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Profit loss per hectare according to profit efficiency level among smallholder rice farmers in Central Liberia

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Self-sufficiency in rice production has been an essential issue in the Liberian agriculture sector. With the increasing demand and low national productivity of rice (1.2 t/ha), Liberia remains a net importer of rice unless domestic production improves significantly. This study was conducted to analyze smallholder rice farmers' level of efficiency and profit-loss due to allocative and technical inefficiencies. A two stage random sampling with stratification was adopted to collect data from 400 rice farmers in Central Liberia. The results show that high level of inefficiency exist with 33% of profit-loss among smallholders rice farmers due to a combination of technical and allocative inefficiencies. The average profit-loss is about 19,900 LRD/ha. Factors that are related to profit-loss and inefficiency are lack of credit and extension services and the non-usage of yield improving technologies such as high yielding improved seeds, fertilizer and herbicide. Lastly, inefficiency and profit-loss were high in upland rice production than lowland rice production.

Key words: Liberia, profit-loss, inefficiency, smallholder rice farmers.

INTRODUCTION

Rice is the primary staple food crop for Liberia's 3.5 million people representing over 33% of their food consumption and accounting for approximately 50% of adult caloric intake; with an annual per capita consumption estimated at 133 kg (USAID-BEST, 2014). There is an increasing demand of rice due the increased in population, especially in the highly populated urban centers. Moreover, rice is largely a price-inelastic commodity in the household, reinforcing the colloquial expression that "one has not eaten that day if one has not eaten rice" (USAID, 2009). In Liberia, rice and its price are considered politically sensitive. Tsimpo and Wodon (2008) estimated that a 20% rise in the price of rice would increase the poverty headcount by 3 to 4% points. Furthermore, the significance of rice in the Liberian diet can be elucidated by its demand and consumption pattern over the years. Average annual production from 2009-2012 was about 290,600 metric tons whereas the total average annual consumption was over 400,000 metric tons (NRDS, 2012; FAO, 2013). With the increasing

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demand, the country will continue to be a net importer of rice unless domestic production improves significantly. This is possible since the country offers ideal conditions for rice production (NRDS, 2012; USAID-BEST, 2014).

For the past decade, there have been many interventions in the agriculture sector by the government and its partners to enhance the productive capacity of farmers to boost rice production in Liberia through research and development. There are programs created to link farmers to inputs such as improved seed, fertilizer, herbicide, insecticide, etc. Other programs have rehabilitated existing rice production facilities, constructed agro-processing facilities and farm to market roads (MOA, 2010). The crop ranks first in terms of research priorities among all crops within the Central Agriculture Research Institute (CARI). CARI conducts research and variety development for the creation of improved rice seed varieties.

Despite the high production potential and various programs, yield in Liberia is just about 1.2 t/ha (NRDS, 2012; FAO, 2013; USAID-BEST, 2014). This is low as compared to other West African countries with 2.7 t/ha in Ghana, 3.0 t/ha in Côte d'Ivoire, 3.4 t/ha in Mali and 4 t/ha in Benin (Donkoh and Awuni, 2011; Oladele et al., 2011; Donkor and Uwusu, 2014). The yield gap is approximately triple as compared to the national rice development strategy potential yield of 4 t/ha (NRDS, 2012). The above figures depict a big potential for increased output. However, the biggest challenge is limited knowledge on the causes of this gap. This study, therefore, aimed at analyzing smallholder farmers' level of efficiency and profit loss per hectare due to allocative and technical inefficiency in rice production so as to fill the identified gap.

Theoretical framework

In microeconomic theory of the firm, production (economic) efficiency is decomposed into technical and allocative efficiency. Farrell provided a framework for the computation of a production frontier. However, it was not until the work of Aigner and Chu (1968) that the frontier function was first explicitly specified in a parametric form. Afriat (1972) used a one-sided error term in which observed variations were said to be endogenous, while weather, wars and droughts were treated as random factors. Aigner et al. (1977) and Meeusen and van den Broeck (1977) employed the concept of a stochastic frontier in which a two sided random error term was introduced explicitly in a production function.

Farrell (1957), defined efficiency in his pioneering study as the ability to produce a given level of output at lowest cost. He distinguished three types of efficiency: (1) technical efficiency, (2) price or allocative efficiency and (3) economic efficiency which are the combination of the first two. Technical efficiency is an engineering concept referring to the input-output relationship. A firm is said to be efficient if it is operating on the production frontier. On the other hand, a firm is said to be technically inefficient when it fails to achieve the maximum output from the given inputs, or fails to operate on the production frontier. Technical efficiency represents a farm's ability to produce a maximum level of output from a given level of inputs. Allocative efficiency is the ability of a farm to use inputs in optimal proportions, given their respective prices and available technology (Rahman, 2003). The combination of technical and allocative efficiency provides the level of economic efficiency. That is to say, if the farm uses resources allocatively and technically efficiently, it is said to have achieved total economic or profit efficiency.

According to Ali and Flinn (1989), profit efficiency, within a profit function context, is defined as the ability of a farm to achieve the highest possible profit, given the prices and levels of fixed factors of that farm and profit inefficiency is defined as profit loss from not operating on the profit frontier given farm specific prices and resource base. Ali et al. (1994) stated that profit function approach combines the concepts of technical and allocative efficiency in the profit relationship and any error in the production decision is assumed to be translated into lower profits or revenue for the producer.

Battesse and Coelli (1995) extended the stochastic production frontier model by suggesting that the inefficiency effects can be expressed as a linear function of explanatory variables, reflecting farm-specific characteristics. The advantage of Battesse and Coelli (1995) model is that it allows estimation of the farm specific efficiency scores and the factors explaining efficiency differentials among farmers in a single stage estimation procedure. The present paper utilizes this Battesse and Coelli (1995) model by postulating a profit function, which is assumed to behave in a manner consistent with the stochastic frontier concept. The stochastic profit function is defined as:

$$\pi_i = f\left(P_{ij}, Z_{ik}\right).\exp(\varepsilon_i) \quad (1)$$

Where π_i is the normalized profit of the i^{th} farm defined as revenue less variable cost, divided by farm specific output price; P_{ij} is the price of j^{th} variable input faced by the i^{th} farm divided by output price; Z_{ik} is level of the k^{th} fixed factor on the i^{th} farm; ε_i is an error term and i =1,…,n, is the number of farms in the sample.

The error term (ε_i) is assumed to behave in a manner consistent with frontier concept (Rahman 2003; Tsue et al. 2012):

$$\varepsilon_i = V_i - U_i \quad (2)$$

Where V_is is assumed to be independently and identically distributed $N(0, \sigma_v^2)$ two sided random errors, independent of the U_is; and the U_is is non-negative random variables, associated with inefficiency in production, which are assumed to be independently distributed as truncations at zero of the normal distribution with mean, $\mu = \delta_0 + \sum_d \delta_d W_{di}$ and variance $\sigma_u^2(|N(\mu, \sigma_u^2|)$, where W_{di} is the d^{th} explanatory variables associated with inefficiencies on farm i and δ_0 and δ_d are the unknown parameters.

MATERIALS AND METHODS

Study location and sampling procedure

This study was conducted in Liberia, in 2015 in two Counties, namely, Nimba and Bong. These two Counties are located in the Central Region of Liberia. Nimba and Bong are generally suitable for rice production; hence it was appropriate for this study. The two Counties ranked the highest in the 2011 rice production with about 61,600 (21.2%) and 60,900 (21.0%) metric tons, respectively. The combined estimates of these two counties accounted for 42.2% of the total production and 41.2% of area of rice harvested in Liberia (NRDS, 2012).

The study adopted a two stage random sampling with stratification. At the first stage, villages from each district were stratified into two (that is, upland and lowland rain-fed villages). In the second stage, a simple random sampling method was used to select farmers from village list of rice producers on probability proportional to size basis. Thus, in all, 400 rice producers (200 from Nimba and 200 from Bong) were selected from the villages. A structured questionnaire was then used to collect primary quantitative data from the sampled population. The data included information on rice farming operations such as: quantities of seeds, planting and topdressing fertilizer, herbicides, pesticides, land area, labour man-days and output data for rice such as quantity sold, consumed and retained for seed. In addition, information on average input prices was also collected from the respondents. Additional data focused on household socio-economic and institutional characteristics such as the farmer's age, sex, years of schooling, farming experience, main occupation, household size, income and asset profiles, distance to the market, marketing information, extension contacts, group membership, pre and post-harvest loses and credit.

Method of analysis

The stochastic profit frontier function (Equation 3), and the inefficiency function (Equation 4) were estimated using the FRONTIER 4.1 computer software (Coelli, 1996). The program combines the two-stage procedure into one and produces maximum likelihood estimates of the parameters of a stochastic profit frontier function. This procedure is superior to two-stage procedures because it does not violate the assumption that the inefficiency effects are independently and identically distributed (Battesse and Coelli, 1995; Coelli, 1996; Kumbhakar et al., 2015). After the translog stochastic frontier estimate, individual farmers efficiency score and actual profit were used to calculate profit loss (Equation 5) using Microsoft Excel and finally, profit efficiency scores and profit loss for the farmers were categorized into tercile (low, medium and high) and analyzed using IBM SPSS vision 21.

Empirical model

This study estimates a flexible translog profit function and inefficiency models for rice production in Central Liberia. More details on the selection of the functional form are according to Saysay et al., 2016. The models were derived as follows:

$$ln\pi' = \alpha_0 + \sum_{i=1}^{4} \alpha_1 lnP_i + \frac{1}{2}\sum_{i=1}^{4}\sum_{k=1}^{4} \tau_{ik} lnP_i\, lnp_k + \sum_{i=1}^{4}\sum_{l=1}^{1} \emptyset_{il} lnP_i\, lnZ_l + \sum_{l=1}^{1} \beta_l lnZ_l + \frac{1}{2}\sum_{l=1}^{1}\sum_{q=1}^{1} \varphi_{lq} lnZ_l\, lnZ_q + v - u \quad (3)$$

And

$$u = \delta_0 + \sum_{d=1}^{11} \delta_d W_d + \omega \quad (4)$$

Where, π' = restricted profit (total revenue less total cost of variable inputs) normalized by price of output (Py); P_i = price of the ith input (Pi) normalized by the output price (Py), where (i = 1, 2, 3, and 4): P_1 = Seed cost normalized by output price of rice (Py); P_2 = fertilizer cost normalized by output price of rice (Py); P_3 = herbicide cost normalized by output price of rice (Py); P_4 = labour cost normalized by output price of rice (Py); Z_l = the quantity of fixed input (l =1); Z_1 = Area planted with rice (hectare under rice); v = two sided random error; u = One sided half-normal error; ln = Natural logarithm; W_d = variables explaining inefficiency effects; d_1 = education; d_2 = farming experience; d_3 = off-farm income; d_4 = household size; d_5 = occupation; d_6 = lack of credit; d_7 = lack of extension services; d_8 = group membership; d_9 = market information access; d_{10} = variety; d_{11} = agroecology

After rice farmer profit efficiency level was known, the profit loss was calculated using the following formula:

$$PL = Maximum\ profit\ (1 - PE) \quad (5)$$

Where, PL is the profit loss and PE is the profit efficiency. The maximum profit per hectare could be calculated by dividing the actual profit per hectare with the efficiency level.

RESULTS AND DISCUSSION

Profit loss according to profit efficiency level per hectare among rice farmers

The indication of profit loss is also a chance of enhancing profit efficiency by identifying the source of profit loss. The results in Table 1 show that profit loss is higher at a lower efficiency level and profit loss is also negatively related to farmer's actual profit. The average profit loss among rice farmers is relatively high approximately more than 19,900 Liberian dollars (LRD) per hectare. This is an indication that there is still a relatively high profit potential to be obtained by farmers if rice production is conducted technically and resources allocated efficiently in the study area.

The average profit efficiency level among rice farmers in the study area was about 67%, indicating the existence of a relatively large level (33%) of profit-loss due to a combination of technical and allocative inefficiencies. In order to determine the characteristics that distinguish profit efficiency level among rice farmers in the study area, profit efficiency scores by farmers were categorized into three, that is, low, medium and high. The low profit

Table 1. Profit loss according to profit efficiency level for rice farmers.

Efficiency range	Frequency	Percentage	Actual profit (LRD/ha)	Profit loss (LRD/ha)
0.10 - 0.20	9	2.3	6,362.86	34,143.19
0.21 – 0.30	14	3.5	11,078.41	32,170.07
0.31 – 0.40	28	7.0	21,411.18	37,185.32
0.41 – 0.50	28	7.0	20,941.74	25,211.30
0.51 – 0.60	38	9.5	29,939.67	23,011.56
0.61 – 0.70	62	15.5	37,254.61	18,915.47
0.71 – 0.80	107	26.8	52,161.24	16,304.69
0.81 – 0.90	110	27.5	83,458.64	14,601.50
0.91 – 0.99	4	1.0	175,047.14	15,900.81
Total	400	100		
Mean			50,769.07	19,915.86
Min			1.05	0.33
Max			245,362.53	90,819.79
Std. Dev			35868.20	10547.71
Median			43,114.94	17,580.16

NB: LRD = Liberian dollar: 85 LRD = 1 USD (March, 2014 Central Bank of Liberia exchange rate).

Table 2. Descriptive statistics of profit efficiency tercile in Nimba and Bong Counties.

Category	N	Mean	St. Dev	Min	Max
Low	139	0.46	0.14	0.13	0.64
Medium	133	0.73	0.04	0.65	0.79
High	128	0.86	0.03	0.80	0.93
Total	400	0.67	0.19	0.13	0.93

efficiency farmers represented 35% of the sample population with the mean efficiency score of 0.46, the medium profit efficiency farmers accounted for 33% with the mean efficiency score of 0.73 and the high profit efficiency farmers represented 32% of the sample population with the mean efficiency score of 0.86 (Table 2).

Profit efficiency and profit loss terciles in rice production among farmers

The results in Tables 3 and 4 discuss profit efficiency and profit loss terciles among rice farmers in the study area. The results show that the proportion of upland rice farmers in the low profit efficiency category is more than twice of farmers in the lowland ecology. On the other hand, the proportion of rice farmers in the high profit efficiency category is approximately two times as larger than farmers in the upland ecology (Table 3). In terms of profit-loss, the proportion of farmers in the upland ecology in the high profit loss category is more than twice larger than the lowland farmers (Table 4). The Chi square test results show a strongly statistically significant difference (P = 0.000). This implies that farmers who are in the lowland ecology as compared to upland farmers tend to be more profit efficient and incur less profit loss.

Furthermore, farmers who cultivated improved (high yielding) varieties as compared to local varieties tend to be more profit efficient and experience less profit-loss (Tables 3 and 4). There is a strongly statistically significant difference between rice varieties cultivated by farmers among the profit efficiency and profit loss categories (P = 0.000). This implies that farmers who cultivated improved variety get high actual profit per hectare due to high output per hectare. The evidence with respect to the effect of improved variety indicates profits higher for those farmers paying higher prices for seeds. However, this may partially reflect farmers' profit made due to use of improved (high yielding) varieties; as it has been noted that the improved varieties seed prices are usually much higher as compared to the local varieties. This result is consistent with finding of Wadud and Rashid (2011) and Galawat and Yabe (2012). Therefore, adopting improved (high yield) varieties in rice production will improve profit efficiency. In addition, farmers who use fertilizer and herbicide in rice production were more in the high profit efficiency category than

Table 3. Profit efficiency tercile in rice production among farmers in Nimba and Bong Counties.

Variable		No.	Profit efficiency tercile LRD/ha			Chi square	P value
			Low (%)	Medium (%)	High (%)		
Agroecology	Upland	225	45	30	25		
	Lowland	175	21	38	41	26.092	0.000***
Variety	Improved	186	23	30	47		
	Local	214	45	36	19	39.240	0.000***
Use of fertilizer	Used fertilizer	50	28	32	40		
	Did not use fertilizer	350	36	33	31	1.919	0.383
Use of herbicide	Used herbicide	37	38	22	40		
	Did not use herbicide	363	35	34	31	2.699	0.259
Sex	Male	348	35	33	32		
	Female	52	33	35	33	0.115	0.944
Experience	Low level experience	116	56	26	18		
	Experienced	105	43	31	26		
	High level experience	179	16	39	45	55.995	0.000***
Off-farm income	Yes	185	35	35	30		
	No	215	34	32	34	0.524	0.770
Occupation	Farming	327	31	31	38		
	Formal employment	73	52	41	7	27.000	0.000***
Access to credit	Had access to credit	245	27	31	42		
	Did not have credit access	155	48	36	16	32.842	0.000***
Extension services	Received extension services	67	25	25	50		
	Did not Receive extension services	333	37	35	28	11.025	0.004***

***Significant at 1% level.

farmers who did not use fertilizer and herbicide but Chi square result shows no statistically significant difference.

Moreover, the Chi square test result confirms that there is no statistically significant difference between sex of rice farmers and profit efficiency (P = 0.944). This result implies that sex is not essential for rice farmer's profit efficiency. Farmers who have high experience in rice farming under the high profit efficiency category were approximately two times larger than the experienced farmers and the low experienced farmers. It is important to note that more low experienced farmers (56%) were found in the low profit efficiency category as compared to the experienced and high experienced farmers. On the other hand, the proportion of farmers with low rice farming experience were more (53%) in the high profit loss category than experienced (32%) and high experienced rice farmers (21%). The Chi-square test confirms a strongly statistically significant difference in level of rice farming experience and profit efficiency (P = 0.000). This implies that farmers who have more experience in rice farming as compared to those who have less experience tend to incur less profit loss and high profit efficiency. This result conformed to the findings of Rahman (2003). Farming experience helps farmers to effectively and efficiently allocate resources, thereby allowing them to operate at higher level of efficiency.

The proportion of the respondents whose main occupation is farming under the high profit efficiency category was more than three times larger than those who were formally employed and doing rice farming as secondary occupation. On the other hand, about half of the respondents who are formally employed (50%) were under the low profit category, which is higher than those that are fully involved into rice farming (31%). The result shows a strongly statistically significant difference. The result implies that respondents who are fully involved in rice cultivation as compared to those who are partly involved in rice production tend to be more profit efficient, achieve high actual profit and incur less profit loss. Engaging in non-farm employment could deprive the farm

Table 4. Profit loss tercile in rice production among farmers in Nimba and Bong Counties.

Variable		No.	Profit loss tercile in LRD/ha			Chi square	P-value
			Low (%)	Medium (%)	High (%)		
Agroecology	Upland	225	21	35	44		
	Lowland	175	49	31	20	38.790	0.000***
Variety cultivated	Improved	186	48	32	20		
	Local	214	21	35	44	39.800	0.000***
Use of fertilizer	Used fertilizer	50	90	10	0		
	Did not use fertilizer	350	25	37	38	83.768	0.000***
Use of herbicide	Used herbicide	37	87	14	0		
	Did not use herbicide	363	28	35	37	53.170	0.000***
Gender	Male	348	33	33	34		
	Female	52	39	36	25	1.876	0.391
Rice farming experience	Low level	116	23	24	53		
	Experienced	105	32	36	32		
	High level	179	41	38	21	31.815	0.000***
Off-farm	Yes	185	35	30	35		
	No	215	32	36	32	1.627	0.443
Occupation	Farming	327	35	35	30		
	Formal employment	73	27	25	48	8.804	0.012**
Access to credit	Had access to credit	245	35	40	25		
	Did not have credit access	155	30	24	46	21.240	0.000***
Extension service	Received extension services	67	42	39	19		
	Did not receive extension services	333	32	32	36	7.083	0.029**

***Significant at 1% level; **Significant at 5% level.

of valuable time to perform farming operations in a timely manner. This result is consistent with the findings of Rahman (2003) and Islam et al. (2011) who found that non-farm employment can lead to an increase in inefficiency and profit loss. This is contrary to Hyuha et al. (2007) who found that access to off-farm income increases profit efficiency. Off-farm income can be used to purchase agricultural input and other services which can improve productivity and enhance efficiency.

The results show a strongly statistically significant difference between credit access and profit efficiency (P = 0.000). Farmers with access to credit under the high profit efficiency category are three times more than those without access to credit. On the other hand, approximately half of the farmers without access to credit (48%) were in the low profit efficiency category, which is larger than farmers with access to credit (27%) in the low profit efficiency category. Furthermore, farmers without access to credit were about twice more in the high profit loss category than farmers with access to credit. This implies that access to farm credit can increase rice farming profit efficiency and reduce profit loss. This result collaborates with the findings of Dwi et al. (2014) and Yasin et al. (2014). The importance of credit support to the efficiency and success of smallholder farmers has also recently been reported by other researchers (Rahman and Smolak, 2014; Sinyolo et al., 2016). Access to credit reduces the liquidity problem that usually affects farmers during the production period, and it enhances the use of agricultural inputs in production by ensuring that farmers secure the inputs in time. This leads to improved, farm level efficiency and agricultural productivity, resulting in increased farming revenues, which subsequently act as incentives that reduce poverty among farmers. As such, the provision of credit should be at the conduit of any effort to improve smallholder production.

The results show that the proportion of farmers with access to extension services under the high profit efficiency category was about twice larger than the farmers without access to extension services. The reverse is true for farmers without access to extension services under the low profit efficiency category, whereby the proportion of farmers without access to extension services (37%) was more than farmers with access to extension services (25%). Also, farmers without access to extension services were more (36%) in the high profit loss category than farmers with access to extension services (19%). The Chi square test confirms that there is a statistically significant difference. This implies that farmers who have access to extension services as compared to those who do not have access to extension services tend to be more profit efficient and incur less profit loss. The result shows that access to extension services can reduce profit loss, increase actual profit and profit efficiency. The result is supported by other findings of Rahman (2003) and Hyuha et al. (2007).

CONCLUSION AND RECOMMENDATION

The study shows that high level of inefficiency exists with 33% of profit-loss among smallholder rice farmers due to a combination of technical and allocative inefficiencies. Smallholder rice farmers in the study area average profit-loss was about 19,900 LRD/ha which could be minimized by improving technical and allocative efficiencies. It is indicated that farmers with more rice farming experience are more efficient and may incur low-profit loss than farmers with less experience. Furthermore, farmers who had access to credit and extension services operate at higher level of efficiency and incur less profit loss than farmers who do not. Also, farmers who were fully involved in rice cultivation were more profit efficient, achieve high actual profit and incur less profit loss than farmers who were partly involved in rice production. The study also shows that farmers in the lowland ecology are more efficient and experience less profit loss than farmers in the upland ecology. The significance of yield improving inputs such as high yielding improved rice varieties, fertilizer and herbicide in improving efficiency is also evident in this study. The use of high yielding improved rice varieties, fertilizer and herbicide enhances efficiency, increases actual profit and reduces profit loss.

The study recommends that policies and interventions in the rice sub sector should focus on the development and rehabilitation of more lowland with good source of irrigation and application of appropriate rice production technologies such as the use of improved high yielding varieties, fertilizer and herbicide. Hence, this underscores the significance of institutional support that would provide for increased participation of farmers and farmers' group in intervention programs that promote the adoption of rice yield enhancing technologies. Programs of such should include farmer field school with focus on demonstration and on-farm trails and promotional events, while rigorous efforts and attention should be given towards ensuring a wider and effective coverage for extension services.

Also, improvement in efficiency would require focused policies and programs increasing and improving access to credit to rice farmers; thereby creating incentives for farmers to get fully involved in rice production. There is need to focus on bringing micro-finance institutions closer and accessible to smallholder farmers, to enhance their ability in purchasing the much needed inputs. Alternatively, inputs credit guarantee scheme can help farmers to timely acquire inputs which will increase productivity and hence reduce inefficiency.

Conflict of Interests

The authors have not declared any conflict of interests.

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