed the determinants of access to credit among smallholder farmers in the North East Benin, using a Logit model. The results analysis has revealed that access to credit by smallholder farmers is determined by education, literacy, membership, guarantor collateral and interest rate. Being educated, literate in the local language, belonging to farmers' cooperatives or having a guarantor increases the probability of farmers' access to credit while having collateral or a high interest rate decreases this probability. Thus, for rural farmers to have greater access to credit, governments and non-governmental organizations should promote education, literacy among farmers as well as their organization in cooperatives. Moreover, to ensure that any credit obtained may be manageable for the farmers, financial institutions should provide loans with low interest rates.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Technical efficiency determinants of potato production: A study of rain-fed and irrigated smallholder farmers in Welmera district, Oromia, Ethiopia

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Increasing productivity through enhanced potato production efficiency could be an important move towards food security. In Ethiopia potato (*Solanum tubersum* L.) production levels and rates have been increasing due to the development and dissemination of improved potato technologies. Despite these efforts by the government, smallholders' potato productivity has remained below potential. However, empirical studies conducted to estimate level of efficiencies and to identify its determining factors in potato production which would guide policy makers in their efforts to do up its productivity are sparse. The purpose of this study was to analyze the technical efficiency, yield loss due to inefficiency and factors affecting efficiency of rain-fed and irrigated potato farmers in Welmera district of Oromia region, Ethiopia. A two stage sampling procedure involving purposive and random selection of the district, kebeles and samples was used to collect data from 72 households (40 from rain-fed and 32 irrigated) using structured questionnaires during 2009/2010 cropping season. The stochastic frontier and translog functional form with a one-step approach were employed to analyze efficiency and factors affecting efficiency in potato production. The maximum likelihood estimates for the inefficiency parameter showed that both most rain-fed and irrigated potato farmers in the study area were not efficient. The mean technical efficiency (TE) was found to be 81 and 68%, and about 4057 and 6185 kg of potato tubers per hectare were lost due to inefficiency factors for and/or from rain-fed and irrigated potato farmers, respectively. Variables such as education, soil condition and seed tuber size affected TE of both rain-fed and irrigated potato farmers, while age of the household head affected irrigated potato farmers' TE positively and significantly indicating that experience through age matters in irrigated potato production. The finding implies that there is an opportunity to improve technical efficiency among the rain-fed and irrigated potato farmers by 19 and 32%, respectively. Improving potato productivity needs owing cares of technical efficiency and farm and household socioeconomic characteristics that influenced technical efficiency in smallholder potato production. Train producers to use appropriate seed tuber size and maintain their soil fertility condition by extension and increase the educational level of the household heads through appropriate literacy.

Key words: Stochastic frontier, technical efficiency, rain-fed and irrigated potato, Welmera.

INTRODUCTION

Potato (*Solanum tubersum L*.) is a root crop and ranks first in its volume of production and consumption followed by cassava, sweet potato and yam in Ethiopia. It has a huge potential to contribute for the national economy, improve food security and income for smallholder farmers through its value-added products. Moreover, Gildemacher et al. (2009) reported the return on cash investment was more than 100% which enables growers reduce cash losses and the return on family labor was higher than the opportunity cost of work. Potato can grow in main season occurs from June to September and belg season (short rain season) occurs from February to May and irrigation (sometimes referred to as off-season). However, the irrigated potato is officially categorized under short rain season production. CSA (2016) indicated that the majority (70.6%) of the area was allocated to short season potato production and the rest 23.6 and 5.7% of the area allocated for main season and off-season (irrigation) potato production. In most irrigable lands, horticultural crops in general, potato in particular play an important role contributing to rural households' income generation and food security (Demelash, 2013; Bogale and Bogale, 2005). It is confirmed that the revenue from potato able to be much ten times higher than grains (Oumer et al., 2014).

The Ethiopian government has given more emphasis to potato research and development to boost production and productivity. Accordingly, about 32 potato varieties were released by the national research system and disseminated to the beneficiaries with its production packages, and reported as they are under production (MoA, 2016), evidenced by the study of Tesfaye et al. (2013) and Limenih et al. (2013), found significant level of adoption and determinant factors. Following these efforts, the production and productivity of potato is steadily increasing over years, while the area allocated to potato went constant (about 0.05 ha per household). According to CSA (2010, 2011, 2012, 2013, 2014, and 2015), the productivity of the main season of potato at a national level increased from 8.2 ton to 13.4 ton per ha, though the attainable yield is well above 25 ton under progressive farmers' fields and 35 ton per ha under on-station (Tesfaye et al., 2013) which indicates there exist gaps between current potato yields and potential yields.

This indicates that crop yields and productivity are not only inevitably affected by weather conditions, quality of seeds and varieties, amount of fertilizers and farming practices used, and/or level of adoptions but also the efficiency of production (Tiruneh and Geta, 2016; Debebe et al., 2015; Alemu et al., 2014; Yami et al., 2013; Ahmed et al., 2012); efficiency reflects the effectiveness and describes the quality of managing the farm. There has been limited number of empirical studies conducted to estimate level of efficiencies and identify its determining factors for major crops including potato (Beshir et al., 2012) and reported a significant level of inefficiencies. Thus, literature on technical efficiency of potato farming is still insignificant and very little is known whether smallholder potato growers are efficient or not in Ethiopia, and to the best of the author's knowledge there were no similar studies started in the study area.

Therefore, this study was proposed to fill this gap with the objective of analyzing technical efficiency of rain-fed and irrigated potato smallholder farmers and its determinant factors, and compute yield loss due to inefficiency.

METHODOLOGY

Study area and data

Taking into account both representativeness and cost of data collection, this study is based on cross-section primary data collected from a total of 72 randomly selected households in Welmera district of Oromia region, Ethiopia. A two stage sampling procedure was used involving purposive selection of a district followed by potato producing kebeles[1] (five kebeles, 3 from main season and 2 from irrigated potato producing kebeles), and finally simple random selection of sample households (40 households from rain-fed and 32 irrigated) from a list of potato growers prepared in both production systems data gathered using structured questionnaires filled by trained enumerators during 2009/2010 cropping season. The collected data from the household include yield of potato, inputs used like area, labor, oxen, seed, inorganic fertilizers and fungicide; plot characteristics such as soil fertility status, rotation and seed tuber size; socioeconomic like age and education of the household head and family size.

Analytical model

Technical efficiency of a farm household has commonly been defined as the ratio of observed outputs to its frontier outputs, maximum output level harvested with inputs at hand and current technology. In short, it is the ability of a producer to achieve maximum output from a given set of inputs (Coelli et al., 2005). Technical efficiency is often modelled either using stochastic frontier analysis (SFA) or data envelopment analysis (DEA) (Charnes et al., 1978; Farrell, 1957). This study is interested in SFA because of the ease in the interpretation and the ability to capture noises from possible external factors and measurement errors. Many different literatures on technical efficiency studies have used Cobb-Douglas or Trans-log frontier production function depending on data fit (Tiruneh and Geta, 2016; Alemu et al., 2014). Some previous studies also used two steps and some other used one step approach to analyze technical inefficiency effects (Yuya, 2014; Jema and Andersson, 2006). It is the interest of this study to use translog frontier function and a one-step approach to run the models simultaneously. Therefore, according to Aigner et al. (1977) and Meeusen and Broeck (1977), the translog production function (1) and the inefficiency equation (2) stated as follows are simultaneously used for its flexibility (places no restriction) and simplicity of running the model.

$$lnY_i = \beta_0 + \sum_{i=1}^{5} \beta_i lnX_i + \frac{1}{2}\sum_{i=1}^{5}\sum_{j=1}^{5} \beta_j \left(lnX_i\right)\left(lnX_j\right) + \left(\nu_i - \upsilon_i\right) \quad (1)$$

where i=1, 2, - - - n1=40 (main season), n_2=32 (irrigation) and X = vector of five input variables.

Based on the model, a stochastic frontier model for potato farmers is given by:

$$\ln(output)_i = \beta_0 + \beta_1 \ln(area)_i + \beta_2 \ln(seed)_i + \beta_3 \ln(costche)_i + \beta_4 \ln(lab)_i + \beta_5 \ln(oxen)_i + 1/2\, \beta_{11} \ln(area)^2 + 1/2\, \beta_{22} \ln(seed)^2 + 1/2\, \beta_{33} \ln(costche)^2 + 1/2\, \beta_{44} \ln(lab)^2 + 1/2\, \beta_{55} \ln(oxen)^2 + \beta_{12} \ln(area) \ln(seed) + \beta_{13} \ln(area) \ln(costche) + \beta_{14} \ln(area) \ln(lab) + \beta_{15} \ln(area) \ln(oxen) + \beta_{23} \ln(seed) \ln(costche) + \beta_{24} \ln(seed) \ln(lab) + \beta_{25} \ln(seed) \ln(oxen) + \beta_{34} \ln(costche) \ln(lab) + \beta_{35} \ln(costche) \ln(oxen) + \beta_{45} \ln(lab) \ln(oxen) + vi - u_i$$

[1]Kebele is the lowest administrative unit under Ethiopian condition.

The stochastic frontier analysis approach specifies technical efficiency as the ratio of the observed output to the frontier output, given the state of available technology, and presented as follows:

$$TE = \frac{F(X_i;\beta).\exp(v_i - u_i)}{F(X_i;\beta).\exp(v_i)} = \exp(-u_i) \quad (2)$$

where F $(X_i;\beta).\exp(v_i - u_i)$ is the observed output (Y) and F $(X_i;\beta).\exp(v_i)$ is the frontier output(Y^*). Following Battese and Coelli (1995), the error term (v_i) permits random variations in output due to external (weather and diseases) factors, and is assumed to be identically, independently and normally distributed with mean zero and constant variance (σ_v^2); that is, v_i ~N(0, σ_v^2). The u_i is the inefficiency component of the error term and a one-sided positive (u>0) random variable and assumed to be independently distributed as truncations at μ of the normal distribution and variance (σ_u^2), that is, u_i ~N (μ_i, σ_u^2), however, if u_i = 0, the assumed distribution is half-normal.

The specification of inefficiency model for potato individual producer at a plot level is given as:

$$\mu_i = \delta_0 + \sum_{j=i}^{6} \delta_j Z_{ji} \quad (3)$$

$\mu_i = \delta_0 + \delta_1 agehh + \delta_2 eduhh + \delta_3 famsize + \delta_4 solfert + \delta_5 precucrop + \delta_6 seedtubsize$

Technical efficiency estimates derived from parametric stochastic production frontier (SPF) was regressed using computer software FRONTIER 4.1C (Coelli, 1996) program.

Definition of variables

Variables often considered in the analysis of technical efficiency of farmers included input variables, household and farm characteristics (Tiruneh and Geta, 2016; Geta, 2013; Beshir et al., 2012; Coelli et al., 2005). In this study, based on a review of relevant literature, a range of input variables, household and plot characteristics were hypothesized to influence technical efficiency of potato smallholder farmers.

RESULTS AND DISCUSSION

Descriptive statistics

Table 1 shows the results of descriptive statistics for production and efficiency variables. The average yield was 17,260 and 13,143.8 kg/ha with high yield variability for sample rain-fed and irrigated potato production greater the national average (CSA, 2010). The mean area allocated for potato production was 0.32 and 0.345 ha, the average amount of seed used was 2102 and 1987.5 kg/ha, similar to the recommendation (Tesfaye et al., 2013), the average investment cost of fertilizers and fungicides was 2,667.68 and 2,158 Birr/ha, the average man-days was about 296.5 and 207.4 per ha, and the average oxen days used was 42.8 and 29.56 per ha for rain-fed and irrigated potato production. Labor productivity is higher in irrigated system while the average yield of rain fed is higher. The maximum yield is also higher in rain fed with a value of higher standard deviation showing also higher yield variability. The higher labor productivity in irrigated potato might be due to the use of hired labor that could be supervised efficiently than rain fed potato in which family labor is mainly used. It is believed that age, education, family size, soil condition, rotation practices and seed tuber size can influence technical efficiency of the farm communities. The average age of the household heads is 42.5 and 35.9 years for rain-fed and irrigated potato growers, respectively showing relatively younger population of irrigated potato growers. Education levels of the household heads are between 0 and 7 and 0 and 4 years of schooling showing low level of education. The average family size is about 6 persons for both rain-fed and irrigated potato farming communities. About 90 and 44% of the potato plots are fertile, 100 and 37.5% of the household used rotation practice and 70 and 28% of households used medium sized seed tubers for rain-fed and irrigated potato growers respectively indicating that rain-fed potato growers relatively used more recommended agronomic practices than the irrigation growers, this might happen because irrigated potato growers are less accessed in terms of production technologies and information.

Parameter estimates

Table 2 shows the results of simultaneously estimated stochastic frontier function and inefficiency effects model using Frontier 4.1C program. The likelihood ratio test showed that trans log stochastic frontier model best fit the data evidenced with the calculated chi-square value of 51.134 and 15.03, while the theoretical value is 14.853 in 5% of significant level with 8 degrees of freedom for both rain-fed and irrigated potato from Table 1 of Kodde and Palm (1986), because stochastic has a mixed chi-square distribution. The coefficients inputs like area, seed, labor, and oxen days were positive in both farming systems, while coefficient of the investments on fertilizers and fungicides was positive in rain-fed and negative in irrigated potato farms, this might be due to inappropriate use of fertilizers. Some farmers reported that they did not use urea and fungicides on their irrigated potato plots. The coefficients of area, labor and oxen days had a positive sign and significant at 1% significant level. Some of the coefficients of interaction terms between and within

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Table 1. Summary statistics for production and efficiency variables (Own Survey Results, 2010).

Variable	Rain-fed potato				Irrigated potato			
	Mean	Std. Deviation	Min.	Max.	Mean	Std. Deviation	Min.	Max.
Production								
Yield (kg/ha)	17260	6502	6900	33300	13143.8	3820.56	6700	21600
Area (ha)	0.32	0.157	0.1	0.75	0.345	0.33	0.1	2
Seed (kg/ha)	2102	438.8	1200	3000	1987.5	335.8	1500	2700
Cost of fertilizers & fungicide (Birr)	2667.68	940.26	1344	5062.5	2158	1037.9	1008	5400
Labor (man-days/ha)	296.5	94.63	164	520	207.4	48.9	116	305
Oxen (days/ha)	42.8	8.98	22	55	29.56	11.49	0	58
Efficiency								
Age (years)	42.5	12.25	22	74	35.9	9.6	20	59
Education (years)	3.53	2.25	0	7	1.88	1.4	0	4
Family size (persons)	6.35	2.2	1	11	5.69	2.95	1	11

	Labels	Frequency	Percent	Frequency	Percent
Soil condition	Fertile=1	36	90	14	43.8
	Less fertile=0	4	10	18	56.2
	Total	40	100	32	100
Rotation	Yes=1	40	100	12	37.5
	No=0	0	0	20	62.5
	Total	40	100	32	100
Seed tuber size	Medium=1	28	70	9	28.1
	Otherwise=0	12	30	23	71.9
	Total	40	100	32	100

inputs were associated with yield positively, while others negatively indicating that considering the interaction between inputs in agriculture is paramount. The 0.869 and 0.999 value of gamma evidenced that inefficiency effect significantly existed among potato farmers in both farming conditions indicating that there was poor management of resources by growers. The mean technical efficiency was 81% (between 50 and 96%), while 68% (between 52 and 91%) for sample households of rain-fed and irrigated potato farmers in the study area suggesting that given the current state of inputs and technology level, there is a room of increasing potato yield up to 19 and 32% on average in rain-fed and irrigated potato production, respectively. Therefore, improving technical efficiency of smallholder potato farmers can improve productivity of potato in the study area.

Factors influencing technical efficiency

The existence of inefficiency factors was confirmed with all the values of the coefficients different from zero (Table 2). The negative sign of age of the household head and significant at 5% significance level as the expectation suggested that relatively elder farmers have the benefit to manage inputs properly in irrigated potato farmers, this might be due to the nature of the farm practice that needed skills acquired through experience. The coefficient of education was negative and significant at 1% significance level as a priori expectation suggesting educated farmers often sought better agricultural technologies and information, and utilization. This result is in line with the study by Tiruneh and Gata (2016) and Geta et al. (2013) and against the study by Bogale and Bogale (2005). The positive sign of family size but insignificant might suggest that families with more persons resulted in more congested family labor; this is in line with work done by Bogale and Bogale (2005). The negative sign of soil condition and significant 1% significant level as expected implied that fertile soil helps farmers ease preparation of farms. Negative sign of rotation in rain-fed and positive sign in irrigated potato farms but not significant may indicate that farmers used inappropriate rotation practices especially in irrigated condition. The negative sign of seed tuber size and

Table 2. Results of trans log-efficiency model for potato production (Model Result, 2010).

Variable		Rain-fed potato		Irrigated potato	
	Parameters	Coefficient	t-ratio	Coefficient	t-ratio
Production					
Constant	β_0	-0.531	-0.531	0.491	0.496
Ln (area)	β_1	0.646	3.918***	0.826	8.379***
Ln (seed)	β_2	0.110	0.822	0.253	0.264
Ln (cost of fertilizers & fungicide)	β_3	0.486	1.917**	-0.549	0.658
Ln (labor)	β_4	0.488	2.545***	0.196	2.157***
Ln (oxen)	β_5	0.191	20.070***	0.723	7.552***
Ln (area)^2	β_{11}	0.325	2.112**	0.072	0.301
Ln (area)Ln(seed)	β_{12}	-0.698	-1.944*	-0.149	-2.281**
Ln (area)Ln(cost)	β_{13}	-0.770	-0.342	-0.652	-0.288
Ln(area) Ln(labor)	β_{14}	0.493	1.849*	0.522	0.715
Ln(area) Ln(oxen)	β_{15}	-0.700	-1.737*	0.347	0.502
Ln(seed)^2	β_{22}	0.301	0.700	0.208	5.153***
Ln(seed)Ln(cost)	β_{23}	0.122	1.979**	0.290	0.554
Ln(seed)Ln(labor)	β_{24}	0.112	1.956	-0.357	-4.566***
Ln(seed)Ln(oxen)	β_{25}	-0.287	-4.866***	0.167	3.100***
Ln(Cost)^2	β_{33}	0.297	0.967	0.182	1.285
Ln(cost)Ln(labor)	β_{34}	-0.159	-3.047***	0.450	0.870
Ln(cost)Ln(oxen)	β_{35}	-0.106	-0.305	-0.550	-1.404
Ln(labor)^2	β_{44}	0.293	0.076	0.144	2.506***
Ln(labor)Ln(Oxen)	β_{45}	-0.148	-0.231	-0.298	-3.593***
Ln(oxen)^2	β_{55}	0.516	1.768*	0.247	0.535
Efficiency					
Constant	δ_0	0.100	0.129	0.829	0.301
Age	δ_1	0.650	0.847	-0.167	-2.199***
Education	δ_2	-0.171	4.247***	-0.133	12.344***
Family size	δ_3	0.280	0.909	0.224	0.574
Soil condition	δ_4	-0.246	-5.174***	-0.278	14.768***
Rotation	δ_5	-0.215	-0.218	0.189	0.639
Seed tuber size	δ_6	-0.319	3.388***	-0.227	5.266***
Sigma squared	σ^2	0.056	1.526*	0.431	5.265***
Gamma	γ	0.869	8.751***	0.999	13.722***
Likelihood Ratio Test	LR	51.134***	-	15.030***	-

*, ** and *** show significant at 10, 5 and 1%, respectively.

significant at 1% significance level suggested that the use of medium sized seed tuber helps farmers to increase productivity as per recommendation (Tesfaye et al., 2013).

Distribution of technical efficiency scores

Table 3 shows the frequency distribution of technical efficiency scores. There was no technical efficiency score less than 0.5 in both potato farming conditions. The majority (37.5%) of rain-fed potato growers score between 80 and 90% efficiency level, while 47% of irrigated potato farmers score between 60 and 70% both around their mean. About 20% of the household score greater than 90% efficiency level in rain-fed potato production while only 3% of the household score >90% efficiency level indicating that rain-fed potato farmers are more efficient than their counter parts, irrigation farmers.

Yield gaps due to inefficiency

Table 4 shows the estimates of potato yield gap due to

Table 3. Frequency distribution of efficiency estimates (Model Result, 2010).

Range of efficiency estimates	Rain-fed potato		Irrigated potato	
	Frequency	Percent	Frequency	Percent
<50	0	0	0	0
50-60	3	7.5	5	16
60-70	4	10	15	47
70-80	10	25	9	28
80-90	15	37.5	2	6
>90	8	20	1	3
Total	40	100	32	100
Mean	0.81	-	0.68	-

Table 4. Estimates of potato yield gap due to inefficiency (Own Computation).

Variable	Rain-fed potato			Irrigated potato		
	Mean	Min.	Max.	Mean	Min.	Max.
Observed yield (kg/ha)	17260	6900	33300	13143.8	6700	21600
Technical efficiency estimates	0.81	0.5	0.96	0.68	0.52	0.91
Computed Frontier yield (kg/ha)	21308.64	13800	34687.5	19329.12	12884.6	23736.3
Computed yield loss (kg/ha)	4048.64	6900	1387.5	6185.32	6184.6	2136.3

inefficiency. This part is the uniqueness of this study, no studies have ever been attempted to estimate the yield gaps resulted from efficiency differentials among farmers. The mean potential yield computed to be 21,308.6 and 19,3329 kg/ha, if the average farmer had an efficiency level of 100% in rain-fed and irrigated potato production without the requirement of additional inputs and technology. However, the increase in potential (frontier) yield was much higher for farmers who had the lowest level of efficiencies (from 6,900 to 13,800 kg/ha for rain-fed and 6,700 to 12,884.6 kg/ha if had 100% efficiency level). Therefore, about 4,048.6 and 6,184.6 kg/ha of yield was lost due to inefficiency effects, on average.

Conclusion

The objective of this study was to analyze technical efficiency of rain-fed and irrigated potato smallholder farmers and its determinant factors, and compute yield loss due to inefficiency. A trans log stochastic frontier and inefficiency effects model was used to analyze the cross-sectional inputs, outputs and socioeconomic data collected from randomly selected households for 2009/2010 cropping season in Welmera district of Oromia region. The inefficiency was observed to exist among smallholder farmers. The efficiency ranges from 50 to 96% among rain-fed potato farmers, while 52 to 91% for irrigated potato farmers which reflected that farmers in the study area experienced irregular farm practices. This study revealed that about 4,048.6 and 6,184.6 kg/ha of yield gap was lost due to inefficiency effects for rain-fed and irrigated potato production. The study identified factors which contributed to the efficiency of potato smallholder growers. Education, soil condition and size of seed tuber were significant determinants that influenced potato production efficiency in rain-fed and irrigated potato farms. Age, a proxy variable for farm experience was significant factor that influenced technical efficiency of households in irrigated potato production.

The findings suggest that improving potato productivity needs owing cares of technical efficiency and farm and household socioeconomic characteristics that influence technical efficiency in smallholder potato production. Train producers to use appropriate seed tuber size and maintain their soil fertility condition and increase the educational level of the household heads through appropriate literacy.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Maximizing the economic return from Egypt's export of the most important vegetable crops in the foreign markets

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This study is set to examine the possibility of maximizing the returns of Egyptian vegetable exports: fresh potatoes, onions, and tomatoes, through the optimal distribution of exports to international markets. Linear programming model is formulated to determine the optimal distribution of exports among the importing countries. This model is restricted by export capacity, import capacity, and suggested organization constraints, determining the optimal plan for various scenarios. The mathematical analysis is based on secondary data from the Central Agency for Public Mobilization and Statistics of Egypt and the United Nations Comrade Database for the period of 2010- 2014. The model solution is obtained using the General Algebraic Modeling System (GAMS). The results show that the major export markets for Egyptian potatoes are Russia, Italy, and Germany, representing altogather about 69% of Egyptian exports. For Egyptian onions, Saudi Arabia, Kuwait, Jordan, and Syria together accounted for 77% of the total exported quantity. For Egyptian tomato exports, Syria, Saudi Arabia, Libya, and Iraq accounted for 85% of the total tomatoes exports from Egypt. The results of the various scenarios showed that there is a prospect to increase the Egyptian export returns through geographical re-distribution of exports from potatoes, onions, and tomatoes. Under the capacity of export-import constraints (Scenario No. 1), the total export value would increase by 19.26, 33.95 and 45.30% for potatoes, onions, and tomatoes, respectively. Under countries group constraint (Scenario No. 2), the export value increases by 12.67, 26.49 and 35.85% for these crops, respectively, more than the current export values. Under the suggested model (Scenario No. 3), the export value would increase by 9.56, 25.45 and 25.26% for potatoes, onions, and tomatoes respectively, much more than the current values of exports. Egyptian exports of potatoes would be directed to many countries: the United Kingdom, Greece, Italy and Russia. For onions, higher quantities would be exported to Saudi Arabia, Kuwait, Belgium, and Romania. The most important export markets for Egyptian tomatoes would be Iraq, Italy, Syria, and Saudi Arabia. The study recommends to re-distribute the Egyptian exports of vegetable crops in the international markets to maximize export returns. These models can be used as a tool for the Egyptian decision makers about optimum export distribution for export development.

Key words: Optimal geographic distribution, export development, linear programming, optimization technique.

INTRODUCTION

The Egyptian exports play an important role in economic development especially agricultural exports. Agricultural exports are one of the most important sources to increase the foreign currency. Thus, it is necessary to focus on promoting Egyptian agricultural exports. It is thereby one of the most important pillars of the economy that help to overcome trade balance deficit. Agricultural exports constitute a proportion of Egyptian total exports, representing about 10.60% of the total exports during the period 2001-2014 (FAOSTAT, 2017). The export of potatoes, onions, and tomatoes is the most important vegetable exports. Therefore, increasing the value of vegetable exports have a significant impact on agricultural export and economic development. Hence, maximizing the return of agricultural export in general and vegetable export in particular is one of the important cornerstone of development.

The total vegetable exports value accounted for USD 969 million representing about 24% of Egypt's agricultural export value as average of the period of 2010 - 2014. Potatoes, onions, and tomatoes export values reached about USD 305, 194, and 43 million representing 31.40, 20.05 and 4.44%, respectively, of the total vegetable export value (UN Comtrade 2016). Despite the low contribution of tomatoes export value in total vegetable export value, its importance comes from the fact of being one of the most essential food commodities as well as acting as a safeguard for many health problem. It is important to understand the actual and optimal distribution patterns of marketed crops to international markets in order to promote Egyptian agricultural exports.

Although Egypt has a comparative advantage in producing vegetable crops, the exporting sector is facing many constraints that are associated with many importing countries differing in export prices and the importing capacity.

Egyptian vegetable exports are spread among more than 25 importing countries in the world, especially for potatoes, tomatoes, and onions. In addition, the fluctuation in exported quantities is resulted in losing Egypt's market share in favor of competing countries. This requires a review of the geographical distribution of vegetable export in different world markets to ensure a share of Egyptian vegetables and maximize the return on export of the same quantity. This needs determining the optimal geographic distribution of vegetables exports especially the most important crops potatoes, tomatoes and onions.

This study mainly aims at optimizing the returns of vegetable export in the importing markets in order to increase the export earnings of Egypt. Specifically, there are three aims to reach. First, understanding the current geographical distribution of export of the most important vegetable crops: fresh potatoes, onions and tomatoes. Second, developing an optimization model to ensure the optimal distribution of export for these crops, and re-distributing of exports for potatoes, onions and tomatoes in different foreign markets to increase the Egyptian export earnings. This model is to serve as a tool for policy makers of planning in export development. To reach the objective of this study, first is a presentation of the methodology and data with special emphasis on the mathematical model formulation. This is followed by the model results and discussions, along with the overall recommendations.

METHODOLOGY AND DATA

Model specification

The study depends on the descriptive and quantitative methods, using linear programming model to determine the optimal distribution pattern of vegetable exports. Linear Programming (LP) is a mathematical technique used in computer modeling to find the best or optimal solution to resource allocation problems. LP model is a well suited for this study because of the following reasons: (a) many activities and restrictions can be considered at the same time,(b) an explicit and efficient optimum seeking procedure is provided, (c) with a once-formulated model, results from changing variables can easily be calculated, (d) the policy instruments can be incorporated by means of additional or modified activities in the models (Hazell and Norton, 1986). The main components of any constrained LP problem are (Hillier and Lieberman, 2009):

a) Decision variables (x_j)**:** Choices available to the decision maker in terms of either inputs or outputs $(\forall\ j = 1,...n)$, their values describing the decisions to be made.

b) Objective function (z)**:** A mathematical expression of a criterion that is to be maximised (e.g. return) or minimised (e.g. cost) $z = c_1 x_1 + c_2 x_2 + ... + c_n x_n$

c) Constraints: A mathematical statement that specifies the elements of the problem such as the restrictions on the values of the decision variables.

$$a_{i1} x_1 + a_{i2} x_2 + ... + a_{in} x_n \le b_1 \quad \forall i = 1,..., m .$$

Functional constraints can be also including bounds that are the variables on an optimisation problem permitted to take an infinite range.

d) Model parameters $(c_j, a_{ij}, and b_i)$**:** numerical values are determined when the LP model is solved.

LP model is applied to determine the optimal geographical distribution of exports. The General Algebraic Modeling GAMS language is used to calculate the optimum solutions (Brooke et al., 2010; McCarl et al., 2015). It is chosen for this study because of its flexibility and easiness to apply. The linear programming model is used to obtain the optimum geographical distribution of exports. It is designed to maximise total export returns, subject to export-import capacities and organization constraints. The model is based on the

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expected situation for the Egyptian exports for vegetable crops in world markets. The mathematical formulation of the applied model includes the following components:

The objective function

The objective function is a mathematical expression that combines the decision variables and their coefficients to achieve the goal of maximum export returns. The quantity of the crop to export for importing countries is the decision variable that is to be maximized. The model is to determine the optimal export structure of export for vegetable crops subjected to the limited export and import capacities, and market constraints. It is assumed that the decision maker has a perfect knowledge and that there is no risk (Dawoud, 2014). The objective function is to maximize the value of Egyptian exports. This can be developed as follows:

$$MaxZ = \sum_{j=1}^{n} P_j \ X_j \quad \text{where j =1 to n}$$

Z **:** The total export value of the crop from Egypt,
N: The number of countries,
P_j : Unite value of exported crop from Egypt to importing country j ($/ton),
X_j : The targeted quantity of the crop from Egypt to exports for importing country j (a decision variable) (tons).

Constraints

The constraints are a mathematical expression to address the limit in the model related to supply, demand, and organization constraints. The model identifies possible solutions that respect these constraints in order to achieve the optimum value of objective function. The constraints are represented by the following sets of constraints:

Supply constraint

This set of constraints implies that the sum of export quantities being distributed to countries (decision variables) in a certain period must not exceed or equal the total quantity available to export. The mathematical illustration of the export capacity constraints is presented as follows:

$$\sum_{j=1}^{n} X_j \leq EX$$

Where, X_j represents a matrix of the export coefficients (ton) to each importing country j. EX represents the total export quantities of crops from Egypt to the foreign markets in a year.

The total available quantities for the modeling were about 112.87, 348.87 and 61.09 thousand tons for fresh potatoes, onions and tomatoes, respectively representing about 99.22%, 93.58%, and 98.80% of the total exported amounts as average of the years (2010-2014).

Demand constraint

This constraint means that the maximum quantity of exported crop to each importing country i should not exceed its total imported capacity of the country. Assuming that there is no demand increase during a year, demand constraints can be written as:

$$X_j \leq IM_j$$

IM is the total import quantity (importing capacity) for each country j.

Organization constraint

The constraint is to ensure the supply of the minimum quantities of export commodities to each market. This suggested constraint is needed for the sake of maintaining export share and keeping stability of exports, and do not losing any market at countries group or country level. At the countries group level, the group export quantities to all countries should not exceed the export quantity in the particular group. The lower limitations on corresponding export quantity are based on the minimum levels of historical quantities exported to each countries group over the period from 2010 t0 2014. This model is to inform policy maker about the impact of economic block markets on exports. The equation for the countries group constraints is formulated as the following:

$$\sum_{i}^{r}\sum_{j}^{n} \alpha_{ij} X_j \geq R_i \quad \forall i = Arab countries, European countries, Asian countries$$

Where α_{ij} represents a matrix of the export coefficients (ton) to each importing country j in counties group i . R_i is a vector of the total export quantity available to each countries group i. This minimal as contract with world markets such as Arab market, European market, Asian market. It is modified to suit the Egyptian export conditions and to avoid marketing problems, realizing competitiveness in the world markets.

At the country level: the lower limitations on corresponding export quantity are 50% of the current levels of exported quantity to each country. These organization constraints can be expressed mathematically:

$$X_j \geq L_j$$

Where X_j represents the total export capacity coefficients (ton) to each importing country j. L is the total export quantity available to each country.

Non-negativity constraints

In order to prevent accidental negative values for the decision variables, the following assumption should also be added to the constraints:

$$X_j \geq 0$$

The first two which constraints are obligatory while the organisation constraints are optional. The planner can introduce them to take into account some other limitations such as market constraints. The model is applied in three possible future scenarios in accordance with organization constraints (from Scenario No. 1 to Scenario No. 3) in order to determine the impact of each policy alternative separately. Scenario No. 1 considers only supply and demand constraints that include first and second constraints, thus providing the impact of export and import capacities constraints on the value of exports. Scenario No. 2 a lower limit over the same period from 2010 to 2014 is placed on the export quantity allocated within each countries group. Scenario No. 3 differs from Scenario No. 2 by limiting the minimum export quantity to be allocated to each country. The lower limit on corresponding export quantity is 50% of the current levels of exported quantity to each country.

RESULTS AND DISCUSSION

Data source

This study is based on data from the Central Agency for Public Mobilization and Statistics (CAPMAS, Unpublished), the National Centre for Information, Egypt, and the United Nations Commodity Trade Database (UN COMTRADE) along with other data and references related to the subject of this study from the internet. For modeling optimization problems the General Algebraic Modeling System (GAMS) is designed (Brooke et al., 2010). Data are entered in familiar list using GAMS. Models are presented in algebraic statements that are easy to read. In the mathematical analysis, the selection of the countries is based on the relative importance of geographical distribution during the period 2010-2014.

Current distribution of Egyptian vegetable exports to international markets

Here presents the current geographical distribution for Egyptian exports of vegetable crops. The current study focuses on exported quantities from fresh or chilled potato, onion, and tomato crops. The exports of these crops are delivered to more than 25 countries in the world. Appendix Table A.1 in the Appendix shows the composition of Egyptian exported crops by importing countries and regions over the period 2010-2014, as follows.

Potatoes

During the period under consideration, EU region was the largest importer of Egyptian potatoes, representing 45.58% of the total Exports. Asian countries ranked second, followed by Arab markets. European countries are mainly restricted to following number of countries: Italy, Germany, Greece, United Kingdom, and Ukraine. More interesting, diverse states namely Italy, Germany, Greece, United Kingdom, Ukraine, Russia, Georgia and Lebanon represented about 87.06% of Egyptian exports for potatoes in 2010-2014. Figure 1 shows geographical distribution for Egyptian exports of Potatoes by major importing countries over the period 2010-2014. The Russian market is one of the most importing Egyptian fresh potatoes, importing 42.28 thousand tons with relative importance of about 37.20%. The quantity exported to Italian market from fresh potatoes was about 18.44 thousand tons accounted for 16.22% of the total quantity of Egyptian exports over the same period. Germany, Greece, Georgia, Lebanon and United Kingdom were also among the importing countries of potatoes representing about 8.73, 6.05, 5.57, 5.22 and 4.36% of the total potato exports from Egypt during the same period, respectively.

Onions

The Saudi market is one of the significant markets importing Egyptian onions. Table A.1 in the appendix shows the quantity exported to Saudi Arabia from onions is about 182.19 thousand tons representing about 48.87% of the total exported quantity to world markets. Also, Egypt's exports of onions were directed to the markets of Kuwait, Holland, Jordan, Syria, and United Kingdom with share of 5.64, 5.31, 4.29, 4.28 and 3.77% respectively, of the Egyptian onions exports to the foreign markets during the period (2010-2014) (Figure 2).

Tomatoes

During the period (2010-2014), Arab countries were the largest importer of Egyptian tomatoes exports. Appendix Table A.1 in the Appendix shows the geographical distribution of fresh tomato exports to major importing countries. The exported quantity of Egyptian tomatoes to Syria was about 15.54 thousand tons as an average for the period (2010-2014), representing about 25.13% of the total tomato's exported quantity. It was followed by Saudi Arabia (20.38%), Libya (19.84%), and Iraq (13.49%). These top four importers, taken together, accounted for about 78.84% of the total tomato exports from Egypt during the same period. Holland was the biggest importer of Egyptian tomatoes in European market, with a share of 8% of the total Egyptian tomato exports. The rest of the countries share a very small proportion (Figure 3).

Optimal distribution of Egyptian vegetable exports to international markets

The LP model is used to find the optimal distribution pattern of the export crops under study. In order to calibrate the model, the actual distribution plan for the reference average of years 2010-2014 are compared with the results generated by the mathematical models. Tables 1, 2 and 3 compare the optimal values of the total Egyptian export returns and export quantities to international markets in the three scenarios vs. the actual distribution pattern.

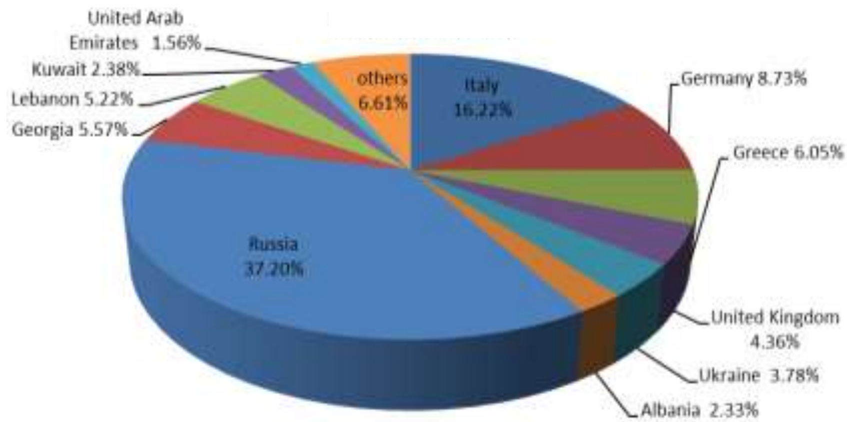

Figure 1. Geographical distribution for Egyptian exports of potatoes during 2010-2014.

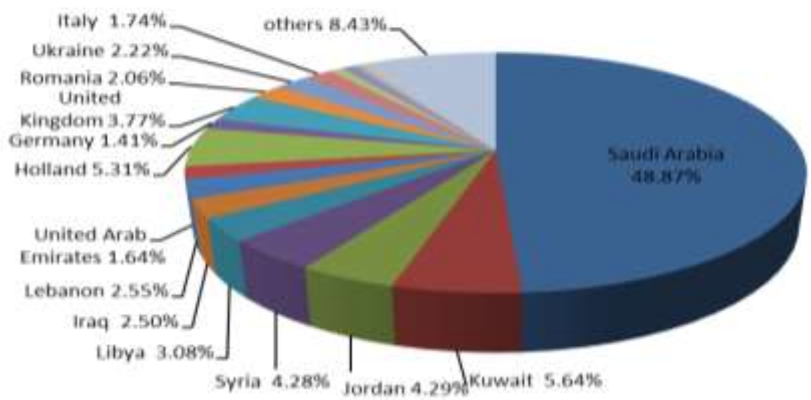

Figure 2. Geographical distribution for Egyptian exports of Onions during 2010-2014

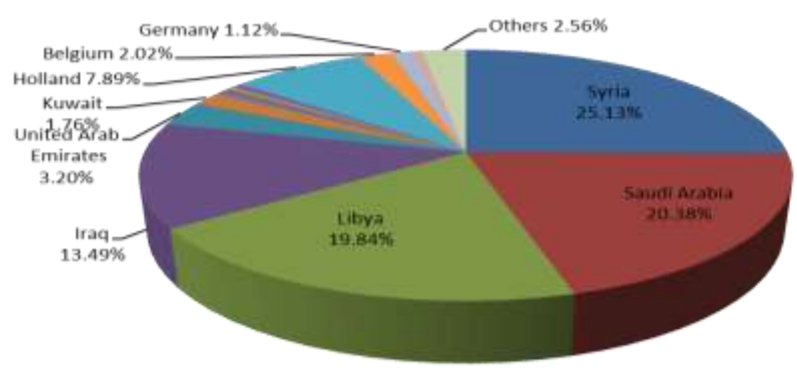

Figure 3. Geographical distribution for Egyptian exports of Tomatoes during 2010-2014

Optimizing the total return for Egyptian potato exports in international markets

Here accounts for optimal scenarios to increase the Egypt's export returns. The results of the LP models are shown in Table 1. The first scenario represents the total exported quantity of potatoes being distributed to high price countries according to imported capacity. It suggests, the total exported quantities distributed to Italy, United Kingdom, Greece and Jordan with shares of

Table 1. Current and optimal geographical distribution for Egyptian exports of potatoes to the international markets, as average during (2010-2014).

Items	Current Plan		Optimal Plans					
			Scenario No. 1		Scenario No. 2		Scenario No. 3	
	Value	%	Value	%	Value	%	Value	%
Export Return ($ million)	52.21	100.00	62.27	19.26	58.71	12.67	57.20	9.56
Suggested Quantity of Exports to Countries (per thousand tons)								
Italy	18.44	16.34	65.13	57.7	0.00	0.00	9.22	8.17
Germany	9.92	8.79	0.00	0.00	0.00	0.00	5.04	4.47
Greece	6.88	6.10	19.5	17.28	19.5	17.28	19.5	17.28
United Kingdom	4.96	4.39	23.18	20.54	32.15	28.48	14.62	12.95
Ukraine	4.30	3.81	0.00	0.00	0.00	0.00	2.15	1.90
Albania	2.65	2.35	0.00	0.00	0.00	0.00	1.33	1.18
Holland	1.53	1.36	0.00	0.00	0.00	0.00	0.76	0.67
Croatia	1.20	1.06	0.00	0.00	0.00	0.00	0.60	0.53
Bulgaria	0.93	0.82	0.00	0.00	0.00	0.00	0.47	0.42
Romania	0.34	0.30	0.00	0.00	0.00	0.00	0.17	0.15
Kazakhstan	0.50	0.44	0.00	0.00	0.00	0.00	0.25	0.22
Spain	0.20	0.18	0.00	0.00	0.00	0.00	0.10	0.09
Russia	42.28	37.46	0.00	38.22	43.14	38.22	43.14	38.22
Georgia	6.33	5.61	0.00	0.00	0.98	0.87	3.16	2.80
Tajikistan	0.20	0.18	0.00	0.00	0.00	0.00	0.10	0.09
Malaysia	0.13	0.12	0.00	0.00	2.98	2.64	2.34	2.07
Thailand	0.10	0.09	0.53	0.47	0.53	0.47	0.05	0.04
Hong Kong	0.09	0.08	0.00	0.00	1.70	1.51	0.05	0.04
Lebanon	5.93	5.25	0.00	0.00	5.58	4.94	2.96	2.62
Kuwait	2.70	2.39	0.00	0.00	0.00	0.00	1.35	1.20
United Arab Emirates	1.77	1.57	0.00	0.00	1.77	1.57	0.88	0.78
Amman	0.61	0.54	0.00	0.00	0.00	0.00	0.31	0.27
Syria	0.32	0.28	0.00	0.00	0.00	0.00	0.16	0.14
Jordan	0.26	0.23	4.08	3.61	4.08	3.61	4.08	3.61
Bahrain	0.30	0.27	0.45	0.40	0.46	0.41	0.08	0.07
Total	112.87	100.00	112.87	138.22	112.87	100.00	112.87	100.00

Source: Mathematical programming models results based on Comtrade data and CAPMAS, various Issues.

57.70, 20.54, 17.28 and 4.08%, respectively, because of their high export prices. Under this scenario, the total export returns are increased by 19.26% above the actual total returns.

Scenario No. 2 maximizes the value of Egyptian potato exports subject to countries group constraint. The constraint is to ensure the supply of the minimum quantities of export commodities for each countries group during 2010-2014. These countries were Arab countries, European countries, Asian countries. European countries were the largest importer of Egyptian export potatoes, representing 51.56% followed by Asian countries (49.33%) and Arab countries constituting (10.53%) of the total potato exports from Egypt during 2010-2014. The largest increase in exported potatoes will be to the United Kingdom, Greece, Russia, and, Jordan. There is a potential to generate an estimated export returns equivalent to about 12.67%, that exceed the current export returns. Scenario No. 3 assumes that the lower exported quantity of potatoes to each country is 50% of the actual exported quantity. The most important countries, which appear in the model results include United Kingdom, Greece, Russia, and Jordan. Egypt's potato exports will increase in countries like the United Kingdom and Jordan. The other countries will remain at minimum levels. The scenario No.3 generates a high export returns about US $57.20 million equivalent to almost 9.56% exceeding the actual total export returns.

Optimizing the total return for Egyptian onion exports in international markets

The results of the LP models for onions exports are

Table 2. Current and optimal geographical distribution for Egyptian exports of onions to the international markets as average during (2010-2014).

Items	Current Plan		Optimal Plans					
			Scenario No. 1		Scenario No. 2		Scenario No. 3	
	Value	%	Value	%	Value	%	Value	%
Export Return ($ million)	177.63	100.00	237.94	33.95	224.69	26.49	222.83	25.45
Suggested Quantity of Exports to Countries (per thousand tons)								
Saudi Arabia	182.19	52.22	0.00	0.00	0.00	0.00	91.02	26.09
Kuwait	21.01	6.02	88.01	25.23	88.01	25.23	88.01	25.23
Jordan	15.99	4.58	0.00	0.00	70.78	20.29	7.77	2.23
Syria	15.94	4.57	0.00	0.00	0.00	0.00	8.07	2.31
Libya	11.49	3.29	0.00	0.00	83.59	23.96	5.87	1.68
Iraq	9.33	2.67	0.00	0.00	0.00	0.00	4.69	1.34
Lebanon	9.52	2.73	0.00	0.00	0.00	0.00	4.84	1.39
United Arab Emirates	6.11	1.75	0.00	0.00	14.49	4.15	3.05	0.87
Amman	2.01	0.58	0.00	0.00	19.16	5.49	1.02	0.29
Bahrain	2.09	0.60	0.00	0.00	0.00	0.00	1.04	0.30
Tunis	0.35	0.10	0.00	0.00	0.00	0.00	0.17	0.05
Holland	19.8	5.68	0.00	0.00	0.00	0.00	9.90	2.84
Germany	5.27	1.51	0.00	0.00	0.00	0.00	2.60	0.75
United Kingdom	14.04	4.02	15.40	4.41	15.41	4.42	15.40	4.41
Romania	7.67	2.20	39.26	11.25	0.00	0.00	30.3	8.69
Ukraine	8.26	2.37	0.00	0.00	0.00	0.00	4.13	1.18
Italy	6.50	1.86	141.07	40.44	0.00	0.00	3.30	0.95
Belgium	2.88	0.83	61.06	17.5	53.36	15.30	61.06	17.50
Greece	2.99	0.86	3.23	0.93	3.23	0.93	3.23	0.93
Cote d'lvoire	1.34	0.38	0.00	0.00	0.00	0.00	0.67	0.19
France	1.07	0.31	0.00	0.00	0.00	0.00	0.52	0.15
Bulgaria	0.87	0.25	0.00	0.00	0.00	0.00	0.44	0.13
Albania	0.71	0.20	0.00	0.00	0.00	0.00	0.35	0.10
Cyprus	0.67	0.19	0.00	0.00	0.00	0.00	0.37	0.11
Croatia	0.41	0.12	0.00	0.00	0.00	0.00	0.21	0.06
Slovenia	0.36	0.10	0.84	0.24	0.84	0.24	0.84	0.24
Total	348.87	100.00	348.87	100.00	348.87	100.00	348.87	100.00

Source: Mathematical programming models results based on Comtrade data and CAPMAS, various Issues.

shown in Table 2. The first scenario suggests that the total exported quantities distributed to Italy, Kuwait, Belgium, Romania and United Kingdom with a share of 40.44, 25.23, 17.50, 11.50 and 4.41% respectively more than the actual export returns, because of their high export prices. This optimum distribution has been coupled with about 33.95% increasing in the total export returns compared to the current situation.

Scenario No. 2 maximizes the value of Egyptian onion exports subject to countries group constraint. Arab countries were the largest importer of Egyptian onion exports, representing about 79% of total Egyptian exports, followed by European countries (21%) of total onion exports from Egypt during 2000-2014. Egyptian onions would be exported to many countries of the world: Kuwait, Libya, Jordan, Belgium, Amman, United Arab Emirates and United Kingdom. The results indicate that the total export returns are increased by 26.49% more than the actual total export returns. For scenario No. 3, the export quantities to Saudi Arabia, Kuwait, Belgium and Romania will increase with a share of 26.09, 25.23, 17.50 and 8.69% of total Egyptian onion exports. The other countries will remain at minimum levels. Scenario 3 generates a high export returns about US $ 222.83 million equivalent to nearly 25.45% more than the actual total export returns.

Optimizing the total return for Egyptian tomato exports in international markets

As shown in Table 3, the first scenario suggests the total

Table 3. Current and optimal geographical distribution for Egyptian exports of tomatoes to the international markets, as average during (2010-2014).

Items	Actual Plan		Optimal Plans					
			Scenario No. 1		Scenario No. 2		Scenario No. 3	
	Value	%	Value	%	Value	%	Value	%
Export Return ($ million)	40.39	100.00	58.70	45.30	54.87	35.85	50.74	25.63
Suggested Quantity of Exports to Countries (per thousand tons)								
Syria	15.54	25.44	0.00	0.00	0.36	0.59	7.56	12.38
Saudi Arabia	12.6	20.63	0.00	0.00	0.00	0.00	6.78	11.10
Libya	12.27	20.09	0.00	0.00	0.00	0.00	5.61	9.18
Iraq	8.34	13.65	22.00	36.01	22.00	36.01	22.00	36.01
United Arab Emirates	1.98	3.24	0.00	0.00	3.73	6.11	1.03	1.69
Kuwait	1.09	1.78	0.00	0.00	25.55	41.82	0.54	0.88
Qatar	0.35	0.57	0.00	0.00	0.00	0.00	0.17	0.28
Amman	0.25	0.41	0.00	0.00	1.37	2.24	0.12	0.20
Yemen	0.17	0.28	0.00	0.00	0.00	0.00	0.09	0.15
Morocco	0.42	0.69	0.00	0.00	0.00	0.00	0.21	0.34
Holland	4.88	7.99	0.00	0.00	0.00	0.00	2.44	3.99
Belgium	1.25	2.05	0.00	0.00	0.00	0.00	0.60	0.98
Germany	0.69	1.13	0.00	0.00	0.00	0.00	0.26	0.43
Italy	0.42	0.69	36.39	59.57	5.38	8.81	10.52	17.22
United Kingdom	0.37	0.61	0.00	0.00	0.00	0.00	0.25	0.41
Turkey	0.15	0.25	0.00	0.00	0.00	0.00	0.08	0.13
Denmark	0.14	0.23	0.00	0.00	0.00	0.00	0.07	0.11
Hungary	0.12	0.20	0.00	0.00	0.00	0.00	0.06	0.10
Slovenia	0.06	0.10	2.70	4.42	2.70	4.42	2.70	4.42
Total	61.09	100.00	61.09	100.00	61.09	100.00	61.09	100.00

Source: Mathematical programming models results based on Comtrade Data and CAPMAS, various issues.

exported quantities distributed to Italy and Iraq with a share of 59.57 and 36.01%, respectively, of the total Egyptian exports. This could be as a result of high export prices. Under this scenario, the total export returns are increased by 45.30% above the actual total returns. Scenario No. 2 maximizes the value of Egyptian tomatoes exports subject to countries group constraint. Arab countries are the largest importer of Egyptian tomato exports, representing 86.87% of the total Egyptian exports. The Scenario shows that the total returns are increased by 35.85% above the actual total net returns. The results of scenarios 3 show that the minimum level is considered by 50% of the actual levels of export quantity to each country. Iraq was largest importer of Egyptian tomato exports, representing 36.01% followed by Italy, (17.22%), Syria (12.38%), and Saudi Arabia (11.10%) of total Egyptian potatoes exports during 2010-2014. The other countries will remain at minimum levels. The results indicate that there is a prospect to generate an estimated export returns equivalent of US $ 50.74 million representing about 25.63% more than the actual total export returns.

Conclusions

Regarding the results of the above analysis, the major potato export markets are Russia, Italy, Germany, Greece, and Lebanon representing about 82% of Egyptian exports from potatoes. The most important countries that import Egyptian onions are: Saudi Arabia, Kuwait, Jordan and Syria accounting together for 77% of total quantity exported to the world markets. Arab countries were the largest importers of Egyptian tomato exports. The top four importers Syria, Saudi Arabia, Libya and Iraq, together representing about 85% of total tomato exports from Egypt.

Based on the results of the suggested mathematical model to explore optimal distribution pattern for vegetable exports, the following conclusions could be deduced:

i) There is a likelihood for improvement in total returns to Egyptian vegetable exports through the optimum geographical re-distribution of crop exports.
ii) The largest increase in Egyptian fresh potato exports will be to United Kingdom, Greece, Russia, and, Jordan.

iii) The most important countries where higher export quantities of Egyptian onions are involved Saudi Arabia, Kuwait, Belgium and Romania.
iv) The most important import markets for Egyptian tomato exports are Iraq followed by Italy, Syria, and Saudi Arabia.

RECOMMENDATIONS

Several recommendations would be made for the future export development policies in Egypt as follows:

i) Producers should be advised to produce high value export crops and increase their production to meet the growing foreign demand.
ii) Government should encourage investment in production projects for export and improve distribution export pattern.
iii) Maintaining Egypt's position of vegetable exports in the actual international markets to meet their needs with the required quality of crops.
iv) The applied mathematical models can be used to provide information to decision makers about likely optimal distribution policy alternatives for export development.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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APPENDIX

Table A1. The geographical distribution for the Egyptian exports of potatoes, onion and tomatoes to the different foreign markets, for average (2010-2014).

Potatoes			Onions			Tomatoes		
Countries	Quantity of Exports	%	Countries	Quantity of Exports	%	Countries	Quantity of Exports	%
Italy	18.44	16.21	Saudi Arabia	182.19	48.87	Syria	15.54	25.13
Germany	9.92	8.72	Kuwait	21.01	5.64	Saudi Arabia	12.6	20.38
Greece	6.88	6.05	Jordan	15.99	4.29	Libya	12.27	19.84
United Kingdom	4.96	4.36	Syria	15.94	4.28	Iraq	8.34	13.49
Ukraine	4.30	3.78	Libya	11.49	3.08	United Arab Emirates	1.98	3.20
Albania	2.65	2.33	Iraq	9.33	2.50	Kuwait	1.09	1.76
Holland	1.53	1.34	Lebanon	9.52	2.55	Qatar	0.35	0.57
Croatia	1.20	1.05	United Arab Emirates	6.11	1.64	Amman	0.25	0.40
Bulgaria	0.93	0.82	Amman	2.01	0.54	Yemen	0.17	0.27
Romania	0.34	0.30	Bahrain	2.09	0.56	Morocco	0.42	0.68
Kazakhstan	0.50	0.44	Tunis	0.35	0.09	Arab countries	53.01	85.74
Spain	0.20	0.18	Arab countries	276.03	74.04	Holland	4.88	7.89
European countries	52.82	45.58	Holland	19.8	5.31	Belgium	1.25	2.02
Russia	42.28	37.17	Germany	5.27	1.41	Germany	0.69	1.12
Georgia	6.33	5.56	United Kingdom	14.04	3.77	United Kingdom	0.42	0.68
Tajikistan	0.20	0.18	Romania	7.67	2.06	Italy	0.37	0.60
Malaysia	0.13	0.11	Ukraine	8.26	2.22	Turkey	0.15	0.24
Thailand	0.10	0.09	Italy	6.5	1.74	Denmark	0.14	0.23
Hong Kong	0.09	0.08	Belgium	2.88	0.77	Hungary	0.12	0.19
Asian countries	49.08	43.19	Greece	2.99	0.80	Slovenia	0.06	0.10
Lebanon	5.93	5.21	Cote d'Ivoire	1.34	0.36	European countries	8.08	13.07
Kuwait	2.70	2.37	France	1.07	0.29	Others	0.74	1.20
United Arab Emirates	1.77	1.56	Bulgaria	0.87	0.23	World	61.83	100.00
Amman	0.61	0.54	Albania	0.71	0.19			
Syria	0.32	0.28	Cyprus	0.67	0.18			
Jordan	0.26	0.23	Croatia	0.41	0.11			
Bahrain	0.30	0.26	Slovenia	0.36	0.10			
Arab countries	11.41	10.45	European countries	72.84	19.54			
Others	0.89	0.78	Others	23.94	6.42			
World	113.76	100.00	World	372.81	100.00			

Source: Based on data from CAPMAS and Comtrade, for the period 2010 to 2014.

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Resource use efficiency in rice production in the lower Anambra irrigation project, Nigeria

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Increasing the output of rice to match the growing demand for rice is a global challenge, and with growing world population, the need becomes more pertinent. For developing countries with high population density like Nigeria, the importance of rice in the food security status of the population cannot be questioned. Although the production of rice in Nigeria has been increasing over time, there is need to move towards sustainable land and water management. This has placed considerable demand to increase productivity per unit of land. The way in which the resources in rice production are utilized is a crucial pointer to the manager of a way to re-organize production to ensure higher productivity. This study examined resource use efficiency in rice production using the Cobb Douglass production function. Respondents for the study were randomly selected among farmers in the Lower Anambra Irrigation Project. The study showed that although rice production is profitable in the area, some resources were not efficiently being utilized. Recommendations for increasing the output of rice were proffered.

Key words: Costs and return, gross margin, staple crop, production function.

INTRODUCTION

Rice (*oryza sativa*) as a crop has received widespread attention from International and regional bodies due to its importance. Research work continues to go on to develop better varieties of the crop suited to a particular climates. In West Africa, under the umbrella of the West African Rice Development Authority (WARDA), some countries of West Africa of which Nigeria is one, are carrying out intensive research and promotion of the cultivation of the crop (WARDA, 1996).

Among the cereal grains, rice is the second only to wheat in terms of total world production (Goni et al., 2007). A recent Food and Agriculture Organization (FAO) estimate of cereal supply and demand puts the 2015/2016 world wheat production at 758.0 million tonnes followed by rice which is 497.8 million tonnes, while data for other grains is aggregated together as

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coarse grains (FAO, 2017). It is a preferred food in urban centers of many countries including Nigeria (Igbokwe, 2001) and in institutions, because of the relative ease of preparation in catering for large numbers of people (Akande, 2002).

In Nigeria, its importance is seen in the fact that it is accepted amongst all cultures (Okeke et al., 2008; Onimawo, 2012), and is normally preferably prepared in social functions. As noted earlier the ease in preparation and its wide usage in festivities have made rice a popular meal in most households in Nigeria, with almost similar recipes for preparation across the cultures. It is estimated that the per capita consumption of rice is about 24.8 kg (Adeyeye et al., 2010).

Rice is a semi- aquatic plant which thrives well in wet parts of the landscape where other cereal crops cannot survive, but is less tolerant of low soil moisture than other crops (Huke, 1976). This means that, it can only be produced where there is enough water within the crop growth cycle. Almost all agro-ecological zones in Nigeria can support rice growth (Akande, 2002; Daramola, 2005). On the basis of water availability, there are two major rice farming systems namely: upland rice and wet paddy or swamp rice. The swamp rice or wet paddy describes a system where the land on which rice is grown is water logged for most part of the year. Such lands are located close to river banks, or in lowland plains covered with water from a dam (FAO, 1984).

Upland rice refers to a system of growing rice on both flatlands and sloping lands that depend on rainfall for moisture (IRRI, 1975). The major rice ecosystems in Nigeria are lowland upland rain-fed, lowland rain-fed, upland rainfed and supplementation of precipitation by Irrigated production systems which together account for 97% of rice produced in Nigeria (Daramola, 2005).

Rice is processed simply by removal of husk and bran. Fat and protein content are low (Erhabor and Ojogho, 2011), so it can store well in a hot and damp climate. It has been noted that rice is the leading food in parts of the world with high population density and in areas where dietary levels are not adequate (Bouman et al., 2007; Huke, 1976).

In terms of consumption in Nigeria, rice is the fourth most important staple crop, rising from a fifth position in the 1960’s (Akande, 2002; Cadoni and Angelucci, 2013; Osifo, 1971). It is thus not surprising to note that rice production in Nigeria has been increasing over the decades (Figure 1).

This spectacular growth in production could be attributed to a variety of factors including the rapidly growing per capita demand for rice, expansion of cultivated area, and the influence of government policies and programs in the rice sector (Erhabo and Ojogho, 2011; Ogundele and Okoruwa, 2006; WARDA, 1981).

This growth notwithstanding, the demand for rice in Nigeria far outstrips the domestic supply (Bamidele et al., 2010; Kebbeh et al., 2003; Odomenem and Inakwu, 2011). The growth in demand is attributed to factors such as increasing population, increased income levels, and rising urbanization (Akande, 2002; Cadoni and Angelucci, 2013).

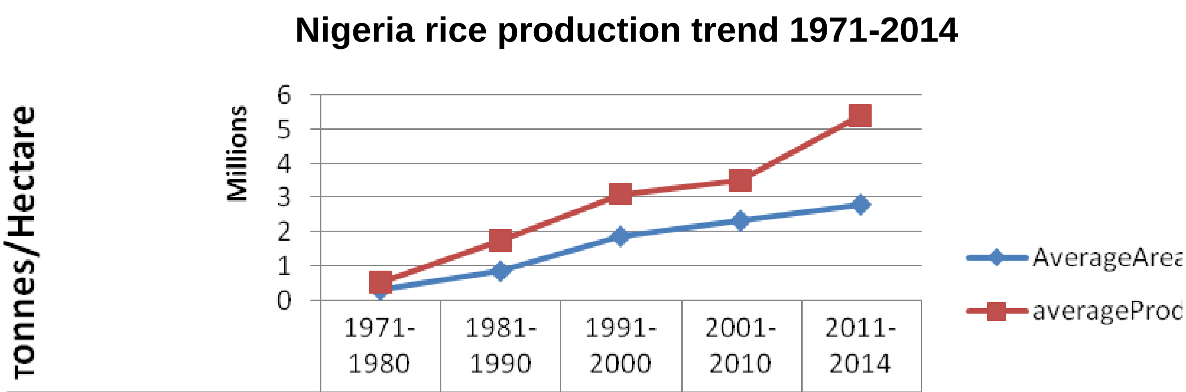
Nigeria is currently the largest producer and consumer of rice in West Africa (Cadoni and Angelucci, 2013; Daramola, 2005; Oyinbo et al., 2013). Nigeria meets its demand deficit through importation of rice from other countries (Ogundele and Okoruwa, 2006; Akinbile, 2010, Adenuga et al., 2013; Obayelu et al., 2017). Currently, Nigeria is the second largest importer of rice in the world (Cadoni and Angelluci, 2013; Oyinbo et al., 2013).

In an attempt to bridge the supply/demand gaps, the Federal Government of Nigeria, under various regimes have come up with programmes and policies to stimulate greater local production and consumption of locally produced rice and other staple crops (Cadoni and Angelluci, 2013; Ajijola et al., 2012; Ogundele and Okoruwa, 2006; WARDA, 2003). The country has the capacity in terms of fertile land, agro-climatic conditions and labour to substantially increase its rice production and output (Coalition for African Rice Development (CARD), 2009).

The attendant benefits this would provide to all in the rice value chain are enormous and worth pursuing. For instance this would create further employment in the production, processing, and marketing aspects of the rice value chain. Also it is important to enhanced accessibility from the production site to the market that this will generate. Apart from increasing income and contributing to food security, increased rice output overtime may turn around the supply-demand gap, saving foreign exchange for the nation.

The Lower Anambra Irrigation project in Omor Anambra State is the focus of this study. Rice is the sole crop grown here. The Irrigation project is situated in Anambra state which is one of the states of South-eastern Nigeria, noted for its high population density (Okafor, 1991), with an estimated density of 1,500-2,000 persons per square kilometer with most people residing in urban areas (Ministry of Economic Planning and Budget, 2005). Rice is also a staple crop here and has grown in importance with the changing socio-economic status of the population. The combination of high population density and insufficient land for agriculture drives the need for increased output of rice in existing rice production technologies. With a poverty estimate of 51% in 2005 and 57.70% in 2008 based on a poverty mapping conducted through the support of reforming the Institutions program (SRIP) of the European Union (EU-SRIP, 2008), there is a need to produce more food and at the same time alleviate poverty in the state.

Increasing the output of rice at a low unit cost so that



	1971-1980	1981-1990	1991-2000	2001-2010	2011-2014
AverageAreaHa	310400	849600	1865620	2318151	2790106
averageProduction	533200	1758132	3113800	3512277	5400719

Figure 1. Nigeria rice production trend 1971-2014. Source: Calculation with data from FAOStat 2017.

farmers can be assured of reasonable profits and poor consumers can purchase at low prices becomes a growing challenge. According to Coalition for African Rice Development (CARD) (2009), rice yield in the Irrigation schemes in Nigeria has the potential to reach 7 to 9 tonnes/hectare, while rainfed lowland has the yield potential of 3.0 to 6.0tonnes/ha but this potential is not being realized. The rainfed lowland realizes only 1.5 to 3.0t/ha of rice (CARD, 2009), while irrigated rice realizes 3.5t/ha (Cadoni and Angelluci, 2013).

Apart from biophysical and institutional factors, a key socio-economic factor in assessing crop performance is the resource use efficiency in the farm**.** An examination of resource allocation scenarios in existing rice production systems would provide starting point information on why rice productivity is less than desired in Nigeria.

This study therefore examines resource use efficiency in the Lower Anambra Irrigation Project (LAIP), Anambra state. The LAIP is a public sector irrigation scheme with the objectives of contributing to food production so as to achieve self sufficiency in food, introduction of advanced farming techniques for high production together with intensive training of staff and farmers, and formulation of optimum cropping pattern, establishment of farm management and farmers' organization (LAIP, 2000). In Nigeria, more than 90% of rice is produced by resource poor small scale farmers (CARD, 2009; Muhammad-Lawal et al., 2013), and most of the farmers have small farm sizes of about 1 to 5 hectares (Odozi, 2014). Given this average size of farm land, economies of application of relevant technologies remain elusive.

Increasing the output of rice and consequently the supply entering the market depends primarily on the quantity of labour, suitable land and capital under the control of farmers, the existing production techniques and constraints as well as access to additional resources and techniques (Winch and Kivunja, 1978).

The incentive for farmers to increase their production of rice will depend upon the relative profitability of rice vis-à-vis the other crops in their farming systems; the ability and cost of adopting technologies; the ability and cost of reducing present rice production constraints; the perceived risk associated with new planting materials and techniques (Winch and Kivunja, 1978). As the Nigerian government's priority is to promote productivity in staples including rice (FMARD, 2016), there is need to examine the efficiency of production so as to proffer policy guideline.

Although rice as a crop and product has attracted several studies in Nigeria, many focused on policy, consumption and marketing dimensions (Cadoni and Angelucci, 2013; Daramola, 2005; Ifejirika et al., 2013; Emodi and Madukwe, 2011; Erhabor and Ojogho, 2011; Adeyeye et al., 2010; Bamidele et al., 2010; Daramola, 2005), while several studies focused on productivity and resource use efficiency in rice production, in other parts of Nigeria. For instance Ogundele and Okoruwa (2006) ascertained technical efficiency differential between improved rice variety farmers and those who planted traditional varieties of rice in Kaduna, Kano and Ebonyi states of Nigeria. The stochastic frontier model was used in the study and showed that there was no significant difference in efficiency between the two categories.

A study by Kebbeh et al. (2003) focused on constraints and opportunities for irrigated rice farming in six irrigation schemes mainly in Northern Nigeria. In the Lake Chad basin, Goni et al. (2007) examined resource use efficiency in rice production using a Cobb-douglas Production function.

Results and findings from these studies cannot be easily applied to rice production in Southeastern Nigeria given the agro-ecological differences between the study areas.

There is need to examine the resource allocation scenarios amongst rice farmers in Southeastern Nigeria, particularly in the highly populated states like Anambra, hence this study. Although the area under study is within a public sector irrigation facility, the rice production studied was under rainfed system as the irrigation scheme had become dilapidated.

Resource use efficiency

Farm resources are inputs of labour, capital, land and management. These are combined in different ways to produce outputs. An increase or decrease in output is a result of the level and or method in which the resources used in production are combined. As defined by Olayide and Heady (1982) agricultural productivity is the index of the ratio of the value of total farm output to the value of the total inputs used in farm production.

Productivity can be enhanced by increase in quality of inputs, changes in techniques, better trained labour, substitution of capital for labour, better organization of production and new ideas even when there are no changes in the quantity and proportion of factors (Olayide and Heady, 1982; Lipsey, 1983).

Optimal productivity of resources denotes an efficient use of resources in the production process. Efficiency is concerned with relative outcome of the processes and activities and techniques used in converting a set of inputs into output. According to Upton (1996), the economic optimum can be obtained by comparing the cost per unit of a resource input with the marginal product earned. The economic optimum is then obtained where the marginal value product equals the unit factor cost (Upton, 1996).

As defined by Ellis (1993), technical efficiency is the maximum obtainable level of output that can be gotten from a given level of production inputs. For a farm to be considered as a perfectly efficient farm, this ratio has to be unity (Olayide and Heady, 1982). This means that the larger the amount of the input the smaller the size of this ratio (Timmer, 1980).

Efficiency techniques can be considered therefore as those techniques that give higher output for a given set of inputs than other possible techniques with lower total production cost. Differences in technical efficiency according to Minjidadi and Norman (1982) can be attributed to at least four factors: differences in managerial ability; the employment of different levels of technology as indicated by the quality or type of input employed; different environmental qualities like soil, rainfall and solar radiation; and non economic and non technical factors which can prevent some farmers from working hard enough on their plots, thus failing to achieve the best level of farm output.

Allocative or price efficiency refers to the ability to choose levels of input and outputs that maximize profit given relative prices (Ellis, 1993).

MATERIAL AND METHODS

The area studied was Anambra state, Nigeria. Anambra state has a total land area of 4,415.54 m^3 and a population of 4.182.032 persons (NPC, 2006).

More than 50% of the population are engaged in agricultural production in the area of food crops, tree crops, fisheries and livestock (Anambra State Agricultural Development Programme (ANADEP), 2006). The actual area cropped with rice in Anambra State is estimated at 12,000 hectares, and the production systems are rainfed lowland and rainfed upland (Ecosystems Development Organisation (EDO), 2003). The rice potential for the state remain largely untapped (EDO, 2003; LAIP, 2000).

A purposive selection of the Lower Anambra Irrigation Project (LAIP) in Aghamelum Local Government area in the state was done due to the large scale of rice production in the area. The irrigation project has a land area of 5,000 hectares. From this, 3,850 hectares were developed for irrigated cropping while the rest (1,150 hectares) is used for rainfed farming (LAIP 2000). There are two distinct seasons in the local government area: the rainy and dry season. The duration of the rainy season is about 7 to 8 months in the area, starting from April/May to October/November. The average annual rainfall in the area is approximately 1,730 mm and this is bi-modally, distributed with peaks in July and September. The area records a maximum temperature of 38°C and a minimum temperatures of 22°C annually (Urama and Hodge, 2004).

Respondents for the study were selected using purposive and simple random sampling methods. Because the study was on rice, the Lower Anambra Irrigation project area was purposively selected in the first instance as it is a major rice growing area. A total of 160 farmers were randomly selected from the list of farmers involved in rainy season production. After data cleaning, 143 farmer responses were finally used for the study.

The data were obtained from primary sources using structured questionnaires. A pilot test of the questionnaire was done so as to remove ambiguity and ensure accuracy. Apart from the socio-economic characteristics of the farmers, data collected included farmers input level and costs, and output level and price data.

To measure resource productivity and enterprise profitability the Cobb- Douglass production function and Gross Margin Analysis were used. These are specified as follows:

$$Y = aX_1^{b1}X_2^{b2}\ X_3^{b3}\ X_4^{b4}X_5^{b5}\ ei$$

Where Y = Output of rice (kg)
X_1 = Land (farm size in hectares)
X_2 = seed (rice seed in kg).
X_3 = Labour (measured in mandays)
X_4 = Fertilizer (measured in Kg)
X_5 = other agrochemicals used (₦).

b_1, b_2, b_3, b_4, b_5, are elasticity of response of X_1, X_2, X_3, X_4, and X_5 to output respectively

a = intercept
ei = error term

In order to determine the resource use efficiencies, the b-values as obtained from the regression results were used to determine the allocative efficiency by estimating the ratio of the Marginal Value Product (MVP) of each input to the factor price or Marginal Factor Cost (MFC) of the factor input. Thus allocative efficiency is best achieved where:

$$\text{Allocative Efficiency} = \frac{MVP}{MFC} = 1$$

Where:

MVP = Marginal Value Product of the resource input
MFC = Marginal Factor Cost of the resource input

If the value of the above ratio is more than one, it means that the farmers were under utilizing the production resource. If on the other hand, the above ratio is less than one, it implies that the survey farmers were over utilizing the production resource. Gross Margin (GM) is specified as follows:

$$GM = TR - TVC$$

where

GM = Gross margin (₦) per hectare
TR = Total revenue (₦) per hectare
TVC = Total variable cost (₦) per hectare

From the Gross Margin the Net Profit is derived as follows:

$$\text{Net Profit} = GM - FC$$

Where FC is the fixed costs of production like rent, depreciation on farm implements

Cost of production and management practices in rice production

The cost of one season production for one hectare of irrigated rice field was not completely uniform amongst the respondents because of certain variations like differences in intensity of weed, time of carrying out operation, disease and pest occurrence, and so many other variables. The averages of the costs and quantities harvested were computed and used in calculations. The average yield of paddy rice was 26.14 bags of 202 kg bag all being equivalent to 4705.2 kg of paddy rice per hectare. The farmers rented the rice fields in plots from the irrigation agency in LAIP.

Each plot is comprised of eight chains. Two plots in the rice scheme, add up to one hectare therefore, a hectare has 16 chains. For most of the operations, labour is paid for per chain of field worked. The first activity undertaken is land clearing and preparation. This is mostly done using tractor, although a few farmers used human labour for this activity. After harrowing, the rice seed is planted by broadcasting across the chains in a manner to ensure even spread. This is usually done by two people.

After two weeks, if there are some portions of the field that did not germinate well, “patching” is done to fill up those portions, by replanting, this time more carefully to ensure germination. The number of people involved in patching is determined by the severity of the germination gap. This is followed by fertilizer application which is by broadcasting too. Two people on the average carried out this activity. The pesticide as well as herbicide used are in liquid form and are applied by spraying using sprayer. Weeding is done using human labour. The average charge for this activity was N580 per chain.

When the rice starts producing panicles, the next thing is to guard against the pests. The major pest in the area is the bird. The farmers guard against it by engaging labourers to watch and drive out birds from the field. Some put a scare crow in addition. The rice is cut when fully mature at about three months after planting. The sheaves are then threshed using a threshing machine to remove the seeds from the sheaves. Thereafter, winnowing is done to separate the sheaves from the seeds. The seeds are then bagged and transported out of the farm. The average costs involved in these processes are as outlined in the results section.

RESULTS

The Cobb-Douglas Production function was used to determine the influence of inputs used for rice cultivation on the output of rice in LAIP. The predictor variables were land, (X1), seed (X2), Labour (X3), fertilizer (X4) and Agrochemicals (X5). The regression result is presented in Table 1.

The overall F-value (F= 217.6751; $p \leq 0.05$) of the regression is significant at 5%. The significant variables are seed, land and fertilizer. These accounted for 88% of the total variation in the output of rice in the location. This study shows that fertilizer has a positive influence on yield. Since the co-efficient of Cobb Douglas equation is the elasticity, it can be said that a unit increase in the level of fertilizer will lead to a 30% increase in rice yield.

Farm size also influenced yield positively. From the table, since the coefficients are the elasticities, it can be said that when a farmer increases his farm size by a unit, output would increase by 108%. The quantity of seed used was also significant but had a negative sign.

Resource use efficiency in rice production

The coefficients of the relevant explanatory variables obtained were used to calculate the efficiency of resource utilization as presented in Table 2. The table shows the measures of efficiency of resource use in rice production in LAIP Omor. The parameters such as the average physical product (APP), marginal physical product (MPP), Marginal value Product (MVP), marginal factor cost (MFC) and the ratio of MVP to MFC were derived and are presented in the table. It shows that there is allocative inefficiency in the utilization of resources. All of the resources were underutilized.

Gross margin analysis

For a gross margin and profit analysis to be done, a crop enterprise cost and return statement or budget is needed. According to Johnson (1990), variable costs are those

Table 1. Estimated Cobb-Douglass function for rice in LAIP.

Variable	Regression coefficients	Standard error	t-value
Intercept	3.729	0.397	9.38
Land	1.081*	0.187	5.77
Seed	-0.233*	0.687	-3.39
Labour	-0.089	0.136	-0.65
Fertilizer	0.302*	0.105	2.86
Chemicals	-0.035	0.041	-0.87

R^2 = 0.88; * = Significant at 1%.

Table 2. Efficiency of resource use in rice production.

Resource	APP (kg)	MPP(kg)	MVP(N)	MFC(N)	MVP/MFC
Land	5229.69	5655.21	232881.54	2200	105.8
Seed	50.73	11.84	487.762	196	2.488
Fertilizer	20.25	2.54	251.898	84	2.998

Note: APP = Average physical product, MPP =Marginal Physical product, MVP= Marginal Value Product, MFC= Marginal Factor Cost.

costs that vary in roughly direct proportion to the level of activity or area planted. They are costs over which a manager has control at a given time (Kay et al., 2008).

The gross margin is the difference between value of production and the marginal cost of that production. In practice, it is taken as the surplus (or deficit) left after variable costs have been subtracted from value of production or gross income. The Table 3 below shows the cost and return statement for rice production in LAIP. The average yield of paddy was 26 bags weighing 202 kg each on the average. The total revenue derived from this was N 216, 320. The major variable cost component was labour used for various farm operations.

Gross margin is given as Total revenue per hectare – Total Variable cost per hectare. In the LAIP scheme total revenue is given as ₦216 320 and total variable cost is ₦123, 518

Gross Margin = TR- TVC

= ₦ 216,320 - ₦ 123,518
= ₦ 92,802

Profit is given by TR - TC

= ₦ 216,320 - ₦ 126,658
= ₦ 89,662

DISCUSSION

The analysis has shown that some resources namely seed, land and fertilizer were significant in influencing yield of rice. Fertilizer had a positive influence on yield. This could be because rice responds highly to fertilizer application.

As noted by Ogundele and Okoruwa (2006), fertilizer is one of the most critical inputs in rice production. Since farm size positively influenced the rice yield, there is room for farm size expansion within the limits of the management capacity of the farmers. The LAIP authorities can do well, to expand the area allocated to farmers in the rainy season, and thus increase an individual farmers allotment.

Use of seed negatively influenced rice output. It could be that they were overusing seeds, as it was observed that they planted rice by broadcasting method, or because of poor seed management practices. It is also possible that farmers were using grains to plant but not seeds, so using additional quantities of seed may not mean much to output.

In a similar study of resource use efficiency by Goni et al. (2007) in the Lake Chad area of Borno state, it was found that labour and fertilizer significantly influenced the rice output at 1% level. Farm size was not significant while seed affected the output at 5% level of significance. The ratio of the MVP to MFC for all the resources shows that, there is allocative inefficiency as resources were underutilized.

Farmers should consider increasing their use of the resources, within the limits of their management capacity and biological relationships, as this has a high potential for farmers to increase their output and income. These

Table 3. Enterprise cost and returns statement for one hectare of rice crop in LAIP.

Item	Unit	Quantity	Price/Unit ₦	Amount ₦
A. Revenue	-	-	-	-
Sale of Paddy Rice	202kgbag	26	8320	216,320
Total Revenue	-	-	-	216,320
B.Variable Costs	-	-	-	-
Seed	Bag	3	4900	14700
Fertilizer	50kg bag	5	4200	21000
Pesticide	Litre	3	1082	3246
Herbicide	Litre	7	1460	10220
Labour	-	-	-	-
Land preparation	Manday	1	6600	6600
Harrowing	Manday	16	400	6400
Planting	Manday	2	500	1000
Patching of Rice Field	Manday	3	600	1800
Fertilizer Application	Manday	2	400	800
Herbicide Application	Manday	3	450	1350
Pesticide Application	Manday	3	430	1290
Weeding	Manday	8	580	4640
Bird Scaring	-	2	4436	8872
Harvesting	-	16	450	7200
Packing of rice panicles	-	10	370	3700
Threshing	-	5	5370 per plot	10740
Winnowing	-	7	560	3920
Gathering	-	6	420	2520
Bagging	-	6	420	2520
Transport	Bag	25	440	11000
Total Variable Costs (B)	-	-	-	123 518
Gross Margin (A-B)	-	-	-	92 802
C Fixed Costs	-	-	-	-
Administrative charge	Ha	1	2 200	2 200
Depreciation	-	-	-	940
Total fixed cost	-	-	-	3140
Total Costs (B + C)	-	-	-	126 658
Profit(TR- TC)	-	-	-	89 662

findings agree with Goni et al. (2007) as their study found that the ratios of MVP to MFC were greater than unity (1) for seed, farm size and fertilizer in the Lake Chad area of Borno State.

The gross margin analysis shows that, the major cost component was labour. This accounted for about 59% of the variable costs in LAIP. It also showed that rice production is a profitable enterprise.

Conclusion

From this study, it can be inferred that although rice production in the scheme is income yielding and profitable, the enterprise is not organized or managed in ways to ensure efficiency. This means that under the current resource management and utilization scenario, increased rice output will not be easily attained. As rice is a major staple crop and its production, processing and marketing are sources of livelihood not only in the area but also all over the nation, there is need to address the underlying factors leading to inefficiency. In the light of this, the following recommendations are proffered:

(1) Since a good proportion of the land in the project area is not put under use in the rainy season, there is need to

increase the size of land allocated to a farmer in the project which utilize economies of scale.

(2) There is need to examine rice seed handling by farmers to ensure that they use viable seeds.

(3) The dilapidated irrigation facilities should be repaired, as rice thrives best with ample water supply, which enable dry season production of the crop.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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