International Journal of Agriculture and Environmental Research

ISSN: 2455-6939

Volume:02, Issue:03

TECHNICAL INEFFICIENCY AND PAPAYA FARM SIZE IN WEST AFRICA: A STOCHASTIC FRONTIER APPROACH ON BENIN AND GHANA DATA

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ABSTRACT

Papaya is an emergent food and cash crop in Western Africa. It is used as an export crop in Ghana and for urban consumption in Benin. Papaya fruits are severely attacked by Papaya mealybug causing significant losses in quantity and quality. To control the papaya mealybug a classical biological control initiative has been developed and is environmental friendly. This study is targeting the production system efficiency and assesses key factors which influence the papaya production. It is conducted using cross-sectional data collected from papaya production systems in the sub-humid zones of West Africa. Results reveal that efficiency in producing papaya are still low in both countries. In Benin factors like land ownership remains important in the production performance, mainly in Ghana. Extension services and secured land tenure are incentives for producers to adopt better production practices to increase efficiency.

Keywords: Papaya, Western Africa, Efficiency, production systems, irrigation, land security

INTRODUCTION

Agricultural sector employs up to 60% of economically active population (34% and 36% to GDP of Benin and Ghana respectively). Papaya like other fruits is a new and lucrative opportunity for export markets. Its potential to generate income and reduce poverty in urban and rural areas is very high. The production has increased over the years in both countries. The world production of papaya (*Carica papaya* L.) was estimated to approximately 12,420,585.00 tons, with 1/3

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produced by India, 1/6 by Brasilia (FAOSTAT, 2013), with the total world trade estimated to be €162 million, representing 263 thousand tons in 2006. Mexica is the first exporter in the world with 74000 tons the year, followed by the Malaysia (54000 tons the year). Papaya is grown in many countries for both local and foreign markets. Medium- and large- fruited varieties that have yellow and red flesh are preferred by local consumers. Exported papaya fruits are usually small or of medium size (Codex, 2005), with yellow or red flesh (Picha, 2006; Pesante, 2003), such as the variety*solo*.

The papaya sector contributed significantly to the economic development of Ghana through the local and international markets. Ghana has great potentials to reap foreign exchange from the export of papaya and need to step up investment in this area. It has the comparative advantage in agro-ecology and institutional environment that can make it a major producer and exporter of papaya; Ghana's geographical location offers favorable climate for papaya production; abundance of sunlight and water, fertile soil and absolutely frost-free conditions (Masahudu, 2009). In Ghana, crops such as pineapples, papaya and mangoes appear promising as options to diversify the traditional exports like Cocoa, Timber and Gold, because of their high labor intensity and the expanding demand for fruits in industrialized nations. The domestic market absorbs a large quantity of fruits when there is an excess supply or when the produce does not meet export quality norms and standards. Producers usually prefer to sell their produce to exporters and the export processing companies because of high prices offered. Ghana's once thriving smallholder papaya production for export has been sidestepped by the market in recent years due to the shift in popularity from the Solo cultivar – traditionally shipped by air – to the Golden variety, capable of withstanding sea freight. Only industrial farms made the switch because the new Golden cultivar requires irrigation and cannot withstand the traditional rain-fed cropping practices used by most smallholder farmers (Egyir*et al.*, 2012).

In Benin, the papaya production is oriented to local market, mainly for urban consumers. Local and improved varieties are concerned, but the successful enterprises, targeting the urban market use the improved variety "Sunrise solo 7212". The production area is located to the southern region of Benin and main producers are vegetables growers.

Papaya is known suffering from infestation of mealybug (*Paracoccusmarginatus*), a new invasive and highly polyphagous pest spreading throughout West and Central Africa. It is then observed a dis-motivation of producers in cultivating the papaya. Specific biological control agents was introduced by IITA (International Institute of Tropical Agriculture) to permanently reduce papaya mealybug pest populations for prevent economic and income losses whilst maintaining sustainability through the application of environmental friendly control methods with no pesticide use. This measure led to increase papaya production area. Various production systems can be observed in both countries. Therefore, the objective of this study is to assess the efficiency level and identify factors influencing the inefficiency of papaya production systems in the view to analyze the competitiveness in Benin and Ghana.

METHODOLOGY

- ***Study area***

The study is conducted using cross-sectional data collected from papaya production systems in the sub-humid zones of West Africa. Two West African countries namely, Benin and Ghana were selected for the study.

The Sub-humid agro-ecological zone with a bimodal rainfall pattern is characterized by a long rainy season from middle-March to July followed by a relatively dry period in August, and a short rainy season of about two and half months starting in September. The annual average potential evapo-transpiration (PET) is 1322.2 mm, this corresponds to a Length of the Growing Period (LGP) of 240 days. The annual rainfall varies between 900 to 1400 mm. Average minimum and maximum daily temperatures are 27 and 31° C respectively. All the farmers in Benin are involved in papaya production for domestic market, whereas, in Ghana, an important part of the production targets the export market. The other main crops grown in both countries Benin and Ghana include maize and cassava.

- ***Sampling***

The study zones were chosen according to the importance of the production. Major papaya producing districts were purposively selected per country. Districts were selected on the basis of their high papaya density and they easy accessibility. These areas are of course covered by the project operation for the biological control.

In Benin, 5 districts were selected in the Southern region: Abomey-Calavi, Allada, Ouidah, Tori and Zê. In Ghana, 3 districts were selected in the Eastern and Central regions: Ayensuano and Nsawam Adeagyiri (Eastern) and Awentu–Senya in Central. In Benin, 20 villages were sampled covering 52 households, while 25 villages, with 60 households were selected in Ghana for data collection.

- ***Data, Variables and a Priori Expectation***

Both primary and secondary data were used in this study. However, primary data was mainly used for the empirical analyses. Secondary data were collected from reports and journals. The primary data were collected during 2015 production year through structured questionnaires

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administered to the sampled papaya producers. Out of 120 papaya producers, in both countries, sampled to be interviewed; only 112 of them responded to the questionnaires and were subsequently used for the analysis. The questionnaires were designed to generate information describing the characteristics of the sampled papaya producing communities and households and it covers areas such as their demographics characteristics, production characteristics and institutional factors. The production quantity is estimated through data collected with questionnaires. The quantities of the following data have been estimated: seed, chemical fertilizer, organic fertilizers, chemical pesticides, bio pesticides, labor, irrigation cost, equipment cost and the land represented by the area of papaya production.

All these variables are expected to have positive effects on the papaya production. So they are expected to positively influence technical efficiency.

- ***Model: Inefficiency effects***

Household characteristics such as age, experience in papaya production, sex, education and household size are included in the inefficiency effect models.

The experience of the household head could either be negative or positive. If older farmers are interested in to adopting better practices for papaya production while younger farmers were more motivated to embrace productivity enhancing technologies that reduces technical inefficiency, then experience will be expected to be positive effect on technical inefficiency. On the contrary, if more experienced farmers who have relatively better access to productive resource are able to translate their experience and knowledge of the production activities into efficient utilization of inputs, then age will be expected to be negative.

More years of education is expected to negatively influence technical inefficiency. As an indicator for human capital, educated farmers have the ability to convert productive inputs to improved productivity (Villano and Fleming, 2006; Ghafoor et al., 2010).

Sex of the household head was assigned the value 1 for male and 0 for female and is expected to have a negative influence on technical inefficiency. Males were expected to have better access to production resources than females in the study locations, and hence are expected to be less technically inefficient.

Larger household size means more labor available for carrying out farming activities in a timely fashion, therefore making the production process more efficient; hence household size is expected to have a negative influence on technical inefficiency.

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Land acquisition is expected to influence the inefficiency. The land tenure status of renting and lease will have a negative effect on the efficiency, contrary to heritage and buying.

- ***Empirical framework***

To estimate the determinants of technical inefficiency in papaya production systems in West Africa, this paper uses the parametric stochastic frontier approach because it allows for conventional statistical tests to be carried out, and also accounts for measurement errors in both the output and the stochastic element and further decompose the effect of noise from the inefficiency effect. We estimate the stochastic frontier efficiency model with purely production covariates and incorporate other household, farm-level and institutional covariates in the stochastic frontier inefficiency model.

The Cobb-Douglas production functional form was considered to define the relationship between output and inputs.

Following Battese and Coelli (1995), the Cobb-Douglas stochastic frontier model is defined by:

$$\ln y = \beta_0 + \beta_1 lnx_{i1} + \beta_2 lnx_{i2} + \beta_3 lnx_{i3} + \beta_4 lnx_{i4} + \beta_5 lnx_{i5} + \beta_6 lnx_{i6} + \beta_7 lnx_{i7} + \beta_8 lnx_{i8} + \beta_9 lnx_{i9} + v_i - u_i$$

where the subscript i indicate the i^{th} farm household in the sample (i=1, 2, …, N);

Y represents the quantity of papaya fruits harvested for the sampled farmer;
x_1 is the quantity of seed (kg);
x_2 is the quantity of chemical fertilizer (kg)
x_3 is the quantity of organic fertilizer (kg)
x_4 is the quantity of chemical pesticide (liter)
x_5 is the quantity of Bio pesticide (liter)
x_6 is the quantity of labor (in man days)
x_7 is the irrigation cost (in USD)
x_8 is the equipment cost (in USD)
x_9 is the total area of *land* (in hectares) used in production

the $v_i s$ are random errors that are assumed to be independently and identically distributed as $N(0,\sigma_V^2)$-random variables; the $u_i s$ are the non-negative technical inefficiency effects that are assumed to be independently distributed among themselves and between the $v_i s$, such that u_i is defined by the truncation (at zero) of the $N(\mu_i,\sigma^2)$ distribution, where μ_i is defined by:

$$\mu_i = \delta_0 + \sum_{j=1}^{3}\delta_{0j}D_{0ji} + \sum_{j=1}^{4}\delta_j Z_{ji} \qquad (3)$$

where D_{01} is the categorical variable that has value 1 if the farmer has none education, 2 for Primary education, 3 for secondary education, 4 for university level, 5 for alphabetization (*education*);

D_{02} is the dummy variable that has value 1 if the farmer had access to land by heritage, and 0 otherwise (*Heritage dummy*);
D_{03} is the dummy variable that has value 1 if the farmer had access to land by renting and 0 otherwise (*Renting dummy*);
D_{03} is the dummy variable that has value 1 if the farmer had irrigated the papaya plantation and 0 otherwise (*Irrigation dummy*);

Z_1 represents experience of the household head (in years) (*experience*);
Z_2 represents the household size (number) (*HH Size*);

The technical efficiency of the *i*-th farmer is defined by

$$TE_i = e^{-U_i} \qquad (4)$$

where the distribution of the $U_i s$ is defined by the specifications of the inefficiency model in equation (3).

The prediction of the technical efficiencies is based on its conditional expectation, given the unobservable composed error, $V_i - U_i$ (see Jondrow et al., 1982; and Coelli et al., 2005).

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- ***Empirical Analysis***

In the technical inefficiency model of equation (3), we control for variations in technical inefficiency that are attributable to differences in socio-economic bio-physical and institutional factors. In the stochastic frontier model, the main focus is to assess the technical efficiency of papaya crop production. Consequently, the covariates are purely inputs used in papaya production.

The parameters of the stochastic frontier production function model, defined by equations (2) and (3), are jointly estimated by the maximum-likelihood technique using the computer programme STATA, version 10.1.

The generalized likelihood-ratio test is applied to test various hypotheses for the parameters in the frontier production function and in the inefficiency models. The generalized likelihood-ratio test statistic is defined by

$$\lambda = -2\{\ln[L(H_0)/L(H_1)]\} \quad (5)$$

where$L(H_0)$ and $L(H_1)$ denote the values of the likelihood function under the null (H_0) and alternative (H_1) hypotheses, respectively. If the null hypothesis is true, the test statistic has approximately a chi-squared or a mixed chi-squared distribution with degrees of freedom equal to the difference between the numbers of the parameters involved in the alternative and null hypotheses. If the inefficiency effects are absent from the model, as specified by the null hypothesis, $H_0 : \delta_0 = \delta_{01} = \delta_{02} = \delta_1 = ... = \delta_4 = \gamma = 0$, where $\gamma = \sigma^2 / \sigma_S^2$ and $\sigma_S^2 = \sigma_V^2 + \sigma^2$, then λ is approximately distributed according to a mixed chi-squared distribution with at least 8 degrees of freedom.

In other hand, it is also of considerable interest to explain the technical efficiency scores by estimating the determinants of the inefficiency of papaya production systems as defined above. The common econometric method usually used by previous studies is the Tobit regression model. This stage of analysis explains relationships between the technical efficiency measure and other relevant variables such as age of head household, level of education, experience of farmers and the land status. Javed et al. (2010) also used similar approaches to investigate the efficiency and the determinants of efficiency of rice- wheat system. The Tobit model is defined as follows for observations:

y* = x β+u i =1,2,…..n,
yi=yi*ifyi*<0

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y = 0, otherwise

where u ~N(0,Σ2),X and β are vectors of explanatory variables and unknown parameters which determines the relationship between the independent variables and the latent variable, respectively. The y* is a latent variable and y is the frontier production score (Amemiya 1984).

RESULTS AND DISCUSSION

Descriptive statistics of the households sample

The table 1 presents descriptive statistics of the sample households. On average, household heads were about 7 years of experience in papaya production; in Benin, it is about 6 years and 8 in Ghana. Irrigation is more practiced in Benin (44%) with 20% of women. Less than 10% of producers (with no women) practiced irrigation in Ghana where papaya production is more rainfed. The use of chemical fertilizers is more important in Ghana than Benin: 80% in Ghana including 91% of women whereas we have 50% in Benin with 80% of women. But the use of organic fertilizers is more important in Benin (75%) than Ghana (23%). Organic fertilizers are composed essentially of poultry droppings and crop stalks. Chemical pesticide is less used in Benin (52%) with an average of 0.76 liter than Ghana (83%) with an average of 9.95 liters and a bio-pesticide of 44.89 liters. Also, the use of other inputs like chemical fertilizer and labor (including hired and family) is more important in Ghana than Benin. An average, 50% of producers own their land by heritage and buying than in Ghana, where the land statuses are more the renting and the lease. More than 80% of producers in both countries are educated, with on average secondary education level.

Table1: Descriptive statistics of papaya producing households in Benin and Ghana

	Benin (N=51)		Ghana (N=60)	
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Production	115861,72	339902,76	186487,93	88222,84
Seed quantity	3,19	3,73	4,35	3,27
Chemical fertilizer	169,52	699,41	382,89	568,44
Quantity of Organic fertilizer	63,44	91,22	3,15	24,21
Quantity of Chemical pesticide	0,76	1,71	9,95	18,27
Quantity of Bio pesticide	-	-	44,89	195,32
Quantity of Total Labor	187,67	237,67	556,67	1166,03

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Irrigation cost	238787,18	910091,49	-	-
Equipment cost	438139,68	636637,60	10753,12	22226,73
Area	1,33	1,95	2,40	3,97
Education	2,51	0,92	2,98	1,32
Experience	6,51	4,81	8,22	4,38
Household size	8,39	3,75	6,68	4,20
Land status:				
- Heritage	0,35	0,48	0,08	0,28
- Buying	0,12	0,32	-	-
- Renting	0,49	0,50	0,53	0,50
- Lease	-	-	0,20	0,40
Practice of irrigation	0,45	0,503	0,07	0,252

EMPIRICAL RESULTS

Technical efficiency of papaya production in Benin and Ghana

The production function indicates that there is inefficiency in the papaya production, as well as in Benin and Ghana (Lamda>1); Lamda = 2.870 and 3.012 in Ghana and Benin respectively.

In Benin, the technical efficiency level is lower than the results of producers from Ghana (table2).

In Ghana, variables including seed quantity, labor, pesticide quantity, equipment cost and the plot area determine the production level. But in Benin, only the plot area is significant. This result indicates that the current level of input use don't allow to realize a differential optimal production. Inputs, such as used now don't determine significantly the production level.

In Ghana, the way, seeds are used presents some advantages for this country than in Benin. This factor presents a positive and significant elasticity on the production. But the current use of the pesticide has negative effect on the production. This means that in both countries, producers continue to use pesticide whereas biological control has been undertook by the project in surveyed areas. So the intensive use of chemical pesticide like in the past time is not again needed and could be not efficient for the production. The seed effect on the production means

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that producers are more using this resource than it can be, and need to be defined properly in the different production systems.

Plot area is the only one factor which has the greatest elasticity in the function production in both countries. Some studies showed the influence of the plot area on the technical efficiency (Alvarez and Arias 2004), Thiam et al.and Nyemeck et al. 2001, Helfand and Levine 2004; Konan et al. 2014). This can be understood that production function is very sensible to the plantation area. An increasing plantation area leads to the efficiency increasing. This result shows the positive effect of the specific biological control agents to permanently reduce papaya mealybug on the papaya production and indicates that the project operation has more encouraged producers to cultivate. In fact, Goergen at al. (2015) reported that the use of the classical biological control reduced drastically the papaya mealybug populations in areas treated.

Table2: Estimation of the frontier production function

Ln quantity production	**Ghana**				**Benin**			
	Coef.	**Std. Err.**	**Z**	**P>z**	**Coef.**	**Std. Err.**	**z**	**P>z**
Ln quantity of seed	0.418***	0.147	2.84	0.005	0.210	0.470	0.45	0.655
Ln quantity of chemical fertilizer	-0.033	0.044	-0.75	0.456	0.007	0.055	0.12	0.903
Ln quantity of organic fertilizer	-0.022	0.078	-0.28	0.779	0.082	0.067	1.23	0.219
Ln quantity of chemical pesticide	-0.254**	0.100	-2.54	0.011	-0.006	0.256	-0.02	0.982
Ln quantity of bio-pesticide	-0.019	0.055	-0.35	0.725				
Ln quantity of labor	-0.999**	0.418	-2.39	0.017	-0.040	0.093	-0.43	0.664
Ln irrigation cost					0.012	0.021	0.59	0.557
Ln equipment cost	0.814*	0.440	1.85	0.064	-0.079	0.074	-1.07	0.285
Ln area	1.715***	0.148	11.63	0.000	2.789***	0.276	10.09	0.000
Constant	9.352	1.490	6.28	0.000	9.869	0.911	10.84	0.000

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/lnsig2v	-2.652	0.778	-3.41	0.001	-1.752	0.738	-2.37	0.018
/lnsig2u	-0.544	0.414	-1.31	0.189	0.453	0.382	1.18	0.236
sigma_v	0.266	0.103			0.416	0.154		
sigma_u	0.762	0.158			1.254	0.240		
sigma2	0.651	0.202			1.746	0.524		
Lambda	**2.870**	0.245			**3.012**	0.361		
	Stoc. frontier normal/half-normal model; N=51; Wald chi2(8)= 171.34 ; Log likelihood=-62.4891; Prob> chi2=0.000 Likelihood-ratio test of sigma_u=0: chibar2(01) = 2.40 Prob>=chibar2 = 0.061				Stoc. frontier normal/half-normal model; N=60; Wald chi2(8)=322.48; Log likelihood=-44.8277; Prob> chi2=0.000 Likelihood-ratio test of sigma_u=0: chibar2(01) = 5.32 Prob>=chibar2 = 0.011			

*Note: The asterisk ***, ** and *, on estimates indicate significance at the 1%, 5% and 10% levels, respectively.*

Technical efficiency indexes

The average level of efficiency at Ghana is about 60%, whereas it is less than 50% in Benin (47%) (table3). The maximum level is around 90% in Ghana, but 83% in Benin; the lowest efficiency level is obtained in Benin. This indicates that there is presence of inefficiency at papaya producers' level.

The efficiency level, according to production systems has some variability. Efficiency level of intensive production system are more important than other results. In Benin, intensive production system presents good results. However, the irrigated intensive system, with modern irrigation don't succeed to do an efficiently use of inputs and equipment in the exploitation. These results show that papaya production systems have still had an important potential to increase their productivity, in both two countries. The way of using the best practices is so required for smallholders. The best results from Ghana are for the intensive manual irrigation and then the traditional systems. The most practiced system in this country (the semi-intensive) is the less efficient compared to the other systems: the semi-intensive system concerned by more than 81%

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of producers has on average an efficiency score of 58.55%, whereas, the two others systems are respectively about 68% and 63%.

Table3: Efficiency levels per country

Production System	Ghana						Benin					
	<0.50		>=0.50<0.75		>=0.75		<0.50		>=0.50<0.75		>=0.75	
	N	%	N	%	N	%	N	%	N	%	N	%
Traditional System	2	28.57	2	28.57	3	42.86	7	58.33	4	33.33	1	8.33
Semi-Intensive	16	32.65	20	40.82	13	26.53	9	50.00	7	38.89	2	11.11
Intensive manual irrigation	0	0.00	3	75.00	1	25.00	2	50.00	2	50.00	0	0.00
Intensive modern irrigation	-	-	-	-	-	-	9	52.94	6	35.29	2	11.76
Whole systems												
Mean TE (%)	59.78						47.05					
Std. Deviation TE (%)	19.36						20.82					
Minimum TE (%)	11.95						2.22					
Maximum TE (%)	89.20						82.93					
Traditional System												
Mean TE (%)	63.39						41.89					
Std. Deviation TE (%)	22.20						24.50					
Minimum TE (%)	30.57						2.22					
Maximum TE (%)	87.08						82.93					
Semi-Intensive												
Mean TE (%)	58.55						50.12					
Std. Deviation TE (%)	19.65						17.76					
Minimum TE (%)	11.95						20.62					
Maximum TE (%)	89.20						78.10					
Intensive manual irrigation												
Mean TE (%)	68.48						45.07					
Std. Deviation TE (%)	7.37						12.55					
Minimum TE (%)	60.39						32.20					
Maximum TE (%)	77.95						56.89					
Intensive modern irrigation												
Mean TE (%)	-						47.90					
Std. Deviation TE	-						23.36					

(%)		
Minimum TE (%)	-	3.31
Maximum TE (%)	-	82.92

Determinants of the inefficiency of the papaya production

The only significant variable for the efficiency for Benin is the education (table4). In Ghana, the important variables for the model significance are assumed by the acquisition status of the land in production, specifically heritage and renting.

In Benin, education revealed to be the most important factor that determines the production efficiency. Producers more educated are not necessary those with high efficiency scores, rather producers capable of using properly inputs. Also, this result could be understood as the most number of producers are educated and papaya production is practiced in Benin by the young entrepreneurs, educated persons who decided to develop their career in the agriculture. Irrigation has also the potential to increase production efficiency. To realize this potential, the irrigation system requires adequate action from producers, but also extension service and policy makers' accompaniment.

In Ghana, heritage and renting have a positive effect on the production efficiency. This means that the land status plays an important role in the papaya production in this country. The land security needs quite attention for papaya producers and the crop promotion in Ghana. Also, results revealed that education and experience in papaya production have a quite important positive influence on the efficiency. The more educated and more experienced are the farmers, the more they have a better efficiency level. These results explain that training producers is important to increase the papaya production efficiency.

Table 4: Tobit model estimation of determinants of the inefficiency (You have to describe the Tobit model methodology and then its results).

	Benin			Ghana		
Inefficiency	Coef.	Std. Err.	P>t	Coef.	Std. Err.	P>t
Education	0.071**	0.029	0.019	-0.064*	0.034	0.067
Experience	-0.007	0.006	0.264	-0.030**	0.013	0.023
Education*Experience				0.008**	0.003	0.022
Heritage	0.108	0.081	0.187	-0.230***	0.085	0.009
Renting	0.001	0.078	0.991	-0.084*	0.046	0.075
Irrigation	0.021	0.054	0.702	-0.116	0.089	0.197

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_cons	0.347	0.119	0.006	0.699	0.115	0.000
/sigma	0.180	0.018		0.1791	0.0164	
	Log likelihood = 15.1442; N =51 ; LR chi2(6)=13.97 ; Prob> chi2= 0.0158 ; Pseudo R2= -0.8558			Log likelihood = 21.6639; N =60 ; LR chi2(2)=15.58; Prob> chi2= 0.0162; Pseudo R2= -0.5617		

*Note: The asterisk ***, ** and *, on estimates indicate significance at the 1%, 5% and 10% levels, respectively.*

CONCLUSIONS AND POLICY IMPLICATIONS

Papaya production systems in West Africa, beside the mealybug problem, are technically not efficient. The efficiency level is less than 50% in Benin and 60% in Ghana. These low scores are highly influenced by farmers' motivation in performing the papaya production. The area size which presents a significant effect on the efficiency explains this idea. Results from this study undertaken shows that classical biological control of the papaya mealybug can a positive effect in the control of mealybug and hence the increase in the quantity and the improvement of the quality of fruits. It appears that the most important cropping system in Ghana has on average is the less efficient. This implies that the papaya industry in this country will gain a lot by helping producers to improve the production system and move toward the irrigation system which presents the best results. The irrigation program can further help producers to increase, apart from yield the quality of the papaya produced and help the Ghanaian papaya industry be more competitive. Results revealed that the land tenure influences the efficiency. It would be therefore one of the most important constraint which limit investment and prevent producers to move for the irrigation system. Thus, while working on the improvement of the production system land should be secured in this country. The positive results of education and experience in this country on the efficiency score inform actors on the emergency to further develop training program to enhance producers' capacity. In Benin, the best practice needs to be promoted to increase the papaya efficiency. Irrigation system should be revised to be more profitable for producers. Therefore, it is required in both countries lighted measures to overcome different constraints observed in the papaya industry, including mealybug and improved production systems.

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