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Full Length Research Paper

Assessing the extent and determinants of adoption of improved cassava varieties in south-western Nigeria

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This paper investigates the determinants of adoption of improved cassava varieties in south-western Nigeria. The data come from a farm household survey of 841 households selected using a three-stage stratified random sampling procedure. The data collection was conducted in 2011 by the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Empirical estimates of a Double-Hurdle model revealed that adoption increases with the age of the household head and is influenced by the gender of the household head, hired labour, cultivated land, and access to credit. The results further showed that the intensity of adoption is influenced by hired labour and farm size; access to information about the improved cassava varieties is determined by the age, gender, and level of education of the household head, and by off-farm income.

Key words: Adoption, improved cassava, double-hurdle, Nigeria.

INTRODUCTION

Cassava plays key roles in African development as a famine-reserve crop, rural food staple, cash crop for urban consumption, and raw material for livestock and industry (Nweke et al., 2002). Cassava is a staple food for over 200 million people in sub-Saharan Africa and an important food and cash crop in several tropical African countries, especially Nigeria where it plays a principal role in the food economy (Agwu and Anyaeche, 2007). Approximately hundred million Nigerians eat cassava-based foods at least once a day and the per capita consumption exceeds 200 kg/year in the north central,

southwest, southeast, and south-south parts of the country (Africa Agriculture News, 2013). Cassava is the most important source of carbohydrates for human consumption in the tropics after maize. The high level of carbohydrates is an advantage in Africa because it makes cassava the cheapest source of food calories (Nweke et al., 2002). In most countries, cassava is becoming an important cash crop that has a high potential for use as an industrial raw material in the manufacture of starch, flour, and many other important products.

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JEL classification: C25, D13, Q16, Q56.

For decades, Nigerian farmers relied solely on the traditional varieties and this reliance generated concern. The limitations of these varieties included a low yield, long maturity period, and high susceptibility to diseases such as Cassava Mosaic Disease (CMD) and brown streak Disease (CBSD). Achieving a substantial increase in cassava productivity which has been one of the major goals of successive Nigerian Governments over several decades requires ability to overcome the above limitations.

To accomplish this objective, the government initiated modern research into cassava in 1954. This research led to the development of some improved cassava varieties. Subsequently, the severe attack of the Cassava Bacterial Blight (CBB) the years that followed necessitated a collaboration between the International Institute of Tropical Agriculture (IITA) and its partners that led to the development of resistant improved cassava varieties to the CBB (Akoroda et al., 1985). IITA releases the first two IITA clones in 1976, namely TMS 30211 and TMS 30395, which were rapidly followed by TMS 30572, TMS 30001, TMS 300017, TMS 30110, TMS 30337, TMS 30555, TMS 4(2)1425 and others (IITA 1984). Since then, efforts to improve cassava have continually increased such that IITA working with national partners has developed more than forty ICVs in the last forty five years (Eke-Okoro and Njoku, 2012).

In a recent study conducted by Abdoulaye et al (2014) ICVs adopters were observed to have a higher yield of about 16 tons/ha compared with 10 tons/ha for non-adopters. The implication is that the desired increase in productivity due to the ICVs and the subsequent impact on poverty reduction will not be achieved unless the ICVs are widely adopted by the Nigerian farmers. However, evidence from the literature shows that the adoption of ICVs is not yet universal in Nigeria. This implies that some farmers cultivate the improved cassava varieties (adopters) and some do not (non-adopters). Also, the level of adoption among the adopters also varies. This implies that there are some farmers among the adopters that utilized all their available farmland for ICVs whereas others only plant ICVs on a share of their farmland. This raises two pertinent questions: first, why are some cassava farmers adopting ICVs and others are not. Second, why does the intensity or the size of the area of farmland devoted to the cultivation of ICVs vary among the adopters?, third, what is the role of access to information on ICVs adoption in Southwestern Nigeria.

Studies that have attempted to provide answers to the above questions which are needed for future agricultural planning is still very scanty and in particular no recent information on ICVs adoption in the southwest is available. The most recent studies on ICVs adoption was conducted in the 1980s (Ay et al., 1983; Ikpi et al., 1986; Keyser, 1984). Thus, leaving a gap in the literature that this study intends to fill. Therefore, the broad objective of this study is to examine the determinants and intensity

of adoption of ICVs in Southwestern Nigeria. Specifically, the study assesses the influence of the farmers' socio-economic/demographic characteristics on the decision to adopt the ICVs and also examines the effect of access to information on the adoption of ICVs in Southwestern Nigeria.

Most importantly, in contrast to most adoption studies in Nigeria that adopted either logit, probit or tobit models (Igodan et al., 1988; Saka et al., 2005; Eze et al., 2006; Saka and Lawal, 2009; Junge et al., 2009; Okoedo-Okojie and Onomolease, 2009; Odoemenen and Obinne, 2010; Kudi et al., 2011), we employ a Double-Hurdle model to deal with the two-stage decision process involved in improved agricultural technology adoption and assess the effect of access to information using the Heckman Probit selection model. In order to achieve the stated objectives of this study, we therefore tested the following hypotheses: The extent and determinants of ICVs do not depend on the farmers' socio-economic characteristics and access to information has no significant effect on the adoption of improved cassava varieties in South western Nigeria.

CONCEPTUAL, ANALYTICAL FRAMEWORK AND ESTIMATION TECHNIQUES

Modeling the intensity and determinants of improved cassava varieties adoption

Rogers and Shoemaker (1971) defined adoption as the decision to apply an innovation and to continue using it. According to Wale and Yallew (2007), farmers' decisions about adoption are either discrete (whether or not to take up the technology) or continuous (the intensity of use of the technology). The theory of utility maximization is generally used to explain farmers' responses to new technology (Adesina and Seidi, 1995; Adesina and Baldu-forson, 1995).

According to this theory, a farmer will adopt a given technology such as ICVs if the utility obtained from it exceeds that of the traditional varieties. For instance, if U_{i0} is the utility derived from

the use of the traditional cassava variety while U_{i1} is the expected utility from the adoption of ICVs; although not observed directly, the utility that farmer i will derive from adopting a given measure of the ICVs (j) can be expressed as:

$$U_{ij} = X_i \beta_j + \tau_{ij} \quad j = 1, 0; \quad i = 1, \dots, n \quad (1)$$

Where X_i is a farm-specific function, β_j is a parameter to be

estimated, τ_{ij} is a disturbance term with mean zero and constant variance. In addition, adoption of any agricultural technology may also be measured by both the timing and extent of utilization by individuals (Sunding and Zilberman, 2001). In this study, a farmer is defined as an adopter if he or she is found to be growing at least one ICV. This implies that an adopter could still be growing the traditional cassava varieties alongside the improved varieties. We defined the adoption variable as a dummy with 1 indicating adoption and 0 otherwise. A farmer would adopt an ICV, that is., $j=1$

if $U_{i1} > U_{i0}$.

The intensity of adoption is measured by the proportion of farmland devoted to the production of ICVs. The literature suggests several theoretical or conceptual models on farmers' decisions to adopt new technology (Feder and Slade, 1984; Abadi and Panned, 1999; Negatu and Parikh, 1999; Isham, 2002). Many of the numerous studies that assessed the determinants of adoption of improved agricultural technology have utilized the Logit, Probit, or Linear probability models.

The objective of this study goes beyond the determinants of adoption to analyze the intensity of ICV adoption in Nigeria. The Tobit model has been employed by many authors to assess the intensity of agricultural technology adoption (Adesina and Baldu-Forsan, 1995; Roos et al., 2000; Alene et al., 2000; Abadi-Ghadim et al., 2005; Jensen et al., 2007). One of the major drawbacks of the Tobit model is the fact that the decisions on whether or not to adopt ICVs and how much to adopt are assumed to be made jointly and hence the factors affecting the two decisions are assumed to be the same. However, it is believed that the adoption process is in two stages; the first stage involves the decision to adopt and the second stage involves the decision on the proportion of the area to be devoted to ICVs. Hence, the explanatory variables in the two stages may differ. Against this backdrop, the use of a single model may be erroneous, since the factors influencing the two-stage decisions will be difficult to analyze using just one model. In this study, we believe that it is likely the decisions on adoption and intensity of adoption of ICVs in southwestern Nigeria may not be made jointly, and the factors affecting each decision may not be the same. Thus we used the double-hurdle model proposed by Cragg (1971) in which the event of a farmer being a potential adopter and the intensity of adoption are treated separately. Furthermore, empirical results by both Moffatt (2003) and Martínez-Españeira (2006) reveal that the double-hurdle model gives results superior to those obtained from Tobit and P-Tobit models.

According to Cameron and Trivedi (2009), a double-hurdle model has the interpretation that it reflects a two-stage decision-making process, each part being a model of one decision. The two parts are functionally independent. The double-hurdle model is a parametric generalization of the Tobit model, in which two separate stochastic processes determine the decision to adopt and the level of adoption of the technology (Green, 2000; Martínez-Españeira, 2006). In addition, the double-hurdle model allows for the possibility of zero observations in both outcomes (Wooldridge, 2001; Cameron and Trivedi, 2005). The model has an adoption (D) equation presented below:

$$D_i = 1 \quad \text{if } D_i^* > 0, \text{ and } D_i = 0 \text{ otherwise} \quad (2)$$

$$D_i^* = \lambda Z_i + \pi_i$$

Where D_i^* is a latent variable that takes the value 1 if the farmer adopts ICVs and 0 otherwise, Z is a vector of household characteristics and λ is a vector of parameters. The level of adoption (Y) has an equation of the following:

$$Y_i = Y_i^* = \gamma' X_i + \tau_i \quad \text{if } Y_i^* > 0 \text{ and } D_i^* > 0, 0 \text{ otherwise} \quad (3)$$

Where: Y_i is the observed answer to the proportion of area planted with improved cassava varieties. X is a vector of the individual's characteristics and γ is a vector of parameters. The error terms,

π_i and τ_i are distributed as follows:

$$\left. \begin{aligned} \pi_i &\sim N(0,1) \\ \tau_i &\sim N(0,1) \end{aligned} \right\} \quad (4)$$

The log-likelihood function for the double-hurdle model is:

$$\text{LogL} = \sum_0 \ln \left[1 - \Phi(\lambda Z_i) \left(\frac{\gamma X_i}{\theta} \right) \right] + \sum \ln \left[\Phi(\lambda Z_i) \frac{1}{\theta} \phi \left(\frac{Y_i - \gamma X_i}{\theta} \right) \right] \quad (5)$$

The independent double hurdle model assumes that the two error terms from the two hurdles are normally distributed and uncorrelated. This suggests that the two stage ICVs adoption decision and the intensity of use/adoption are done independently by the farmers. Under the assumption of independency between the error terms π_i and τ_i the model as originally proposed by Cragg (1997) is equivalent to a combination of a truncated regression model and a univariate probit model.

The double-hurdle and the closely related two-part model have been used extensively to assess agricultural technologies adoption by Cooper and Keim (1996), Uri (1998), Teklewold et al. (2006), Shiferaw et al. (2008), Langyintuo and Mungoma (2008), Legese et al. (2009), Kassie et al. (2009), Gebregziabher and Holden (2011), Smith et al. (2011) and Alamerie et al. (2013) among many others. Empirically, the double model contains logit and Tobit model estimated as a single equation in STATA and the estimated equations are presented implicitly below:

$D = f(\text{age, age2, educ, hlab, ownland, extconta, gender, moccup, fasize, error term})$

$Y = f(\text{age, age2, educ, hlab, ownland, extconta, gender, moccup, fasize, error term})$

Where D and Y are the adoption status and the proportion of area devoted to ICVs production, respectively.

Access to information and adoption

Awareness or exposure to improved agricultural technologies through information either from the extension agents, mass media or mobile phone has been identified as one of the vital determinants of technology adoption (Diagne and Demont, 2007; Dongsop-Nguezet et al., 2011). In addition, information source have been reported as important stimulus to individuals in the adoption process (Rogers, 1995). Certainly, the adoption of ICVs is not likely to be possible if the farmers are not aware of or exposed to ICVs through access to information. Hence, the adoption of ICVs can be described as a two-stage process (Cragg, 1971).

The first involves obtaining all the available relevant information about ICVs and the second involves taking a critical decision whether to adopt ICVs or not. This leads to a sample selectivity problem, since only those who obtain information about the varieties are in a better position to adopt it, whereas it is mandatory to make an inference about ICV adoption among the rural population as a whole. Thus, we adopt Heckman Sample Selectivity model (Maddison, 2006). The Probit model for sample selection assumes that an underlying relationship exists between the independent (socio-economic and demographic characteristics of the farmers) and the dependent variables (access to information) (Deressa et al., 2008), the latent equation being given by:

$$y_j^* = x_j \alpha + \tau_{1j} \quad (6)$$

Such that we observed only the binary outcome given by the probit

Table 1. Description of the variables included in the analysis.

Variables	Description	Expected sign
Dependent variable		
Adoption status(binary)	1 if farmer adopt at least one ICV, 0 otherwise	
Proparea	The share of ICVs area to total farmland (%)	
Independent variables		
Age	Age of household head in years	-/+
Age2	Square of age of household head	-/+
Gender	Dummy (1=male)	-/+
Offinc	Off-farm income. Dummy (1=yes)	+
Educ	Years of formal education of household head (years)	+
Extconta	Contact with extension agents. Dummy (1=yes)	+
amtcredit	Total amount of credit obtained in Naira	+
Fasize	Total farmland cultivated (ha)	+
Reland	Rented land. Dummy (1=yes)	+
Patecheva	Participation in technology evaluation. Dummy (1=yes)	+
Moccup	Main occupation. Dummy (1= farming, 0 otherwise)	+
Ownland	Ownership of farmland . Dummy (1=yes)	+
Hlab	Hired labour. Dummy (1 if cost of hired labor is greater than mean of the group and 0 otherwise)	+/-

model as:

$$y_j^{probit} = (y_j^* > 0) \quad (7)$$

The dependent variable is observed only if j is observed in the selection equation

$$y_j^{select} = (w_j\phi + \tau_{2j} > 0) \quad (8)$$

$$\tau_1 \sim N(0,1)$$

$$\tau_2 \sim N(0,1)$$

$$Corr(\tau_1, \tau_2) = \rho$$

The selection equation is (6), while (8) is the outcome equation. Where: x is a k -vector regressor, w is a m vector of repressors.

τ_1 and τ_2 are the error terms. In cases where $\rho \neq 0$, standard probit techniques applied to Equation (6) will generate biased estimates. However, the Heckman Probit (heckprob) provides consistent, asymptotically efficient estimates for all parameters in such models (Statacorp, 2003).

Therefore, in this study, the Heckman Probit selection model is employed to analyze the effect of access to information on the adoption of ICVs in southwestern Nigeria. The first part of model is the probit model, estimating the determinants of access to information. In the second part, we estimate the determinants of adoption of ICVs with access to information as one of the explanatory variables. The description and definition of the variables used in the models are presented in Table 1.

Data and descriptive statistics

The study area is Southwestern Nigeria. The data for this study

originated from a survey conducted by IITA. Five (Ekiti, Osun, Ogun, Ondo and Oyo) out of the six States that comprise the Southwestern geopolitical zone were selected for the study. A three-stage stratified random sampling procedure was employed, whereby States were used as strata to improve sampling efficiency and account for possible major differences in the adoption of ICVs across States. Rural Local Government Areas (LGAs) were used as primary sampling units (PSUs). Enumeration areas (Eas), defined as a cluster of housing units, were used as secondary sampling units (SSUs) and households were the final sampling units.

LGAs were selected from each State based on probability proportional to size, where size is measured in terms of the number of Eas. The Eas that formed the sampling frame were obtained from the Nigerian Bureau of Statistics which uses the 2003/2004 master sampling frame of the National Integrated Survey of Households. The advantage of using Eas as sampling units is that each EA is approximately the same size. This ensured that all farmers had an equal probability of being selected. Within each LGA, four Eas were selected at random from a sampling frame classified as rural or semi-urban, giving a total of 80 Eas.

Finally, a list of households was developed for selected Eas and a sample of at least 10 farming households was selected randomly in each of the sampled Eas, giving a total of at least 841 households (Table 2). The survey was carried out over three months from August to October 2011. Community and household questionnaires were administered by trained enumerators with a senior agricultural economist in the field and the general supervision of IITA's economist. Data collection involved Focus Group Discussion (FGD), farmers' interviews, field observation of varieties, and plot area measurements.

Socio-economic characteristics of the respondents

The percentage distribution of adopters and non-adopters of ICVs by State (Table 3) shows that Ogun has the highest number of adopters (94%) followed by Osun (87%), Ondo (86%), Ekiti (81%)

Table 2. Distribution of the sampling households across the selected states.

Characteristics	State					
	Ekiti	Ogun	Ondo	Osun	Oyo	All
All enumeration areas (EAs)	11561	12754	19213	25910	31137	100575
All local government areas (LGAs)	16	20	18	30	33	117
Sample LGAs	2	3	4	5	6	20
Sample EAs or communities	8	12	16	20	24	80
Sample households	88	125	175	209	244	841

Source: IITA/DIIVA Adoption and Impact Survey (2011).

Table 3. Percentage distribution of adopters and non-adopters of ICVs by State.

State	Adopters (N=670)	Non-adopters (N=155)
	Percentage	Percentage
Ogun	94.35	5.65
Osun	87.44	12.56
Ondo	86.39	13.61
Ekiti	81.40	18.60
Oyo	65.27	34.73

Source: IITA/DIIVA Adoption and Impact Survey (2011).

and Oyo (65%). Table 4 shows the main socio-economic characteristics of the farmers by adoption status. As revealed by the t-test there is no significant difference between the adopters and non-adopters in age, total area of farmland cultivated, share of cassava in the farmland cultivated, and amount of credit obtained for cassava planting material and fertilizer. More importantly, there is no significant difference in the cost of planting material.

This shows that the average cost is the same for ICVs and traditional varieties and has a negative implication for the seed sector. However, the adopters and non-adopters of ICVs are statistically significantly different in the number of years of education, number of mobile phones, and cost of hired labor, herbicide, and fertilizer.

RESULTS AND DISCUSSION

Determinants and intensity of improved cassava varieties adoption

The result of the double-hurdle model is presented in Table 5. A positive significant coefficient in the first Hurdle-Logit model signifies that the corresponding regressor increases the probability of a positive observation in the adoption process. Similarly, in the second part, a positive coefficient means that, conditional on a positive count, the corresponding variable increases the value of the count (Cameron and Trivedi, 2009). The results of the first part of the model show that the log-likelihood of -77.83 and the LR χ^2 (10) 481.25

(significant at 1% level), imply that the model is fitted and the explanatory variables used in the model are collectively able to explain the extent and determinants of ICV adoption in southwestern Nigeria.

The results of the first part of the double-hurdle model are basically the Logit model of determinants of ICVs adoption and show that the coefficient of the gender of the household head is negative and statistically significant. This implies that adoption of ICVs is higher among female-headed than male-headed households. Labor is one of the main inputs in cassava production. Improved practices are labor intensive, hence availability (both hired and farm labor) is necessary for improved technology adoption. The coefficient of hired labor is positive and statistically significant. This shows that those farmers that have access to labor are more likely than not to adopt ICVs.

This finding is consistent with that of Hailu (2008) for the adoption of improved technologies for teff and wheat production in Ethiopia, Land is an important variable in agricultural production. The size of the land available for farming is usually a major factor in explaining technology adoption (Just and Zilberman, 1983). If farmers are land constrained, the probability of adoption would be very low. Owned farmland is more important than rented farmland in crop production. Hence, farmers producing crops on their own farmland are expected to have a higher probability of adopting ICVs. The result shows that

Table 4. Socio-economic/demographic characteristics of adopters and non-adopters.

Characteristics	Adopter (A) (N=670)	Non-adopter (NA) (N=155)	Mean difference (A-NA)	T-test statistics	P- value
Age (years)	50.00	49.00	0.82	0.56	0.57
Years of formal education	6.00	5.00	0.96	2.08**	0.04
Farmland (ha)					
Total farmland cultivated	3.16	2.85	0.31	0.72	0.47
Own land cultivated	2.43	2.34	0.08	0.19	0.85
Rented land cultivated	1.85	1.76	0.09	0.19	0.85
Sharecropped land cultivated	0.16	0.21	0.05	0.50	0.62
Cassava share of farm land cultivated (%)					
Cassava share of total farm land cultivated	64.55	63.61	0.94	0.38	0.70
Cassava share of owned land cultivated	46.45	47.98	1.53	0.39	0.69
Cassava share of rented land cultivated	38.29	39.59	1.29	0.28	0.78
Cassava share of sharecropped farm land cultivated	8.10	12.56	4.47	1.18	0.24
Household asset endowment					
Number of radios	2.00	2.00	0.04	0.39	0.09
Number of television sets	1.00	1.00	0.09	1.05	0.01
Number of mobile phones	2.00	1.00	0.23	3.59***	0.00
Access to credit					
Amount of credit borrowed for planting material	2113.32	2018.07	95.25	0.11	0.55
Amount of credit borrowed for fertilizer	1316.92	387.09	929.82	1.45	0.35
Estimated cost of cassava production (₦)					
Hired labor for land preparation	17918.06	22425.47	4507.41	1.66*	0.06
Hired labor for planting	6645.68	8202.02	1556.33	1.01	0.85
Hired labor for weeding	13346.46	15951.26	2604.79	1.48	0.82
Hired labor for harvesting	6526.78	6806.92	280.14	0.22	0.98
Cost of cassava planting material	6355.51	2473.08	3882.45	1.43	0.35
Cost of herbicide/pesticide	3328.91	2557.69	771.22	2.87***	0.002

*, **, *** implies significant at 10%, 5% and 1%, respectively, Source: IITA/DIIVA Adoption and Impact Survey (2011).

the coefficient of owned farmland is positive and statistically significant. This reveals that farmer-owners are more likely to adopt than those that practice farming on rented farmland.

The age of the household head, regarded as a primary variable in technology adoption, is negative and statistically significant thus indicating that younger farmers are more likely than older farmers to adopt ICVs (Rämö et al., 2009; Jensen et al., 2007). This is in line with the general literature on technology adoption and has been explained by the fact that older farmers are usually more reluctant to change. In addition, the young farmers are less risk-averse (Rogers, 1983; Alavalapati et al., 1995). This finding is similar to those of Jensen et al. (2007) and Rämö et al. (2009), but in contrast to the

findings of Teklewold et al. (2006) and Hailu (2008).

However, the positive coefficient of age-square reveals that age shows a quadratic pattern in the adoption of ICVs. This implies that the adoption of ICVs among the younger farmers would increase to a certain level and then start to decrease as age increases in line with the life cycle hypothesis. Access to credit and specifically the amount of credit obtained are very important in agricultural production as credit allows farmers to invest in new technology or acquire other productivity enhancing inputs such as agro-chemicals and fertilizer. Thus, the amount of credit obtained is expected to increase the probability of adoption. The result shows that the amount of credit obtained by the farmers significantly increases the adoption of ICVs in the study area.

Table 5. Determinants and intensity of adoption of improved cassava varieties: Double-hurdle.

Variables	First-Hurdle		Second-Hurdle	
	Coefficient	Std. Error	Coefficient	Std. Error
Amount of credit	0.000*	0.000	9.35E-07	1.36E-06
Age2	0.002**	0.001	-0.0001	8.44E-05
Age	-0.257**	0.116	0.005	0.009
Education	0.023	0.055	-0.005	0.006
Hired labor	1.009*	0.521	0.136*	0.055
Own farmland	8.943***	1.309	-0.309	0.376
Extension	0.023	0.47	-0.005	0.053
Gender	-3.187**	1.393	-0.024	0.079
Main occupation	0.652	0.691	-0.045	0.094
Total farmland	0.001	0.096	-0.069***	0.011
Constant	2.446	3.008	4.539	0.461
LR Chi2(10)	481.25***		46.96***	
Pseudo R2	0.76		0.012	
Log likelihood	-77.83		2009.5594	
Inalpha			-1.33	0.076
Alpha			0.264	0.019

***, **, and *, implies significant at 1, 5, and 10% respectively, Source: IITA/DIIVA Adoption and Impact Survey (2011).

This implies that adoption would increase as farmers gained more access to credits related to agricultural production. A significant positive effect of access to credit on the adoption of improved maize varieties was reported by Feleke and Zegeye (2006) and Paudel and Matsuoka (2008). Similar effects on the adoption of fish enterprises were observed by Matiya et al. (2005). In the same vein Beshir et al. (2012) also obtain a positive effect of credit on determinants of chemical fertilizer technology adoption in North eastern highlands of Ethiopia. Beke (2011) found that the coefficient for predicted probability of being credit constrained has a negative and significant effect on the adoption and use intensity of improved rice varieties in Ivory Coast. This suggests that credit constraints tend to reduce the adoption of improved agricultural technologies. The implication is that farmers should also be granted access to adequate credit to achieve increased adoption of ICVs.

The result of the second part of the double-hurdle shows that the coefficient of hired labor has a positive and significant effect on the probability of increasing the proportion of total farmland devoted to cassava production in the study area. However, a negative and significant coefficient was observed for total farmland. This could be due to the fact that as the area of available farmland increases, there is a tendency for the farmers to go into multiple cropping, thereby reducing the land for cassava production. This is in agreement with the findings of Roos et al. (2000), Villami et al. (2008), Breen et al. (2009) and Rämö et al. (2009) on perennial energy crop adoption, but contrary to the findings of Doss and

Morris (2001) for the adoption of inorganic fertilizer.

The effect of information on adoption of ICVs

Information is an essential component of agricultural technologies adoption. A farmer that is not aware of the existence of ICVs will not be likely to adopt. In this paper we empirically examine the effect of access to information on the adoption of ICVs in Nigeria using the Heckman Probit Selection model. To justify the use of this model we evaluate its appropriateness over the standard probit model by examining the presence of any sample selection. This is done by checking if there is any correlation between the error terms of the outcome (regression) and selection (Probit) models. The result shows that the rho is significantly different from zero (Wald $\chi^2=24.66$, with $\rho=0.003$), thus justifying the use of this model to assess the effect of information on ICV adoption in the study area.

The results of the Heckman Probit selection model are presented in Table 6. The first stage is referred to as the selection model and takes into account whether or not the farmer has access to information about ICVs. The second stage, known as the outcome model, examines whether the farmer adopted any ICV, conditional on whether any information was obtained about the ICV. The dependent variable of the first stage model (access to information) is specified as binary, which is equal to one if the farmer has access to information about the ICVs and

Table 6. The results of the heckman probit selection model.

Variables	Selection model		Outcome equation	
	Coefficient	Std. Err.	Coefficient	Std. Err.
Age	-0.016***	0.004	0.013**	0.006
Gender	0.333**	0.161	-0.257	0.243
Years of formal education	0.067***	0.015	0.025	0.018
Rented farmland	-0.287*	0.147	0.531*	0.317
Own farmland	-0.034	0.158	0.045	0.157
Off-farm income	0.577**	0.233	-0.308**	0.156
Participate in technology evaluation	0.219	0.231	0.241	0.172
Hired labor	0.600***	0.124	0.353	0.236
Contact with extension agents	0.072	0.180	-0.036	0.175
Constant	0.617	0.405	-0.094	0.555
Wald(X^2)	24.66***	$\rho = 0.003$		

***, **, and *, implies significant at 1, 5, and 10% respectively, Source: International Institute of Tropical Agriculture (IITA)/DIIVA Adoption and Impact Survey (2011).

0 otherwise. The dependent variable of the adoption model is also binary, equal to one and if the farmer planted at least one ICV and 0 otherwise. The results of the first stage show that the factors that tend to significantly affect farmers' access to information are age, gender, years of formal education, rented farmland, and off-farm income. The coefficients of gender, education, off-farm income, and hired-labor variables are positive and statistically significant. Since, gender is one if the household head is male and 0 otherwise.

Therefore, the positive significance of gender implies that the male-headed households have a higher probability of having access to information than female-headed households. The significance of education at 1% suggests that education is a very important determinant of access to information. The implication is that the educated household head, the primary decision-maker, is more capable of obtaining and assimilating information about the advantages of the adoption of an ICV and the negative effects that could result from not adopting it. Participation in off-farm activities could further predispose the farmers to getting access to information.

The coefficients of age and rented farmland are both negative and statistically significant in determining farmers' access to information. This implies that younger farmers are more likely than older farmers to have access to information. Those farmers that operate on rented farmland are likely to experience limited access to information. The result of the outcome model reveals that the adoption of ICVs based on access to information is positively and significantly determined by the age of the household head and use of rented farmland; off-farm income has a negative and statistically significant effect on the decision of farmers to adopt ICVs in the study area.

SUMMARY, CONCLUSION AND POLICY RECOMMENDATIONS

The collaboration between IITA and its partners has resulted into the development of ICVs and their subsequent dissemination to farmers in Nigeria. This study provides empirical information concerning the factors that determine the adoption of ICVs and the intensity of adoption in southwestern Nigeria, using sub-nationally representative data collected by IITA from about eight hundred and forty one households for the study.

The results of the Double-Hurdle model reveal that the adoption of ICVs is higher among female-headed than male-headed households. Those farmers that have access to labor are more likely to adopt ICVs than those who are labor-constrained. In addition, farmers that own their farmland are more likely to adopt than those that practice farming on rented farmland. Younger farmers are more likely than older farmers to adopt ICVs. Access to credit increases ICV adoption tremendously and access to abundant hired labor is important in the study area. As the area of available farmland increases, there is a tendency for the farmers to go into multiple cropping, thereby reducing the area for cassava production. This suggests that an increase in area could have the tendency to encourage multiple cropping and thus reduce the intensity of ICV adoption.

The Heckman Probit selection model is employed to analyze the two-stage process of access to information and adoption of ICVs-having access to information, which creates awareness about the ICVs, in the first stage and then in the second stage adopting the IVCs, based on the information about the attributes and benefits inherent in adoption. The results further indicate that age of the

household head, gender, education, and off-farm income are the variables that are positive and statistically significant in determining access to information on ICV adoption. Factors determining adoption are age, rented farmland, and off-farm income.

Finally, this study has been able to empirically establish that cassava farmers in southwestern Nigeria are capable of intensively adopting ICVs if they have access to credit and hired labor, and own their farmland. Therefore, we recommend that access to credit should be improved and the present land tenure system in the rural areas should be re-examined to ensure that farmers have adequate access to land for agricultural production.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

An economic viability assessment of sisal production and processing in Limpopo: A stochastic budgeting analysis

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Creating sustainable jobs in the agricultural sector is an important aspect of rural development. Agriculture is often viewed as a *sine qua non* for rural development, because it provides the necessary economic stimulus for rural households to participate in productive economic activities. Yet, identifying viable agricultural projects that have the potential to create jobs in rural areas has continued to overwhelm policymakers. In this paper, the economic feasibility of sisal production and processing in Limpopo province is analysed. The study was motivated by the sisal crop's proven abilities to create many jobs and the growing appeal that natural fibres are currently receiving globally. Using both a deterministic and stochastic budget, this paper shows that sisal production and processing could be a viable investment in Limpopo. However, given the high costs of labour, investors are cautioned to look for community partnerships in order to spread the economic costs and benefits of sisal production and processing in Limpopo.

Key words: Sisal production, processing, stochastic, GRKS, simetar.

INTRODUCTION

Given increased job losses in the agricultural sector of South Africa (BFAP, 2012), there is a need to invest in labour intensive agricultural projects. It is envisaged that the identification and establishment of labour intensive agricultural enterprises could help redress the high unemployment levels in the rural economy. This is particularly so when considering that whilst commercial agriculture continues to employ a significant number of rural people; over the past 20 years, areas known for

intensive farming have moved away from permanent workers to seasonal workers (BFAP, 2012). Similarly, "many people who used to live and work on farms no longer do so, principally as a result of the uncertain investment climate created by speculation around property rights" (BFAP, 2012). As well, "the application of labour legislation to agriculture has provided the motivation for farmers to increasingly use the services of labour brokers in an attempt to avoid the hassle factor

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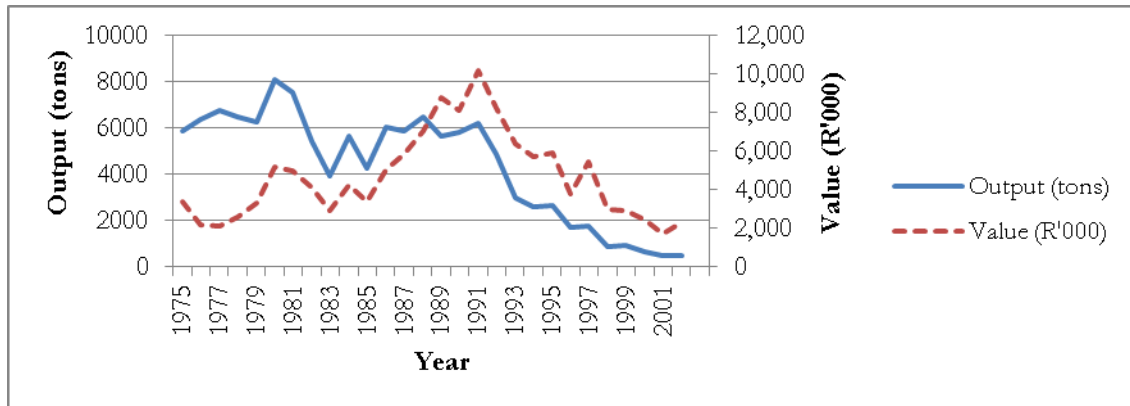


Figure 1. Production and sale of sisal in South Africa. Generated using data from the Department of Agriculture, Fisheries and Forestry (DAFF).

that comes with employing large numbers of workers for short periods of time” (BFAP, 2012).

This suggests that in trying to address the unemployment challenge in the rural sector, potential investments in agriculture ought to guard against the growing trend of farm workers being “exploit[ed] by unscrupulous employers ...[especially] labour brokers” (BFAP, 2012). Likewise, such investments should be directed to the households in the affected communities if their true value is to be realised. Especially, there is a case to base the notion that for agricultural investments to have the desired job creation impacts, they may have to be focussed on the communities where the effects of unemployment and lack of sources of livelihoods are largely felt.

One project that has gained substantial consideration and possesses the ability to employ large numbers of people is sisal (*Agave sisalana*) production. Formally set up in the 1930s, sisal production is not new in South Africa, let alone in Limpopo. It gradually grew from less than 1000ha in 1950 to peak at 44000 ha in 1965 (Henderson, 1994). At its peak, Henderson (2012) reports that over 4000 people were employed by the sisal industry. Its growth was in part motivated by focussed government support and a vibrant local sisal market. The then Department of Agriculture and Forestry played a pivotal role, providing sisal growers with start – up resources, including technical assistance and guaranteed market access.

During the South African sisal production boom in the mid 1970s to early 1980s, local consumption varied considerably and was closely linked to the local economic situation much more than to what was happening abroad. Typically local demand was in the region of 4000 tons per annum with a potential supply of over 5000 tons per annum, which left an excess that was sold via export markets. By 1989, sisal produced locally was being exported to 11 countries by the National Sisal Marketing Company (NSMC) (Henderson, 1994).

This saw the export of about 1500 tons of sisal per year. Available data shows that sisal production grew from 5900 tons per annum in 1975 and peaked at 8107 tons per annum in 1980 (Henderson, 2012). However, since then, due to growth in synthetic based fibres, the production of sisal decreased significantly in South Africa. For example, between 1980 and 2002, production decreased by over 16 folds to hit a production low of 522 tons, as shown in Figure 1. Similarly, gross sisal income increased from 1975 to reach a peak of R10 million in 1991 and thereafter decreased to reach a low R1.7 million in 2001.

In Limpopo, sisal production was started at Malamulele village in the Vhembe district with support from the Department of Trade and Industry (DTI) in 2005 to 2006, to revitalise the now defunct sisal industry in South Africa. The DTI also made an initial investment of R25 million towards the establishment of a sisal processing plant. The project area consists of 212 ha of communal land of the Madonsi and Xigamani Traditional Authorities, and is known as the Khindimuka sisal project. However, owing to limited support and maladministration, the project was only functional for a very limited period where after it was closed down.

Currently, available data (see for example Henderson, 2012) suggests that, in South Africa, there is no production of sisal. This is notwithstanding a lucrative local market (Bruce Sunderland, 2012 pers. comm.). For example, South Africa imports sisal on an annual basis from as far as Tanzania, which further confirms the existence of a local market that needs rekindling with locally produced sisal. Resuscitating an almost non-functional sisal plantation and processing plant could be risky. A need to conduct an economic viability assessment of the Khindimuka sisal production and processing project in Limpopo province becomes essential to form opinions on whether or not to continue investing on the project. Such an analysis is important because once set up, it becomes impossible to reverse

the investment. In South Africa, added to the above concerns are labour laws which make the cost of labour to be higher than in most countries in southern Africa. Likewise, failure of rural households to internalise sisal production may have serious ramifications on the viability of maintaining the existing sisal processing plant. There are also higher production and marketing uncertainties that derive from output and price variation uncertainties and rising production costs. This implies downside risks which need to be considered in any economic viability assessment and especially before large amounts of resources are channelled into the project.

This paper presents the results of a stochastic budgeting model for a 212 ha sisal farm and processing plant in Limpopo. It is outlined as follows: First is a summary of the economic benefits of the sisal plant. Next is a description of the methods that were used to conduct the economic analysis, followed by presentation of the results or findings and then conclusion.

ECONOMIC VALUE OF SISAL

Sisal can be used for a variety of industrial products, ranging from heavy industrial uses such as composite material for the automotive industry and reinforcement in the construction industry to paper, newsprint, and telephone cable paper. It can be used to produce wood free thinning paper or Bible paper and floor coverings. As well, sisal can be used for domestic purposes such as household fuel and building materials. In the United Kingdom, sisal floor coverings have gained considerable consumer preference because of sisal's stain resisting abilities (Morley, 2011). In addition, current research shows that sisal has a potential to be used for pharmaceutical purposes (e.g. *Sisalana Americana*); in the production of cattle feed, decorative panels, hand bags and fashion accessories for women, as well as geotextiles. Sisal is a plant with remarkable qualities that allows it to survive harsh arid conditions. The plant is productive for roughly 6 to 9 years, in a 12 year growing cycle (Henderson, 2012). Usually, the first leaves are harvested 3 to 4 years after establishment. During its lifetime a plant produces 200 to 250 leaves and can weigh up to 135 kg. In fertile areas, Henderson (2012) reports that up to 8 tons of sisal fibre can be produced per plant per hectare. This could drop to 4 tons per hectare in less fertile and drier areas. Generally, the plant can survive with 1000mm of water per year. However, in South Africa, sisal has successfully been planted in areas with substantially lower rainfall (250 to 375 mm) per annum. Sisal prefers dry, permeable soils especially calcareous soils with an approximately neutral soil reaction (Dannhauser, 1999). With climate change and its superseding factor unreliable rainfall making it increasingly difficult to produce some commercial crops in many semi-arid parts of Limpopo (Maponya and Mpandeli, 2013), sisal could be a viable replacement

cash crop.

Sisal production in Limpopo

The decline in, or collapse of, sisal production in South Africa has two implications. First, it suggests that nearly all the sisal used locally is imported. Secondly and given the high labour intensiveness of sisal production and processing, there is a case to argue that resuscitating sisal production locally could stimulate the establishment of new sisal plantations which could add significantly to job creation especially in the rural areas. This is truer in Limpopo where a comprehensive study by D'Haese et al. (2011) has suggests that 52% of the people in Limpopo's rural areas are severely food insecure, whilst 46% of households in the area are most likely to experience a hunger spell during the year. It is thus not farfetched to anticipate that the resurrection of sisal production could be a game changer for the rural economy in some parts of the Limpopo Province, especially in Malamulele where remnants sisal plants, in old sisal plantations, are still productive today. Industry experts and buyers of locally produced sisal have noted that the Malamulele project produces good sisal, in spite of the fact that the plantations are no longer being maintained.

With enough investments geared towards the resuscitation of these fields and the factory that was used for processing, it is not implausible to anticipate that these plantations could provide the much needed economic stimulus required for the creation of jobs especially in the hot and somewhat dry areas of the province where employment, probably because there is little economic activity taking place, is very scarce. In addition, and given that sisal has vast industrial and domestic uses, focussed investments in sisal production could lead to the development of additional sisal intensive industries which could help boost economic growth in the province. As well, given the sisal plant's special qualities to grow in water stressed areas, sisal could act as an ideal cash crop for rural households to produce, where other crops have failed, thus earning them some income. Lastly, sisal could be used to develop a green niche market in South Africa especially in the light of rising costs of producing synthetic fibres. Yet for all this to happen, sisal production must make business sense, which is explored next in this paper.

MATERIALS AND PROCEDURES

To conduct the analysis, the study used information gathered from different sources. Primary data was collected through structured interviews with stakeholders involved in the project. Secondary data was gathered from the Department of Agriculture, Fisheries and Forestry (DAFF). The opinions of experts on sisal production and marketing in South Africa were also solicited and captured. Other forms of data were collected from some of the firms that process

sisal in South Africa as well as in existing literature. In order to programme the financial feasibility analysis model, the following assumptions were made:

Land: Using currently existing old sisal lands, it was assumed that 212 ha of old sisal land will be used for the project. This is made up of 30 ha in Boltman and 182 ha in Xigamani. These two production areas make up the Malamulele Sisal Project, which owns a sisal processing plant on land that belongs to traditional authorities. The community has been granted a 'permission to occupy' leasehold, so land was assumed to be 'free'.

Field layout: Because the project is being introduced on old sisal producing lands, the layout of the field was assumed to go to stay the same, that is, it will follow the current layout of the fields, where recommended planting patterns were a series of double rows 60 cm apart with a 2.5 m alley between a pair of rows.

Plant spacing and population: Plant spacing is at 75 cm, which gave 25000 plants per hectare. In the primary nursery, plant spacing was assumed to be 10 by 10 cm which yields 986, 300 plants per ha. In the secondary nursery, a 25 by 50 cm spacing pattern was assumed.

Current factory: The current processing facility was established in 2005 to 2006 through an investment from the DTI and was assumed to be producing 250 kg of twine per hour or 30 tons of twine in a five day working week, in a single 8 hr shift.

Sisal yield: It was assumed that a plant produces 100 to 135 kg of leaves and the lifespan of a plant was put at between 6 to 9 years. Moreover, this period could be longer by at least a few years.

Wage rate: A wage rate of R80/day was used, rather than the recently approved minimum wage of R105/day; a scenario where the minimum wage of R105/day is used was also explored.

Fertilisation: Ureum, lime-ammonium nitrate (LAN), and superphosphate are some of the chemical nutrients that are used for sisal fertilisation. The price for ureum and LAN was R14.10/kg and R17.50/kg, respectively.

Decortication: Decortication costs using a 6-door decorticator were computed to be R386.86/ton.

Species: *Agave sisalana*.

Key products: Sisal fibre harvested from old sisal lands was assumed to be the main product being produced by the two communities, which is then processed by the factory into twine. The twine is further processed into ropes and additional fibre products.

Harvesting and transportation costs: The cost for harvesting and transporting sisal from the fields to the factory were found to be R0.604/kg.

Other costs were also added in the financial model. The financial feasibility analysis used annual time steps and a planning horizon of 12 years based on a discounted cash flow design. To programme the model, the cash flow consisted of investment inputs, variable inputs and returns values. Following on Richardson and Mapp (1976) and Barry et al., (2000), the net present value (NPV), internal rate of return (IRR) and break-even year were used as key output variables (KOVs) in the model. A discount rate of 8% was assumed based on the minimum acceptable return that an investment of this magnitude would fetch¹ in South Africa.

The study used deterministic and stochastic budgeting procedures. Because deterministic budgets use point estimates, they are unable to give direction on the probability of success of an investment and management decisions on the farm (Lien, 2003). The stochastic budgeting procedure, on the other hand, allows the decision maker (DM) to assess the probability of failure or success of an enterprise before committing resources to a project. Since in reality, outcomes always change, the stochastic budget helps in obviating some of the shortcomings of the deterministic budget, by accounting for uncertainties and providing distributions of outcomes (Richardson et al., 2000). The stochastic budgeting model was programmed in Excel® and simulated using Simetar® through a three step process. In the first step, the probability distributions affected by sources of risk, namely price and output, were assigned to the model. In the second step, the resultant stochastic values were sampled from the probability distributions and used in a set of accounting equations to calculate production, receipts, and the KOVs. Lastly, the stochastic budgeting model was simulated using the random values for the risky variables. Drawing from Hardaker et al. (2004) the model used price and yield because they were assumed to have the biggest effect on the level of risk related with a certain outcome in the sisal enterprise.

Sisal output

Given that sisal production has long been abandoned in South Africa, it was impossible to get historical data to empirically determine the distribution functions of output and prices. Using expert opinion, sisal output was model based on the total amount of old sisal land available which is 212 ha. For the purpose of the analysis, sisal production was assumed to reach peak production in year six. A uniform distribution was used for the output values in the production areas. In a uniform distribution, the likelihood of occurrence is the same for all possible outcomes, such that the population of a continuous uniform distribution is defined by a minimum and a maximum value (Evans and Huntley, 2011). In order to specify the uniform distribution, the study used (Evans and Huntley, 2011):

$$U_i(a, b) \quad (1)$$

where U_i denotes a uniform distribution in year i and a and b are the minimum and maximum yield values per ha, respectively. In year 1 to 4, only sisal from the already existing sisal was used, whereas from year 5 onwards, sisal from newly planted fields in the old sisal plantations was used. For that reason, output in year 1 to 4 was assumed to vary from a minimum of 0.7 tons/ha to a maximum of 0.9 ton/ha, whereas from year 5 to 13 it was assumed to vary between 1.1 ton/ha to 1.7 ton/ha. The minimum, middle and maximum sisal output of 0.7, 0.9 and 1.7/ha were used to generate the stochastic sisal output variable after taking into consideration the impacts of weather and farm management practices on possible yield.

Prices

The price was assumed to follow a GRKS distribution. Richardson (2012) defines a GRKS distribution as a "non-parametric distribution which allows the random variable to fall outside the minimum and maximum values" (Richardson, 2012). To obtain the GRKS distribution, minimum, middle, and maximum price values were defined. Furthermore, "pseudo minimum and maximum values [were] added so the stochastic value can extend beyond the min and max by about 2.25%" (Richardson, 2012).

¹ This is given that in 2012 the South African Government's 10 year Treasury bond was 7.8%.

Considering that the price of sisal varies based on the grade, an all grade average was used after extensive consultations with industry experts who have imported sisal into South Africa. The minimum, middle and maximum sisal prices of R4800, R6400 and R8000/ton were, respectively used to generate the stochastic sisal price variable after taking into consideration the impacts that increased production of sisal could have on local prices. The fitted price distribution was then obtained using the GRKS menu on Simetar®. This was then followed by constructing a cumulative distribution function (CDF) chart for the price.

Cost of labour and other costs

Labour costs were increased by about 10%, whilst other costs were assumed to increase by 8%, per year. The reason for increasing labour at a higher rate than other costs was informed by recent policy changes in South Africa which have led to an increase of the agricultural minimum wage rate by over 30%. So much that this has become a matter of serious concern, the cost of labour in South African agriculture is becoming a very critical factor in farm profitability. For that reason, and considering the fact that the primary motivation of establishing a sisal plantation and factory is to use sisal production to stimulate job creation, in quantifying the most progressive wage rate for the project, different daily wage rates were used to compute the minimum wage price for farmworkers and in the processing plant.

It should be kept in mind that the focus was on making an informed decision on the wage price that would make the project feasible. To arrive at such a decision, a uniform distribution of labour was used. A minimum, middle and maximum of R70, R75, and R80/day was therefore used. Keeping in mind that currently, there is no economic activity on the old sisal farms, the focus of the analysis was to develop the minimum acceptable wage rate that would make the project worthwhile to investors whilst meeting the short term need to create jobs. This is because of a provision that make it possible for agribusinesses which are struggling and have provided evidence to that effect to be exempted from paying the minimum wage, up until a time that they are financially liquid.

The stochastic budget results were then compared to the results of the deterministic budget.

RESULTS

Table 1 presents the results of the financial feasibility analysis. The net present value (NPV) is above zero on both analyses, suggesting that the Malamulele sisal project could be a financially viable investment over the 12 year planning horizon, under the assumptions of this study. For the deterministic budget, the NPV was found to be R20.352m whereas for the stochastic budget it was calculated at R2.573m with a standard deviation of R5.911m - signifying that the viability of the project will possibly be influenced by output and price variability. The minimum and maximum values for the stochastic NPV are R16.664m and R21.646m, respectively. Figure 2 shows the results of the cumulative distribution function (CDF) for the NPV in the stochastic analysis.

The CDF demonstrates a 33.4% chance that the NPV will be below zero at any time during the planning horizon. There is a 90% chance that the NPV will be less than R10m, whereas the probability that the NPV will be less than R5m is 66.6%, as shown in Figure 2. Increasing

the area planted to sisal led to an increase of the deterministic and stochastic NPVs to about R47 and R22m, respectively whereas increasing the costs of variable inputs in the deterministic budget by 10% led to a decrease in the deterministic NPV from R20.352m to R7.565m suggesting that the project is sensitive to the costs of adjustable inputs.

Likewise, when either the yield or price was increased by 10%, the deterministic internal rate of return (IRR) decreased from 22.2 to 18 and 18.4%, respectively suggesting that increased output could depress prices or that increased prices could stimulate increased production which would in turn negatively affect prices in the long term. The IRR was calculated at 22.2% for the deterministic budget, whilst the results of the stochastic budget gave an IRR of 16.16% as shown in Table 1 and Figure 3. This further confirms that the project is financially viable and profitable. Even though the IRR is generally positive and above 15% which is often considered by financial analysts to mean that a project is substantially viable when stochastic prices and yields were used, the IRR decreased by 6.2%.

Sensitivity analysis

To conduct sensitivity analysis of the discount rate of 8% that was used in the model, discount rates of 5 and 15%, respectively were also verified. Using a discount factor of 5%, the deterministic NPV increased from R20.352m to R26.280m whereas the stochastic NPV increased from R2.573m to R3.474m. A 15% discount rate led to a decrease in the NPVs of both models, as shown in Table 1. Regardless, in both (5 and 15%) scenarios, the NPVs were positive. However, using a threshold analysis, the results show that an increase of 75 and 60% in either yield or prices would, respectively cause the deterministic NPV and the stochastic NPV to be below zero or unprofitable.

When the land under operation was increased from 212 to 1000 ha, the IRR increased from 22.2 to 36.1% for the deterministic budget and from 16.16 to 33.92% for the stochastic budget, suggesting that the project could be more viable if the amount of land under production were to be increased to at least 1000 ha.

DISCUSSION

The main aim of this paper was to investigate the viability of sisal production and processing in Limpopo, with the view of creating jobs that are expected to address the high unemployment challenge in the area. The results reveal that a total of 92 jobs would be created using the findings of the deterministic budget. The stochastic budget gave a total of 90 jobs, with a minimum and maximum of 82 and 97 jobs, respectively, and a standard deviation of 3 jobs.

Table 1. A contrast of viability indicators concerned with establishing and operating a 212 ha sisal farm and processing firm in Limpopo Province, South Africa.

Items ^a	Deterministic	Stochastic
Main assumptions		
Enterprise Scale (ha)	212	212
Initial investment ('000R)	2,708.00	2,708.00
Total decortication costs / month ('000R)	326.22	405.75
Average input costs(R / ha)	982.27	892.02
Average expected price ('000 R/ton)	6.40	5.60
Average marketable fibre yield (tons/ha)		
Year 1 – 4	0.5	0.56
Year 5 – 12	1.5	0.83
Cash flow analysis		
NPV ('000 R)	20,352.40	2,573.13
MIN	-	-16,663.46
MAX	-	21,646.00
IRR (%)	22.20	16.16
MIN	-	-3.83
MAX	-	30.45
Sensitivity (scenario) analysis		
NPV (R'000)		
at 5%	26,280.33	3,474.71
at 15%	12,442.49	959.73
IRR if		
Yield or prices decreased by 10% (%)	18.00	16.00
Variable inputs costs increased by 10% (%)	18.34	16.00
Land were to increase to 1000 ha (%)	36.10	33.92
NPV if		
Land were to be 1000 ha (R'000)	47,448.73	22,659.49
Land were to be 1000 ha and variable costs were to increase by 10% ('000 R)	7,565.84	68.28
Threshold analysis		
Investment becomes unprofitable if:		
Yield or prices decreased by (%)	75	60
Break-even year	7	8
Total number of jobs	92	90

^aEnterprise scale refers to the size of the sisal farm in ha; initial investment is the amount of money essential to start the farming business. It comprises the costs of capital equipment; as well as all possible values a random variable can take (Barry et al., 2010); NPV is a risk free assessment of the profitability of an enterprise. A negative NPV means the investment is unprofitable whereas an NPV above zero denotes a financially viable business (Richardson and Mapp, 1976). The higher the NPV, the more likely the business will be profitable; payback period, is the time period it will take for the accumulated receipts to cover completely the initial investment (Barry et al., 2010). A shorter period is preferred to a longer period.

Most of the jobs were assumed to come from the processing facility, whilst most of the sisal was assumed to come from Boltman and Xigamani. This suggests that for the project to be successful, interested investors may have to consider using community based sisal out-grower schemes over and above the current sisal producing areas to increase production whilst spreading the

economic costs and benefits of sisal in the communities. The out-grower schemes may also be beneficial in wage related repercussions of the project².

Using sensitivity analysis, the study considered what

²In South Africa, the minimum wage in agriculture increased from R76/day in 2012 to R105/day in 2013.

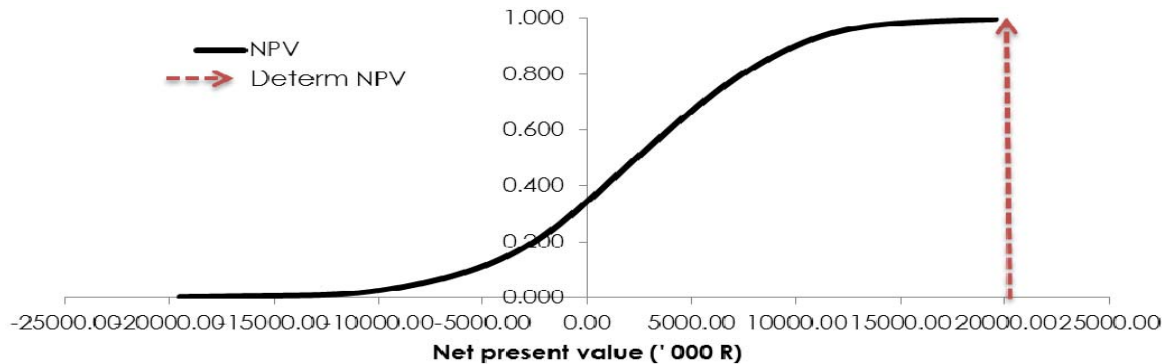


Figure 2. A cumulative Distribution Function (CDF) of NPV of a 212 ha and sisal processing unit in Limpopo Province. The CDF shows that there is a 33.4% chance that the stochastic budget NPV would be less than zero. The NPV from the deterministic budget is about R 20m, which is shown by the red-dotted arrow line.

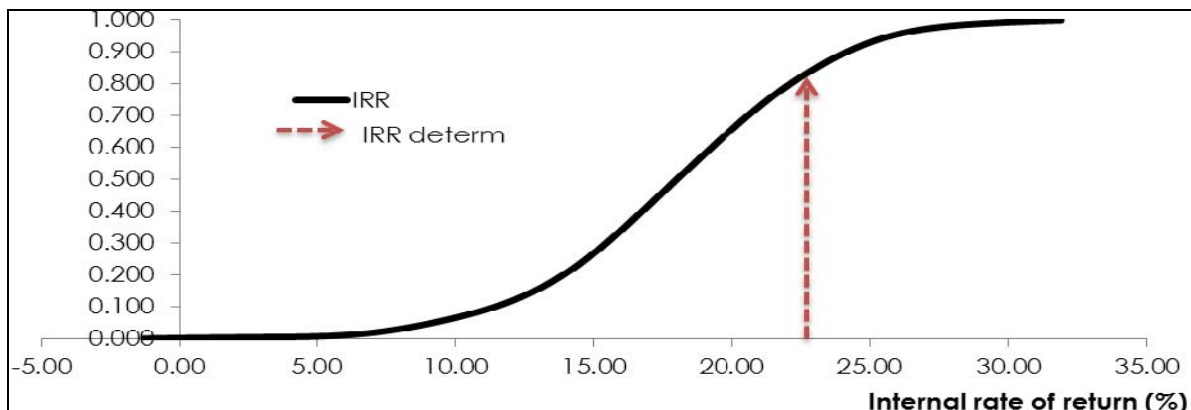


Figure 3. A Cumulative Distribution Function (CDF) of IRR of establishing a 212 ha sisal farm and sisal processing unit in Limpopo Province of South Africa. The brown dotted arrow line shows the determinist budget IRR. The probability that the IRR would be less than zero is 0.3%. There is a 0.5 or 50% chance that the IRR would be equal to 17.5%.

would happen to the project if an increase in the price of labour of 31.25% were to be effected. Shocking the wage rate by 31.25% to the current government gazetted wage rate of R105/day, the project collapses. The IRR as well as the NPV became negative. The jobs became negative. However, a wage increase of below 16% per annum was found to be benevolent on the viability and job creation aspect of the project. When the daily wage rate is decreased by 50%, for example, the NPV of the project increases. The probability that it will be negative decreases to 3.55% (from 33.4%), whilst the IRR improves to 34%.

This suggests that sisal is ideal in areas where the opportunity cost of land and labour is low, which generally excludes a high wage environment. In trying to make sisal production have the desired impacts of creating jobs, it might be helpful for interested investors to introduce the community into the project at its early stages. Continued increases in the cost of labour will have a negative effect

on the probability of success of the project. One way of accomplishing this is through community out-grower schemes, where groups of farmers are organised into sisal farmers' cooperatives to supply the main factory. This could help reduce the cost of labour by using the households as key growers and suppliers of sisal to the processing plant.

The model assumed that there was a consistent demand for sisal as documented from the opinion of experts in the industry who cited the annual imports of sisal into South Africa, as an example. If that is the case, capturing and maintaining a growing market share coupled with supply consistency will be crucial for project viability as well.

Secondly, we advise that for the project to be successful; it requires that workers are made owners of the project. This could be achieved by creating a business model that allows the workers to have ownership in the project so as to participate in profit sharing.

Conclusions

The purpose of this paper was to evaluate the feasibility of sisal production in Limpopo province of South Africa, using a stochastic budgeting analysis of a 212 ha sisal farm and processing facility. The Malamulele Sisal project is an initiative of the local community. It is supported by the DTI and is managed as a cooperative that is owned directly by the beneficiaries and indirectly by the local community. Apart from accessible land, the project has one major asset; a sisal processing factory with a value in excess of R25 million. This factory includes a decorticating unit and a mill able to produce 30 tons of twine per month, or 250 kg per hour during a shift of 8 h. The results suggest that sisal production in Limpopo could be a viable investment project. Especially, the financial simulation model shows that 90 jobs could be created via the processing of sisal. Moreover, it was found that if included from the onset farmers could benefit enormously from sisal production. It should, however, be noted that establishing a sisal production and processing unit is a significant investment, especially since harvesting can only commence in the third year. Investors are cautioned to look for ways to manage and reduce the costs of labour, establishment costs, processing equipment and energy in the form of electricity and fuel (diesel) for establishment, maintenance and processing, to get the best out of the project.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Full Length Research Paper

Adoption of drought-tolerant rice in Thailand: Participatory varietal selection and implications for breeding programs

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Rice production in Northeast Thailand has been suffering because of drought and limited irrigation. In this area, glutinous rice is generally produced for household consumption. The new drought-tolerant glutinous rice, RD12, developed to target drought-prone area in Northeast Thailand, was approved by the Rice Department in 2007. The breeding of this new variety has incorporated farmers' participation to identify preferred traits. This study aims to determine key factors contributing to the adoption of RD12 by focusing on farmers' preference for traits subjectively selected from the farmer participatory varietal selection (PVS) program. Key findings are that farmers who are exposed to more late-season drought because their fields are at higher elevations are more likely to adopt drought-tolerant varieties despite their preference for other better tasting varieties. Also, those who prefer the cooking characteristics of RD12 are more likely to adopt it, instead of the existing drought-tolerant variety. These two characteristics are significant for the adoption of RD12 and were identified as a result of PVS. This suggests that PVS is essential in the breeding program to promote new and appropriate technology to farmers.

Key words: Rice, drought tolerant, Thailand, adoption, participatory varietal selection, participatory breeding.

INTRODUCTION

Thailand is the sixth largest rice producer after China, India, Indonesia, Bangladesh, and Vietnam, and since the 1980s has been the largest exporter in the world market - until 2012 when it was surpassed by Vietnam and India. In spite of this, rice productivity in Thailand is the second lowest in Asia after Myanmar (International

Rice Research Institute, 2010). Insufficient water is one important reason for Thailand's low productivity, particularly in the Northeast which produces more than 40% of total rice production in the country and where more than 60% of the total area cultivated is in rice (Office of Agricultural Economics of Thailand, 2011).

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Northeast Thailand has the largest share of agricultural land and the largest number of farms. Due to salinity, low soil fertility and inadequate water infrastructure, this area is one of the least developed in the country's economy. Water storage and irrigation is a key production constraint in the Northeast Thailand. Despite investments in small, medium and large-scale irrigation systems (that is, dams, pumping stations, and irrigation) in the past sixty years, irrigation is concentrated on supplementary irrigation in the wet season and Northeast Thailand remains a predominantly rainfed area (Floch and Molle, 2007). Although rice can be produced two to three times a year, the majority of rice production in the Northeast is limited to the wet season (planting during May to October; harvesting during August to April) because of water accessibility during the dry season (planting during November to April; harvesting during February to October). With limited irrigation, farmers have to leave their land idle during the dry season. In 2010, 6.05 million hectares of rice were cultivated during the wet season in the Northeast compared to only about 0.48 million hectares during the dry season (Office of Agricultural Economics of Thailand, 2011).

Drought can adversely affect rice productivity at different times during the production cycle. In Northeast Thailand, it can occur both early, late and intermittently during the cropping season. Drought early in the cropping season causes a delay in rice transplanting and subsequently results in yield loss. It also increases the probability of late season yield loss from a delay in flowering. Yield loss during late-season drought, which develops at the end of the wet season before crop maturation is more severe than early-season drought. The estimates of yield reduction from late-season drought were 45 to 50% and 15 to 20% for the upper and middle top sequence, respectively (Jongdee, 2003). A twenty year simulation of yield loss in the Northeast showed that drought was more likely to develop in the latter stages of crop development; thus, high rainfall could still result in low yield if a drought occurs at a critical stage (Jongdee et al., 1997).

Prapertchob et al. (2007) found that during the late wet season, the upper Northeast has the lowest rainfall but the highest coefficient of variation. Although this zone was identified as low-risk of drought based on rainfall, hydrology and physical aspects of landscape according to Mongkolsawat et al. (2001), it is exposed to higher probability of yield and economic losses from late-season drought. Drought caused by climate change is expected to continue in the future and will have a significant impact on agriculture. The current impact of rainfall on agriculture based on the Generalized Monsoon Index shows that Northeast Thailand is experiencing severe drought, particularly in August and September (Thai Meteorological Department, 2012) when wet season crop planting occurs. Rainfall in Northeast Thailand has

fluctuated in the past few decades and is expected to be lower by 2090 (Thai Meteorological Department, 2010). Adaptation strategies such as changing planting and harvesting time, switching to different cultivars and developing drought-tolerant crops were suggested as options (Asian Development Bank, 2009).

The Rice Department of Thailand successfully developed RD12, glutinous drought-tolerant rice suitable for the Northeast. It was approved by the Rice Department in March, 2007. Nongkhai province is the first area where RD12 has been disseminated. This province is bordered by Laos PDR to the North and by the Mekong River to the East. The mountains to the West cause intermittent and late droughts during the wet season. The climate in this area is dry during the planting time of the dry season (November to April) with the average rainfall of less than 100 mm and humid during the planting time of the wet season (May to October) with the average rainfall almost 300 mm; however, rainfall drops dramatically in October to about 108 mm on average (Nongkhai Rice Research Center, 2013). Even though low fertility and coarse-textured and loamy sandy soils constrain production, weather especially variable rainfall distribution plays an important role in crop productivity and stability. Despite several large rivers, including the Mekong River, and small creeks and irrigation projects, less than 7% of agricultural land benefits from water management projects (Nongkhai Rice Research Center, 2013). Most farmers in this target drought-prone area are small farmers whose glutinous rice production is mainly for household consumption. Thus, preferences toward cooking characteristics are just as important as other traits.

Furthermore, as Prapertchob et al. (2007) found, farmers in this zone allocate their land to rice cultivation more than in other zones, but their yield and net returns from rice cultivation are the lowest. The development of drought-tolerant rice varieties for this target area will not only alleviate poverty, but also will ensure food security in the households. The breeding program of RD12 took into account farmer preferences by integrating participatory varietal selection (PVS) in the breeding process as a key determinant towards variety approval. Despite several released varieties, not all of them have been well-accepted by farmers mainly due to the superiority of some traits of the existing varieties. RD12 is one of the first released varieties recommended for drought-prone areas. PVS is relatively new to the rice breeding program in Thailand. To date the impact of varieties developed using PVS has not been assessed. This paper aims to reveal whether the preferred traits of glutinous rice discovered by the PVS for rice breeding in drought-prone areas influence the adoption of the new variety. Specifically it seeks to identify factors affecting the adoption of RD12 by focusing on farmer preferences, particularly for early maturity and eating quality.

Participatory varietal selection for drought-tolerant rice

Drought-tolerance traits can be classified into primary traits (such as, root depth), secondary traits (such as, leaf rolling), integrative traits, phenology (such as, flowering time) and plant-type traits (such as, plant height) (Kamoshita et al., 2008). Though simple, early flower genotype is often the most effective way of increasing yield under late-season drought (Kamoshita et al., 2008). Early flowering and early maturity varieties can escape from a late-season drought (Jongdee et al., 2006) which is a common problem for rice cultivation in Northeast Thailand. In non-irrigated areas, higher elevated paddies are likely to lose standing water earlier than those in lower positions. Thus earlier-flowering varieties would also reduce the risk of late-season drought and increase potential yield in drought-prone areas of the Northeast. Because glutinous rice is grown mainly for household consumption in upper Northeast Thailand, eating quality is likely as important as agronomic traits for farmers.

Despite the availability of recommended rice varieties for rainfed areas, the adoption of new varieties has had only partial success, to some extent due to the lack of traits important to farmers. Recently International Rice Research Institute (IRRI) recommended PVS be included as a standard part of all rainfed rice breeding programs (International Rice Research Institute, 2006). PVS trials are conducted on farms under the complete management of farmers; thus, it helps breeders and agronomists learn about the performance of new varieties under the real conditions faced by farmers and which varieties are preferred by them. In recognizing farmers' preferred traits, PVS has been increasingly implemented in several breeding programs (Bellon and Reeves, 2002; Ceccarelli and Grando, 2007; Doward et al., 2007; Efiue et al., 2008; Manzanilla et al., 2011; Morris and Bellon, 2004; Rasabandit et al., 2006; Witcombe et al., 1999; Wurzinger et al., 2011). Evidence shows that PVS improves the exposure to and adoption of new varieties (Diagne, 2006; Tshewang and Ghimiray, 2010; Witcombe et al., 1999); however, it has not been evident in the case of drought-tolerant glutinous rice in Thailand.

The "mother-baby" model was used in the breeding program of drought-tolerant rice in Thailand (Pantuwan et al., 2006; Jongdee et al., 2006) adopted from Snapp's technique (2002). The "mother" trial is replicated within-site to test a range of varieties and research hypotheses under a breeder's management either located on a research station or on-farm. The "baby" trial comprises a number of satellite trials of large plots under farmers' management and farm resources. The objective of "mother" trials is to assess the agronomic characteristics of different lines designed and managed by breeders while the "baby" trials are designed by breeders and managed by farmers to elicit farmer perceptions. In this

rainfed lowland rice breeding program, four hundred and seventy one field experiments were conducted in three provinces in the North and twelve provinces in the Northeast by selecting existing local varieties, existing modern varieties and promising lines from the breeding program for each location. Both upper toposequence position (upper paddy) and lower toposequence position (lower paddy) were selected for trials. In the mother trials, agronomic characteristics including yield, number of panicles, height, flowering days were analyzed, and the farmers vote for the variety they most preferred. In the baby trials, the experiment varieties were compared to farmers' own varieties based on agronomic characteristics. Grain characteristics (example, size, color) of both paddy rice and milled rice, and eating quality (example, softness, sweetness, and aromatic) of cooked rice were evaluated by farmers in both mother and baby trials.

Farmers' preference for agronomic characteristics revealed appropriate maturity matching with water conditions in paddies. Varieties with appropriate maturity (that is, early maturity for upper paddy), resistance to disease and insect pests, having good tillering with erect-strong stems, tall stature, similar level of height of panicles, droopy leaves and small number of leaves, big and long panicle, even panicle size, many grains per panicle, dense grains within panicle and long-slender grains are preferred. Furthermore, long slender and white grains are preferred while fragrance was farmers' preference, but not a strong requirement. PVS also showed that cooking and eating quality are the most important characteristics. Farmers could reject varieties preferred as paddy and milled rice if they dislike the cooking and eating qualities (Pantuwan et al., 2006).

RD12 is a cross between RD6 and Hahng Yi71. RD6, photoperiod-sensitive glutinous rice, has been well-preferred in this area due to its supreme cooking quality and higher selling price. However, RD6 is susceptible to blast disease, especially when growing in the upper terrain. Hahng Yi71, photoperiod-sensitive early-maturity and blast-resistant glutinous rice has been commonly grown in upper terrain to avoid the risk of late-season drought (Saleeto et al., 2009).

Nevertheless, Hahng Yi71 has poor cooking quality and is not favored for consumption. The perceived advantageous traits of RD12 include early maturity, high yield and good milling; whereas, cooking quality is poorer than the popular RD6 (Jongdee et al., 2006). RD12 is resistant to blast and has earlier maturation than RD6; however, it is less resistant to drought than Hahng Yi71. From the PVS in rainfed lowland rice breeding program discussed above, RD12 is recommended for rainfed areas in the Northeast, particularly in short rainy season or upper terrain area (Rice Department, 2009).

If the PVS were to improve the adoption of the new variety, Given the joint density of random vector

$\varepsilon_n = (\varepsilon_{n1}, \dots, \varepsilon_{nJ})$, preferred traits (particularly early-maturity) would be one major factor influencing the adoption of RD12 in the intermittent and late season drought environment. The following area discusses economic concept and model of technology adoption.

ANALYTICAL FRAMEWORK

Several of adoption studies have focused on farm and farmer characteristics with little attention to the characteristics of the varieties (Feder et al., 1985). Doss (2006) emphasized the advantage of micro-level cross-sectional analysis to understand farmer preferences, growing conditions in specific areas and what varietal characteristics are important to farmers. Recent studies accentuated farmer perceptions of varietal traits and their influences on the adoption behavior (Adesina and Zinnah, 1993; Adesina and Seidi, 1995; Adesina and Baidu-Forson, 1995; Edmeades et al., 2008; Hintze et al., 2003; Joshi and Pandey, 2006; Wale and Yalew, 2007; Ramasamy et al., 1999), with particular interest in hedonic pricing (Dalton, 2004; Pingali et al., 2001) and revealed preferences of trait valuation (Useche et al., 2009). In this study, farmer preferences for drought-tolerant glutinous rice are of particular interest; thus, traits subjectively selected from PVS breeding program are hypothesized to influence the adoption of RD12.

By taking into account production characteristics (example, yield, duration, disease resistance) and consumption characteristics (example, taste), the adoption of glutinous rice variety in the drought-prone areas assumes a utility maximization behavior. An individual farmer (or household), n , would obtain a certain level of utility (and/or profit) from each variety alternative, j , and will choose one that provides the greatest utility. The true utility that farmer n obtains from variety j is U_{nj} , $j = 1, 2, \dots, J$. He will choose variety i if and only if $U_{ni} > U_{nj} \forall j \neq i$. The true utility of farmers is unknown, but varietal traits and perception on traits, labeled $x_{nj} \forall j$, and farm and household characteristics, labeled s_n , can be observed. Following technology adoption based on technology attributes (Rahm and Huffman, 1984; Adesina and Zinnah, 1993), the representative utility, denoted $V_{nj} = V(x_{nj}, s_n) \forall j$, depends on these observed variables. Since $U_{nj} \neq V_{nj}$, true utility is decomposed as $U_{nj} = V_{nj} + \varepsilon_{nj}$, where ε_{nj} is assumed to be random. The probability that farmer n chooses variety i (Train, 2009) can be written as:

$$\begin{aligned}
 P_{ni} &= \text{Prob}(U_{ni} > U_{nj} \forall j \neq i) \\
 &= \text{Prob}(V_{ni} + \varepsilon_{ni} > V_{nj} + \varepsilon_{nj} \forall j \neq i) \\
 &= \text{Prob}(\varepsilon_{nj} - \varepsilon_{ni} < V_{ni} - V_{nj} \forall j \neq i).
 \end{aligned}
 \tag{1}$$

The cumulative probably in Equation (1) can be written as:

$$P_{ni} = \int_{\varepsilon} I(\varepsilon_{nj} - \varepsilon_{ni} < V_{ni} - V_{nj} \forall j \neq i) f(\varepsilon_n) d\varepsilon_n.
 \tag{2}$$

where $I(.)$ equal 1 when the expression in parentheses is true and 0 otherwise. For this study, we assume that ε_{nj} is independently, identically distributed extreme value, and the cumulative distribution of $\varepsilon_{nj} - \varepsilon_{ni}$ follows the logistic distribution

$$F(\varepsilon_{nj} - \varepsilon_{ni}) = \frac{e^{\varepsilon_{nj} - \varepsilon_{ni}}}{1 + e^{\varepsilon_{nj} - \varepsilon_{ni}}}
 \tag{3}$$

Given that the logit probability of V_{ni} is sigmoid, the logit model provides appropriate implications for this study. It implies that a small increase in V_{ni} (presumably from improved traits) has little effect on the choice probability when V_{ni} of a variety is either very low or very high, compared to other varieties. The greatest effect of an increase in V_{ni} on the probability of it's being chosen is when the probability is close to 0.5. For example, in the drought-prone area if the utility from growing a drought-tolerant variety i is very low (or very high) compared to other varieties, a small improvement in the drought-tolerant trait will have little effect on the probability that a farmer will adopt variety i . The change of probability that variety i is adopted from an improved drought-tolerant characteristic will be greatest when there is 50-50 chance that it is being chosen. Omitting the proof of algebraic manipulation (Train, 2009), the logit choice probabilities of Equation (3) are given as:

$$P_{ni} = \frac{e^{V_{ni}}}{\sum_j e^{V_{nj}}}
 \tag{4}$$

The representative utility is specified to be linear in parameters: $V_{nj} = \alpha' x_{nj} + \beta' s_{nj}$. Thus, a logit choice probability in Equation (4) is defined as:

$$P_{ni} = \frac{e^{\alpha' x_{ni} + \beta' s_{ni}}}{\sum_j e^{\alpha' x_{nj} + \beta' s_{nj}}}
 \tag{5}$$

Parameter estimates from Equation (5) are interpreted as a pairwise comparison between the effects of changes in independent variable on alternative i and the base alternative. The change in probability that farmer n chooses variety i given a change in an observed variable x_{ni} (or s_{ni}) is:

$$\frac{\partial P_{ni}}{\partial x_{ni}} = \frac{\partial \left(\frac{e^{\alpha' x_{ni} + \beta' s_{ni}}}{\sum_j e^{\alpha' x_{nj} + \beta' s_{nj}}} \right)}{\partial x_{ni}}
 \tag{6}$$

This marginal effect evaluated at the sample mean is given as:

Table 1. Sampling design and sample size.

Stage I: Rice production potential zone*	Stage II: Districts by RD12 promotion intensity	Total rice farming households	Population proportion	Expected sample size	Actual sample size	Actual sample proportion
A (High)	High: Muang Nongkhai	11,209	0.18	44	36	0.14
B (Medium)	High: Phon Phisai, Ratanawapi	19,516	0.32	77	103	0.40
	Low: Pak Khat	3,743	0.06	15	24	0.09
C (Low)	High: So Phisai	9,704	0.16	38	38	0.15
	Low: Fao Rai	6,749	0.10	27	21	0.08
D (Unsuitable)	Low: Bung Kan	10,973	0.18	43	36	0.14
	Total	61,894	1.00	244	258	1.00

*, Based on rice production potential zoning defined by Nongkhai Rice Research Center (2007).

$$\frac{\partial P_{ni}}{\partial x_n} = P_{ni}(\alpha_n - (\bar{\alpha}_n + \bar{\beta}_n)) \quad (7)$$

Where

$$\bar{\alpha}_n + \bar{\beta}_n = \sum_l P_{nl}\alpha_l + \sum_k P_{nk}\beta_k \quad (8)$$

Data

The target area for RD12 is the upper Northeast of Thailand where intermittent and late-season drought has been a major constraint on rice productivity. Since the adoption of the new variety is assumed to reveal preferences, the scope of the study area is limited to Nongkhai province in the upper Northeast of Thailand where farmers have access to RD12. Two stage stratified sampling technique was adopted. In the first stage, districts are grouped based on rice production potential zoning defined by Nongkhai Rice Research Center (2007).

The rice production potential zones were classified soil and water conditions combined with climate, top sequence, and farm management. In the second stage, each rice production potential zone is stratified by the intensity of RD12 accessibility. The number of farmers who received RD12 is used as a proxy to capture the extent where RD12 has been promoted. The intensity of RD12 promotion is classified low (less than twenty five farmers who received RD12 seeds during 2003 to 2008) to high (less than 25 farmers who received RD12 seeds during 2003 to 2008). The data are collected from households in seven districts of Nongkhai province in upper Northeast Thailand.

This study assumes a 5% statistical significant level and 20% distribution of RD12 in Nongkhai during the pre-survey. Adopting Tyfos (1996), the sample size is identified as 244 based on the total of 61,894 rice farming

households in seven selected districts (Nongkhai Statistical Office, 2004). The two-stage stratified proportional sampling technique (to total number of rice farm households) was used for the 2009/2010 cropping season. Table 1 shows the actual number of samples in each district. Farmers were interviewed to obtain rice farming information on every plot owned (or rented) by a household, including both during the wet and dry seasons.

EMPIRICAL MODEL

Based on collected data the four major glutinous rice varieties grown in the sampling area are Hanhg Yi71, RD12, RD10, and RD6. The summary of traits comparison among these varieties is shown in Table 2. A multinomial logit model derived from Equation (5) is estimated for choices of glutinous rice variety j based upon the assumption of a linear utility function. Thus,

$$U_{nj} = \sum_{l=1}^L \alpha_{nl} x_{jl} + \sum_{k=1}^K \beta_{nk} s_{jk} + \varepsilon_{nj} \quad (9)$$

In the multinomial logit model, traits and farmers perception on traits (x) includes the yield and taste preference of the new variety (RD12), and the popular high cooking quality rice (RD6), relative to the existing drought-tolerant variety (Hanhg Yi71). The extension of this logit model is to include taste variation associated with observed variables (Train, 2009). We assume that the utility a farmer receives from yield varies depending on the proportion household consumption of glutinous rice to total rice production (CONSUMP). As a result differences in taste could be reflected in the parameter of yield; thus $\beta_{n,yield} = \rho * (\text{CONSUMP})$.

Farm and household characteristics (s) includes the production condition in the drought prone area such as toposequence, access to water, cropping season, recent experience of blast disease, and whether rice production is the main source of income. Access to water is limited in the rainfed areas, particularly during the dry season so these conditions are hypothesized for the adoption of the drought tolerant variety. Aside from drought, blast disease is also the major production problem in sampling areas so the experience of blast disease may also influence the adoption decision. Focusing on the occurrence of RD12 adoption, a binomial logit model is

Table 2. Traits comparison of popular glutinous rice varieties.

Variety	Photo-period sensitive	Dry season	Harvest time	Appropriate for upper terrain	Drought-tolerant	Potential yield (ton/ha)	Cooking quality	Blast tolerant
Hanhg Yi71	Yes	No	Nov. 4	Yes	Drought escape	3.16	Soft/chewy	Yes
RD12	Yes	No	Nov. 7-17	Somewhat	Drought escape	3.26	Good, soft/chewy	Somewhat
RD10	No	Yes	130 days	No	No	4.12	Soft	Somewhat
RD6	Yes	No	Nov. 21	No	Yes	4.16	Very good, soft/aromatic	Susceptible

Source: Rice knowledge bank, Rice Department, 2009.

Table 3. Description of variables in choice models.

Dependent variable	
VARIETY	Glutinous rice variety: Hanhg Yi71, RD6, RD10, RD12
ADOPT	RD12 adoption: 1 if adopt, 0 otherwise.
Independent variables	
Traits and Perception on Traits, X_i	
YIELD	Rice yield (kg/rai)
CONSUMP*YIELD	Proportion household consumption of glutinous rice to total rice production * YIELD
PRICE	Output price (baht/kg)
RD12TASTE	Farmer perception of RD12 taste: 1 if farmer thought RD12 has better cooking quality than Hanhgyi71, 0 otherwise
RD6TASTE	Farmer perception of RD6 taste: 1 if farmer thought RD6 has better cooking quality than Hanhgyi71, 0 otherwise
RD12HARVEST	Farmer perception of the ease to harvest RD12: 1 if farmer thought RD12 is easier to harvest than Hanhgyi71, 0 otherwise
RD12PLANTING	Farmer perception of the ease to transplant RD12: 1 if farmer thought RD12 is easier for crop establishment than Hanhgyi71, 0 otherwise
Farm and household characteristics, S_k	
CONSUMP	Proportion household consumption of glutinous rice to total rice production
TOPOSEQUENCE	Toposequence of rice production plot: 1 if upper sloping terrain, 0 otherwise.
WATER	Access to water source: 1 if irrigated or availability of other water resources, 0 otherwise.
SEASON	Cropping season: 1 if dry season, 0 otherwise
BLASTEXP	Experience of blast disease: 1 if farmer experience blast disease in the past five years, 0 otherwise
MAININC	Main income source: 1 if rice is major source of income, 0 otherwise.

1 ha=6.25 rai.

estimated (1 if adopted, 0 if not adopted). Since RD12 is photoperiod-sensitive, the binomial logit model of RD12 adoption includes only the wet season. Farmers' acceptance of RD12 is hypothesized to be influenced mainly by trait perceptions of RD12 relative to Hanhg Yi71—the existing drought tolerant variety. Table 3 lists all variables of the choice models.

RESULTS AND DISCUSSION

Tables 4 to 6 show the summary of glutinous rice

varieties grown in the study areas. Based on four hundred and forty four plots, RD12 and RD6 are the most preferred varieties (about 35% individually), followed by Hanhg Yi71 and RD10, respectively. Both RD12 and RD6 are photoperiod-sensitive and have good cooking quality, compared to the others. San Pah Tawng and RD4 were other glutinous rice varieties found in this area, but they are not popular.

The two varieties together accounted for less than 2%. This probably is because San Pah Tawng and RD4 have

Table 4. Glutinous rice varieties grown in Nongkhai province, 2009/2010.

Variety	No. of plots	Percentage
Hanhg Yi71	97	21.85
RD12	155	34.91
RD10	26	5.86
RD6	159	35.81
RD4	6	1.35
San Pah Tawng	1	0.23
Total	444	100.00

Table 5. Glutinous rice varieties in Nongkhai province by toposequence, 2009/2010*.

Variety	Lower terrain		Upper terrain	
	No. of plots	Percentage	No. of plots	Percentage
Hanhg Yi71	7	3.52	90	37.82
RD12	34	17.09	121	50.84
RD10	14	7.04	12	5.04
RD6	144	72.36	15	6.30
Total	199	100.00	238	100.00

*Excluding RD4 and San Pah Tawng.

Table 6. Glutinous rice varieties grown in Nongkhai province by cropping season, 2009/2010*.

Variety	Wet		Dry	
	No. of plots	Percentage	No. of plots	Percentage
Hanhg Yi71	96	22.97	1	5.26
RD12	154	36.84	1	5.26
RD10	11	2.63	15	78.95
RD6	157	37.56	2	10.53
Total	418	100.00	19	100.00

* Excluding RD4 and San Pah Tawng.

poorer cooking quality, are susceptible to blast and are not drought resistant. These findings are similar to the studies by Isvilanonda and Hossain (2000), Gypmantasiri et al. (2003) and Vejpas et al. (2005). Prior to the release of RD12, RD 6 was the most common glutinous rice variety in the rainfed area of Northeast Thailand. Early maturing varieties, including RD15 which has shorter duration than KDML105 (non-glutinous Jasmine rice varieties) were becoming more popular for rainfed lowland area during the wet season (Vejpas et al., 2005). In the upper terrain, RD12 is the most popular variety and accounted for about half of all plots. Hanhg Yi71 which was the recommended variety for upper terrain before the development RD12 is the second most popular (Table 5). In the lower terrain, however, RD6 which has the highest cooking quality is the most popular variety and accounted

for over 70% of all lower terrain production. Rice production in the study area is very limited during the dry season as is evident from Table 6. Again, RD12 and RD6 are the most popular varieties in the wet season. Unsurprisingly compared to RD10 which is non-photoperiod sensitive; the farmers are less likely to choose Hanhg Yi71, RD12 and RD6 in the dry season.

The parameter estimates of the multinomial logit model are presented in Table 7. More useful results are the estimates of marginal effects presented in Table 8. One of the most interesting findings is that the probability of choosing Hanhg Yi71 or RD12 significantly increases by 35% for upper terrain while there is only about 4% probability of choosing RD10. The probability of choosing RD6, however, decreases by about 7% for the upper terrain. This implies that to minimize the risks from late-

Table 7. Parameter estimates of multinomial logit model (RD10=base).

Variable	Hanhg Yi71		RD12		RD6	
	Parameter (β)	Std. Err.	Parameter (β)	Std. Err.	Parameter (β)	Std. Err.
CONST	0.229	1.319	2.618**	1.226	3.949**	1.241
CONSUMP*YIELD	0.004	0.003	0.003	0.003	0.001	0.003
RD12 TASTE	-0.103	1.000	-0.159	0.981	-1.781	1.130
RD6 TASTE	3.204**	1.523	1.443	1.537	3.355**	1.565
TOPOSEQUENCE	0.218	1.130	-1.062	1.067	-4.914**	1.097
WATER	-0.255	0.763	0.031	0.721	0.069	0.769
SEASON	-4.490**	1.573	-6.040**	1.477	-6.997**	1.348
BLAST	0.812	0.674	0.459	0.629	1.119	0.704
MAININC	0.072	0.876	0.218	0.830	-0.147	0.891
Log likelihood	-342.039					
Number of plots	434					

Table 8. Marginal effects of multinomial logit model.

Variable	Hanhg Yi71		RD12		RD6		RD10	
	Coeff	Std. Err.	Coeff	Std. Err.	Coeff	Std. Err.	Coeff	Std. Err.
CONSUMP* YIELD	0.0003*	0.000	0.0002	0.000	-0.00004**	0.000	-0.00006	0.000
RD12 TASTE	0.077	0.073	0.150*	0.089	-0.240**	0.061	0.013	0.032
RD6 TASTE	0.147*	0.081	-0.381**	0.068	0.268	0.111	-0.034**	0.017
TOPOSEQUENCE	0.353**	0.040	0.352**	0.047	-0.743**	-0.035	0.0384**	0.017
WATER	-0.046	0.056	0.022	0.079	0.024	0.082	0.0003	0.017
SEASON	-0.100	0.118	-0.440**	0.072	-0.286**	0.039	0.826**	0.139
BLAST	0.026	0.055	-0.114	0.070	0.109	0.067	-0.021	0.024
MAININC	-0.003	0.068	0.066	0.084	-0.061	0.081	-0.002	0.019

** = significance at 5% level, * = significance at 10% level.

season drought, the early maturity trait of Hanhg Yi71 and RD12 is the key reason for adopting drought tolerant varieties in the upper sloping terrain.

Another interesting result is the perception that RD12 has better cooking quality than Hanhg Yi71. This increases the probability of adopting RD12 by about 15% and lowers the probability of adopting RD6 by 2.4%. It suggests that if farmers have a higher preference for the cooking quality of RD12 than for Hanhg Yi71, they will be more likely to adopt RD12 if they believe that RD12 is appropriate for protection against drought. In contrast, the perception that RD6 has a preferred cooking quality than Hanhg Yi71 decreases the probability of RD12 by 38%. This is because RD6 is superior for consumption in the existing market. The adoption of new variety RD12 is diminished when farmers have strong cooking preferences for existing varieties.

It is hypothesized that yield could be an important determinant of variety adoption. By allowing variability of yield preference by the proportion of household consumption, it was found that yield as valued by

household consumption increases the probability of cultivating Hanhg Yi71, but lowers the probability of cultivating RD6. This could be because RD6 is premium glutinous rice that also has high market price. As demand of household consumption increases despite increasing yield, the probability of adopting RD6 decreases. In other words, as household rice demand increases, farmers are more likely to grow Hanhg Yi71 and less likely to grow RD6. Farming in the dry season is possible only for the non-photosensitive variety. Predictably, it increases the probability of growing RD10 (non-photosensitive variety) and decreases the probability of growing RD12 and RD6 (photosensitive varieties).

The results of RD12 adoption excluding dry season from the binomial logit model are shown in Table 9. It is found that for the upper terrain, the probability of adopting RD12 increases by 41%, compared to the lower terrain. Similar implication drawn from this binomial model is that for upper sloping terrain, increasing risk of late-season drought results in a higher likelihood of new early maturity variety. The studies by Joshi and Bauer (2006),

Table 9. Parameter estimates and marginal effect of binomial logit model of RD12 adoption in wet season.

Variable	Parameter (β)	Std. Err.	Marginal effect	Std. Err.
CONST	-5.328**	1.722		
YIELD	-0.0004	0.001	-0.00009	0.000
PRICE	0.381**	0.186	0.078**	0.038
RD12 TASTE	0.685	0.982	0.156	0.239
RD12 HARVEST	-0.799	0.864	-0.139	0.122
RD12 TRANSPLANT	-2.041	1.526	-0.248**	0.087
TOPOSEQUENCE	2.238**	0.518	0.418**	0.079
CONSUMP	1.434**	0.671	0.295**	0.137
Log likelihood	-79.409			
Number of plots	147			

** = significance at 5% level, * = significance at 10% level.

Nanfumba et al. (2013), and Ward et al. (2013) also suggest that farmer's preferences towards early-maturity or short duration significantly affects rice variety choice in the rainfed area. Because glutinous rice production in this region is important for household consumption, taste preference can be important to the adoption decision. The probability of adopting RD12 increases as the percentage of household consumption increases, perhaps owing to the superior taste and higher potential yield than the existing drought tolerant variety. Similarly, increasing the selling price for rice with the improved cooking quality makes farmers more likely to adopt RD12.

The physical appearance of rice paddy RD12 is more similar Hahng Yi71 (long, skinner, darker yellowish brown) than RD6. Since RD12 is new to the market and not easy to distinguish by appearance, the market price of RD12 is generally the same as Hahng Yi71 although it's cooking quality is similar to RD6. This may suggest that if RD12 were to become more recognized in the market with a higher price, farmers would be more likely to adopt it.

Between two competing drought tolerant varieties: RD12 and Hahng Yi71, RD12 has stronger stalks than Hahng Yi71 so it's believed to be easier to harvest, especially in environment where wind and storms can cause fallen stalks. However, the perception that RD12 is easier to harvest than Hahng Yi71 insignificantly affects the adoption decision of RD12. This is not surprising because from the PVS, tillering is not one of the key preferred traits and our result implies that it may not be important to farmers. Surprisingly, perception of superior cooking quality of RD12, compared to Hahng Yi71, does not affect the probability of RD12 adoption. This could be because in the binomial model, the dry season is excluded and the cooking quality of the new drought tolerant variety is not as important as the drought escape characteristic thus, even if RD12 is superior to Hahng

Yi71 for consumption, the taste alone does not influence the adoption of RD12. The result is similar to Joshi and Bauer (2006) that taste is not significant toward variety choice in the rainfed area of Nepal. It is surprising that the perception that RD12 is easier to transplant than

Hahng Yi71 negatively affects RD12 adoption. It is possible that the ease of transplanting is mistakenly perceived as weaker rooting and germinating and negatively has impacted the adoption.

CONCLUSION AND RECOMMENDATION

The breeding program of the Rice Department released the new glutinous rice variety RD12, to target the drought problem in Northeast Thailand in 2007. In the RD12 breeding program, farmers' participatory selection was the key in the selection process to ensure the acceptance of the new variety. The major improved characteristics of RD12 which were identified from PVS included early maturity and good cooking quality. RD12 has been promoted in Nongkhai province in the upper Northeast of Thailand where late season drought is a major constraint, particularly for upper terrain. Hahng Yi71 had been the most appropriate variety to target the drought problem prior to the release of RD12 and it has been widely adopted despite its poor cooking quality. Our results show that major traits of RD12 identified by the farmer PVS significantly influences the adoption of the new variety. Farmers in the upper terrain production are more likely to adopt RD12 to minimize the risk from late-season drought. The taste preference towards RD12 compared to existing drought tolerant variety, Hahng Yi71, also significantly increases the probability of RD12 adoption and lowers the probability of adopting RD6, the superior cooking quality variety. However, since RD12 is photoperiod-sensitive, it is less preferred for cultivation in the dry season. The current market still does not

recognize the quality of the RD12 and often suppresses its price because of its similar physical appearance to the lower quality variety. The result shows that a higher price increases the adoption of RD12; this suggests that when RD12 becomes more recognized in the market and when its price reflects its superior quality, it will be more accepted by farmers. The adoption RD12 has been found to be closely related to farmer perception of its traits. The preferred traits identified by farmer PVS program in rice breeding of RD12 effectively enhance its adoption.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Full Length Research Paper

Financial profitability and technical efficiency of horticultural crops in the Nakanbé River Watershed in Burkina Faso

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In the watershed of the Nakanbé River in Burkina Faso, horticultural crops are financially profitable with high gross incomes, cost/revenue ratios and attractive hourly returns to labor. Based on a 6-h work day, profitability indicators of horticultural crops show that farmers are better-off compared to the 'less than one dollar' situation of people in Burkina Faso; horticultural crop production could thereby be an important part of a poverty reduction strategy in the studied sites and other rural areas. The proportion of efficient producers ranged from 35% for tomato in Ouonon to 100% for onion in Zekeze. Considering efficiency for individual crops, onion production in Zekeze was the most efficient, with a maximum score of (100%), followed by the production of cucumber in Ouonon and green beans in Kongoussi with respective scores of 98%. Inputs (seeds, fertilizers and pesticides) are used in excessive quantities which tend to reduce technical efficiency and could have negative environmental impacts. Improving horticultural crop producers' capacities to use appropriate rates of chemicals and organic inputs or biological treatments is recommended since the survival as well as the development of this kind of farming increases rural households' incomes and supplies fresh food to an increasing urban population at a reasonable price.

Key words: Horticulture, cost/revenue ratio, hourly return, efficiency, input excess, environment, Burkina Faso.

INTRODUCTION

Burkina Faso is one of the poorest countries in the world; the incidence of poverty is 43.9% at the national level (INSD, 2010). Poverty is greater in rural than urban areas. In order to ensure their economic and nutritional survival, rural, urban as well as peri-urban populations produce horticultural crops under irrigation, particularly during the dry season. In Burkina Faso, only 12% of the total irrigable land is under irrigation (Government of Burkina Faso, 2005), and 30% of the irrigated area produces horticultural crops. Burkina Faso has been an

exporter of fruit and vegetables such as fresh green beans since 1970, but in recent years the competitiveness of this sector has sharply declined. This decline in competitiveness of horticultural products and the sub-sequent reduction of exports has been 'the result of an intrinsic decline in the quality of the product' (Government of Burkina Faso, 2005). Any loss of competitiveness leads to a loss of market and therefore, to a reduction of exports earnings. Since the daily income per capita is less than one U.S. dollar in Burkina Faso,

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any decline in export earnings reduces per capita income and then worsens poverty.

Reduced quality of horticultural products not only has a negative influence on the competitiveness of the sector, but also leads producers to use excessive amounts of inputs (fertilizers and pesticides) during production, which poses environmental problems.

According to the definition of Koopmans (1951), 'a producer is efficient if he maximizes output given the input he uses; that is, transforming inputs to outputs he needs a certain kind of technology. Since this type of efficiency deals solely with technology this type of efficiency is called technical efficiency', while allocative efficiency measures the ability of the farmer to use inputs in optimal proportions, given input prices.

Technical efficient is rather the ability of the farmer to produce maximum output from a given level of inputs, whatever these inputs are.

It is therefore important to identify bottlenecks and weaknesses in horticultural production to understand the production decline in recent years in order to improve production in the future. This objective of this study is to analyze the profitability and technical efficiency¹ of horticultural crop production in the Nakanbé River watershed in Burkina Faso.

METHODOLOGY

Data collection

The first step in data collection was the choice of study sites in the watershed with farmers' cooperatives and associations. The selection criteria were (i) the volume of horticultural crop production during the dry season of candidate sites, (ii) ease of access to the production area, and (iii) the level of cooperation of the producers in the sites.

Using the above criteria, four (4) sites were chosen (Figure 1): Kongoussi, in the Bam province; Titao, in the Loroum province; Ouonon, in the Passore province and Zekeze in the Boulgou province.

The survey was conducted during the 2004 dry season to a total of 131 randomly selected farmers: 31 in Kongoussi, 24 in Titao, 36 in Zekeze and 40 in Ouonon. The questionnaire used for data collection included the (i) farmers' socio-demographic characteristics (ii) land parcel identification, crops and cropped areas, and land tenure, (iii) cropping calendar describing the succession of farming operations (iv) quantity and cost of inputs used, (v) family labor indicated by the number of persons and amount time spent working by gender, age, crop produced, and cropping operation, (vi) amount of hired labor in hours and payments in cash and in-kind (vii) inventory of equipment used (purchased or borrowed), (viii) cost of equipment repair and maintenance, (ix) quantities harvested and sales by crop, and (x) marketing problems.

Method of analysis

The method of analysis included profitability, technical efficiency and measures of excess inputs use.

¹ This technical efficiency differs from the agronomic efficiency (fertilizer or irrigation).

Indicators of financial profitability

Production budgets were used to assess profitability, especially cost/revenue ratio and hourly payment, during the dry season. For a given crop, the household average production was computed and valued at average sale prices to get the gross income (GI).

The corresponding cost/revenue ratio (C/RR) is calculated as: $C/RR = GI/VC$ where VC is total variable costs to produce the crop. The related hourly payment (HP) is obtained, dividing GI by the number of family hours (FL), that is $HP = GI/FL$.

The higher the gross income and hourly payment, the more profitable is the crop².

Technical efficiency

The Data Envelopment Analysis (DEA) method was used to analyze the technical efficiency of horticultural crops producers which is a non-parametric method, a deterministic measurement of technical efficiency. This method is based on models of optimization and linear programming techniques. The analysis was performed using the DEAP (Data Envelopment Analysis Program) (Coelli, 1996); in addition to the level of efficiency it provides, this software also gives information on the variables which are the sources of the inefficiency.

The method is based on the measurement of the ratio output/input in the form $u'yi/v'xi$ where u is a $M \times 1$ vector of relative weights of outputs and v a $K \times 1$ vector of relative weights of inputs. Optimal weights are obtained by solving a problem of mathematical programming, specified as follows:

$$\text{Max } u, v \quad (u'yi/v'yi),$$

$$\text{st } u'yj/v'yj \leq 1, j = 1, 2, \dots, N \\ u, v \geq 0.$$

The objective is to find values for u and v such that the measure of the efficiency of the unit of decision i (a farmer in our case) is maximized under the constraint that all measures of efficiency are less than or equal to 1. This formulation of ratio has the disadvantage of having an infinite number of solutions since if (u^*, v^*) is a solution of the program, then so is $(\alpha u^*, \alpha v^*)$.

To overcome such a difficulty, an additional constraint is imposed and the problem is reformulated after transformation; the DEAP model developed by Coelli (1996) uses the dual program as reformulated (Coelli, 1996).

Some authors such as Boles (1966) and Afriat (1972) proposed methods of linear programming to estimate the isoquant frontier; such methods did not receive attention until Charnes et al. (1978) introduce the term "Data Envelopment Analysis". The model developed by Charnes et al. (1978) focused on the inputs³ and based on the assumption of the constancy of returns to scale. Later on, alternative hypotheses were introduced; Banker et al. (1984) proposed a model rather based on the assumption of variable returns to scale.

Inputs excess

Referring to Figure 2 illustrating this idea of input excess, it can be seen that on the same linear segment of the isoquant convex frontier SS', you can have an optimal point with the possibility of

²Gross income was preferred to net income due to difficulties to get required data, that is, opportunity cost of labor in the absence of a rural labor market, costs related to crop production.

³Some models are centered on the output but we use here the option input-oriented DEA software.

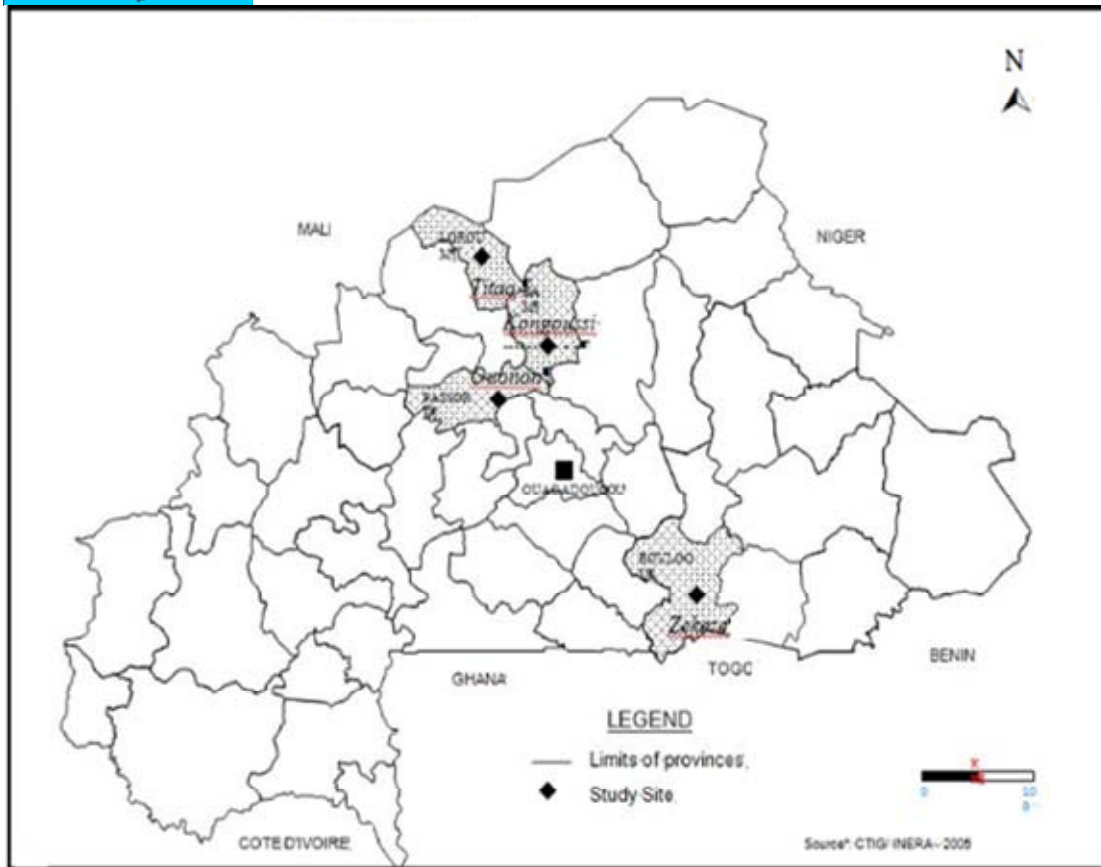


Figure 1. Location of study sites.

reducing the quantity of inputs (x_1 and x_2) used without reducing the level of production (y). We may then wonder if such a point is optimal; it is an excess of inputs used, that could have been saved, since this does not increase the level of production. The technical efficiency for decision units A and B are respectively of OA/OA' and OB/OB' ; the question that can be raised is whether point A' is efficient since the quantity of input x_2 can be reduced by CA' without reducing the level of production; CA' is therefore the input excess of x_2 . The Data Envelopment Analysis software provides options for the calculation of the excess inputs.

RESULTS AND DISCUSSION

Main crops production

The main crops in Titao are onion and potato; green beans predominate in Kongoussi while at Zezeze, onion,

tomato and banana are the most important vegetable crops. In Ouonon, the main crops are tomato, eggplant and cucumber (Table 1).

Profitability of horticultural crops⁴

Potato and onion in Titao have the highest gross incomes per hectare, followed respectively by onion in Zezeze, green beans in Kongoussi, banana in Zezeze, onion and tomato in Ouonon, tomato in Zezeze, eggplant and cucumber in Ouonon (Table 2). However, the cost/revenue ratio of 8.77 reveals the greatest profitability for onion in Ouonon. Potato and green beans, despite good gross incomes, recorded relatively poor cost/revenue

⁴ US dollar 1.00= FCFA 500.

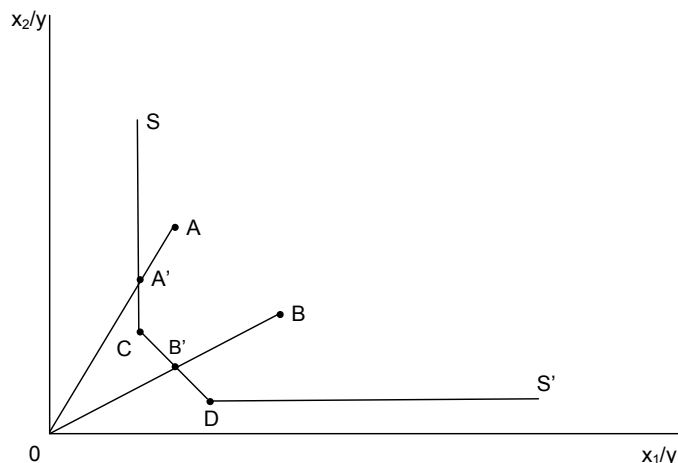


Figure 2. Measure of efficiency and excess inputs. x_1/y : quantity of input x_1 to produce a unit of production y ; x_2/y : quantity of input x_2 to produce a unit of production y . Source: Coelli (1996).

Table 1. Main crops areas by study site.

Sites	% of households	Area (m ²)
Kongoussi-Bam		
Green Beans	87	2,978
Titao-Lorum		
Onion	58	433
Potato	39	511
Ouonon-Passoré		
Tomato	80	8,113
Onion	75	7,993
Eggplant	53	3,640
Cucumber	40	3,700
Zezeze- Boulgou		
Banana	56	11,000
Tomato	47	6,147
Onion	47	4,755

Source: Author's computations.

ratios due to high input costs, especially for seeds and water. Green beans producers had to pay a water fee of 400,000 FCFA/year and the seed cost was estimated at 225,650 FCFA per hectare, while potato required 2,126,600 FCFA of seed per hectare for its production.

The cost/revenue ratio was significantly higher for tomato in Ouonon than in Zezeze. Eggplant and cucumber had the lowest gross revenues, but still financially rewarding with revenue/cost ratios of 1.72 and 1.77, respectively.

Potato had the highest gross margin per hour (1733 FCFA). The hourly remuneration of green beans was

intermediate in Kongoussi (525 FCFA), and lowest for cucumber in Ouonon (206 FCFA) and banana in Zezeze (260 FCFA) which was the most labor-demanding.

Onion had a higher hourly payment in Ouonon than in Titao and Zezeze. Tomato recorded a higher hourly remuneration in Ouonon than in Zezeze.

Based on a 6-h work day, profitability indicators show that farmers are better-off compared to the 'less than one dollar' situation of people in Burkina Faso. Pro-poor rural economic policy could therefore be promoted through the production of horticultural crops.

Technical efficiency

Scores of efficiency

Scarce studies are available on horticulture efficiency in Africa and in Burkina Faso. However, Jema (2008) conducted an interesting one in Ethiopia and found that mean technical efficiency for vegetable production was 96% in two districts of eastern Ethiopia.

In our study, it is found that technical efficiency scores (Table 3) showed that the proportion of efficient producers ranged from 35% for tomato in Ouonon to 100% for onion in Zezeze.

Cucumber production in Ouonon, green beans in Kongoussi, tomato in Zezeze, potato in Titao and eggplant in Ouonon also recorded a technical efficiency score greater than 70%.

Considering efficiency for individual crops, onion production in Zezeze was the most efficient, with a maximum score of 100%, followed by the production of cucumber in Ouonon and green beans in Kongoussi with respective scores of 98%. Onion had a lower efficiency score in the northern site of Titao, and in Ouonon (88% and 84% respectively); the lowest technical efficiency score was recorded in Ouonon for tomato with a score of 68.4%. Green beans and potato producers were less efficient than onion producers in the southern site of Zezeze and cucumber producers in Ouonon. The reasons for this inefficiency should be investigated in order to improve the profitability and competitiveness of horticultural crops.

Excess inputs

The use of excessive levels of inputs is one source of technical inefficiency. In Kongoussi, the inputs that most farmers used in excessive quantities, included seeds (probably because of poor quality) and fertilizers (NPK and urea) (Table 4).

The use of fertilizers in excess quantities reflects the decline in soil fertility that producers tried to compensate yield decrease by increasing application rates which might result in environmental pollution. Less important excess uses were observed on family labor, energy and

Table 2. Per hectare production budgets (FCFA).

Item	Kongoussi	Titao		Ouonon				Zekeze		
	Green beans	Potato	Onion	Onion	Eggplant.	Tomato	Cucumber	Banana	Tomato	Onion
Gross Income (FCFA)	2 091 486	8 369 262	3 534 948	1 463 926	447 564	1 201 404	388 080	2 074 317	708 985	2 148 133
Variable costs (FCFA)	856 747	3 080 201	1 141 320	166 857	260 427	181 767	219 372	673 327	354 995	598 704
Seeds	225 650	2 126 600	291 288	15 844	13 968	15 996	15 189		33 000	175 882
NPK fertilizer	77 750	480 066	428 260	32 743	45 120	39 432	31 654	107 803	40 500	82 536
Urea	35 424	-	65 869	11 508	24 000	12 393	20 003	177 680	26 059	44 469
Organic manure	28 703	196 929	121 580	18 333	25 038	22 386	24 720	-	8 437	56 666
Insecticide	23 350	124 645	100 595	12 450	25 717	13 743	14 167		17 312	17 500
Water fee	400 000	-	-	-	-	-	-	-	-	-
Labor Cost	20 000									
Diesel/gasoline	-	131 361	131 361	15 180	38 909	18 935	26 500	224 607	132 326	138 300
Repairs and maintenance	4 100	20 600	2 367	9 522	2 511	9 960	2 524	93 467	20 173	23 133
Hired labor	41 770	-	-	51 277	85 164	48 922	84 615	69 770	77 188	60 218
Cost/revenue ratio	2.44	2.72	3.10	8.77	1.72	6.61	1.77	3.08	2.00	3.59
Family labor (hours)	3 980	4 830	4 025	1 654	2000	1549	1884	7967	2979	3878
Hourly payment based on gross margin (FCFA)	525	1 733	878	885	224	776	206	260	238	554

Source: Author's computations.

Table 3. Technical efficiency by site and crop in the Nakanbé River watershed.

Item	Kongoussi	Titao		Ouonon				Zekeze		
	Green beans	Potato	Onion	Onion	Egg-plant	Tomato	Cucumber	Banana	Tomato	Onion
Technical efficiency (%)	97.5	95.8	88.2	84.3	91	68.4	98.2	88.5	91.1	100
Proportion of efficient producers (%)	74	82	61	60	79	35	94	68	82	100

Source: Author's computations.

depreciation for 43% inefficient farmers.

In Titao, excess use of inputs was observed in the production of potato and onion: excess use of seeds and NPK fertilizer for 513,059 FCFA/ha and 150,111 FCFA/ha respectively for potato. For onion production, excess levels were of 293,697 FCFA/ha for seed, 203,695 FCFA for NPK fertilizers,

61,919 FCFA for urea, 201,739 FCFA for the organic manure and 106,795 FCFA for pesticides. On the production site of Ouonon, not only inputs were used in excess quantities; hired labor also recorded a peak of excess level of 39,778 FCFA/ha and 50,117 FCFA/ha for onion and tomato, respectively.

In Zekeze, banana inefficient producers recorded on average an excess inputs use of 112,076 FCFA/ha for the NPK fertilizer, 138,237 FCFA for urea and 125,064 FCFA for energy. Unlike banana, the recorded major excess input use was in tomato production: 169,889 FCFA/ha (100% of farmers) for energy and 116,780 FCFA

Table 4. Excess production factors (in FCFA/ha).

Input/factor	Kongoussi	Titao		Ouonon				Zezeze		
	Green Beans	Potato	Onion	Onion	Eggplant	Tomato	Cucumber	Banana	Tomato	Onion
Seeds	18016 (57)	513059 (100)	293697 (71)	9924 (25)	2492 (100)	8489 (55)	0	0	7667 (67)	0
NPK fertiliser	21374 (71)	150111 (100)	203695 (71)	14069 (67)	27352 (40)	21461 (80)	110 (100)	112076 (100)	6891 (100)	0
Urea	7957 (71)	0	61919 (86)	5265 (75)	24000 (20)	8937 (65)	555 (100)	138237 (67)	6482 (100)	0
Organic manure	7700 (85)	22211 (50)	201739 (100)	10274 (58)	20984 (100)	12985 (90)	13 (100)	0	2221 (67)	0
Insecticide	6291 (71)	60173 (50)	106795 (57)	4648 (75)	4927 (40)	9138 (55)	625 (100)	0	5040 (33)	0
Energy	3347 (43)	0	46864 (43)	5995 (92)	1343 (20)	15072 (100)	0	125054 (67)	169889 (100)	0
Hired labor	0	0	0	39778 (33)	0	50117 (60)	0	50345 (33)	116780 (33)	0
Depreciation	700 (43)	18120 (50)	4704 (71)	4490 (75)	2181 (60)	8772 (75)	0	6067 (33)	0	0
Family labor	1021 (43)	0	14501 (71)	584 (67)	2245 (40)	738 (70)	110 (100)	6695 (33)	2330 (67)	0

Source: Author's computations. Figures in parentheses are the proportion of inefficient producers in the use of input or factor of production. Energy=diesel/gasoline repairs and maintenance.

for hired labor (33% of farmers).

In general, all sites recorded excess inputs including fertilizers (NPK, urea) and insecticides. This means that producers are losing money by applying such high quantities of fertilizers and insecticides. In addition to the reduced profitability, excessive use of fertilizer and insecticides can reduce the sustainability of their production system due to negative long-term effects on the environment. Furthermore, this would contribute to reduce market demand as consumers are more and more demanding for use of ecological and healthy production practices.

CONCLUSION AND RECOMMENDATIONS

The results of the study show that production of horticultural crops is financially profitable in the Nakanbé River watershed in Burkina Faso. Satisfactory cost/revenue ratios were found, especially in Ouonon for tomato and onion. Horticulture has relatively high hourly payment: 525 FCFA/hour for green beans in Kongoussi,

1,733 FCFA for potato in Titao, 885 FCFA and 776 FCFA in Ouonon, respectively. Promotion of horticultural crop production could be part of a sound pro-poor strategy in rural areas. Despite good financial performance, horticultural crop producers are not totally efficient and improvements are possible. Farmers exhibited technical inefficiencies, which indicates that they have not mastered existing technologies and that improvements are needed. These inefficiencies should be addressed before new costly investments are made and future research should investigate the causes of the technical inefficiency. Agronomic studies are necessary to assess the impact of excess input use (particularly of fertilizer and insecticides) on the environment. Producers need training on input rates, substitution of organic for chemical inputs, and use of biological techniques, and sensitization on the environmental risks associated with excessive chemical rates.

The survival as well as development of horticultural crop production is important to increase rural household income while supplying

fresh food to an increasing urban population at a reasonable price.

Conflicts of Interest

The authors have not declared any conflict of interest.

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