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ECONOMICS OF WEED CONTROL PRACTICES ON RICE FARMS IN OBAFEMI-OWODE AREA OF OGUN STATE, NIGERIA

Ologbon O. A. C.[1] and Yusuf S. A.[2]
[1]Department of Agric. Economics and Farm Management, Olabisi Onabanjo University, Yewa Campus, Ayetoro, Ogun State, Nigeria
[2]Department of Agricultural Economics, University of Ibadan, Ibadan, Oyo State, Nigeria
E-Mail: chrislogem@yahoo.com

ABSTRACT

The economic analysis of weed control practices on rice farms in Obafemi-Owode area of Ogun State, Nigeria was examined. The study was based on primary data collected from 88 respondents. Multistage sampling procedures were used to randomly select the communities that were interviewed. Ten (10) major weeds were found to be predominant on the rice farms visited, which were Guinea grass, Broom weed, Stubborn grass, Carpet grass, Centro, Tridax, Amaranth, Pig weed, Goat Weed and Water leaf among others. Weed control was done by manual and chemical application methods. Average weed cost estimate in the study area was ₦80, 100.00 per hectare, Farmers' production efficiency was positively influenced by land size, hired labour, quantity of fertilizer used, cost herbicides and number of farm land cultivated. Only the frequency of manual weeding significantly increases the inefficiency level on rice farm. It was recommended that local rice farmers should be encouraged by supplying required technology inputs that may improve on their level of production, while further education should be given to farmers on fertilizer application to avoid its' excess application.

Keywords: weeds control practices, production efficiency, rice farm, herbicides, cost estimates.

INTRODUCTION

Precision farming or site-specific farming is a recent agricultural technology born out of the availability of new technologies (e.g. Differential Global Positioning System, DGPS), and socially due to greater level of farmer and government concerns about the reduction of potential agrochemical contaminants (fertilizers or herbicides). Precision farming consists of applying just the right amount of crop inputs at the right location and is based on crop and site specific requirements. Precision weed management is recommended only if the weed population within a field is distributed in patches. Such agricultural management has drawn attention to the need for methods to describe and analyze the spatial distribution of weeds, and develop weed maps for a site-specific herbicide treatment. Several techniques have been used to map weeds (González-Andújar *et al*., 2001). Methods to estimate weed densities and to evaluate weed species with real time detectors or remote sensing have been reported (Wartenberg and Dammer, 2001).

Weeds restrict crop production and so impose opportunity costs on producers and consumers from production. Such costs could translate into higher grain prices to consumers. Alternatively, widespread weed control practices increases production and this may generate lower price under the competitive market condition. Weed detection and identification have been reported by several authors using remote sensing techniques for surveying weed infestations on range and forest lands (Everitt *et al*., 1996). There has been a considerable research effort over the last few years to identify weed threshold levels in non-organic crops (e.g., Wilson, *et al*., 1993; Welsh, *et al*., 1999; Wartenberg and Dammer, 2001) however, very few studies have aimed to do the same for organic crops. This study had estimated the weed control expenditure of rice farmers and estimated the effect of the inclusion of weed control input variables on the technical efficiency of rice farms in Obafemi-Owode area of Ogun State, Nigeria.

Conceptual framework in estimating the yield loss effect of weed infestation

The impact of weeds upon a production system can be demonstrated using the basic concept of production function. The quantity of rice output is determined by the quantity of fixed and variable inputs into the production process, represented algebraically by production function.

$$Y = f(V, F) \tag{1}$$

where Y is yield, V and F are variable and fixed inputs in rice production, respectively. The variable and fixed production inputs include such factors as rice variety, soil type, soil fertility, rainfall, temperature, among others. Weed infestation affects the parameters of this relationship and reduce output for any given level of input. The yield loss associated with weeds can be expressed as a reduction in output resources (excluding expenditure on weed control) to neutralize the effects of weeds, or any combination of consequent output and revenue adjustments between the extremes. Introducing input variables specifically for weed control extends the production function framework as follows:

$$Y = f(V, H, F) \tag{2}$$

where H is weed control input such as a herbicide in rice production. Increasing the weed control input variable will reduce losses and result in a higher level of outputs V and F.

The above framework avoids comparison of the benefits of a weed control technology to a hypothetical and usually unattainable weed-free scenario. Weed losses (L) are defined as the losses resulting from yield reduction due to residual weeds after control, in addition to price

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penalties for contaminated grain. Weed control expenditure (E) is defined as the costs incurred on herbicides application, mechanical weeding and tillage. This implies a direct financial impact of weeds either as a result of income reduction from lower output, or the price effect from increasing production cost. Conceptually, weed loss effect is computed as the addition of yield loss effect (YL) and price penalty (PP) of weed infestation on a farm. Specifically, the yield loss effect of weed infestation on rice farms is determined as:

$$YL = \sum_{j=1}^{n} A_{jki} Y_0 D_{jki} \tag{3}$$

where

YL = Yield Loss due to weed infestation (Tonnes/Ha)
A = Area of farm plot infested by weed (Ha)
Y_0 = Estimated weed-free yield (Tonnes/Ha)
D = Yield loss coefficient (a constant)
j = 1… n (number of species of weed endemic on the farm plots of the i*th* rice farmer).

The subscripts j and k stand for weed type (or species) and weed density, respectively. j = 1 for grass and 2 for broad-leaves weeds, respectively (which were the focused weed types in this study). K and D are predetermined quantities in literatures (e.g., Jones *et al.*, 2000). D is a proportional factor bounded by zero; an increase in its value for any crop represents greater yield damage due to higher weed density (Jones *et al.*, 2000).

The *revenue loss* in rice crop is a function of the yield loss due to weed infestations and the commodity (rice) market price. The loss in revenue due to weed infestation is computed as:

$$RL_i = \sum_{i=1}^{m} p.YL_i \tag{4}$$

where

RL = Revenue Loss (Nigeria Naira /Ha)
P = Unit commodity marlet price (Nigeria Naira/Kg of paddy rice)
m = Number of rice plots of the i^{th} farmer infested by weed YL is as previously defined

The *price penalty* arises as a result of rice grain contamination on the field. Grain contamination refers to a reduction in the quantity and quality of grain as a result of direct contact of grains with chemical substances during weed treatment, and grain deformity as a result of stunted growth caused by heavy weed infestation. The price penalty arising from grain contamination is computed as:

$$PP = \sum N_f pc(T.P_r + G_c) \tag{5}$$

where

PP = Total Price Penalty in the study area (Nigeria Naira)
N_f = Number of farm plots affected by severe weed infestation in the 2008 cropping season in the study area
Pc = Percentage area of farm penalized for weed contamination (%Ha)
T = Total estimated tonnage of rice grain contaminated in the referenced cropping season (Tonne)
P_r = Average price reduction, computed as the difference between the asking price for uncontaminated grain and the actual price due to contamination (Nigeria Naira)
G_c= Average grain cleaning costs per farm (cost incurred in wading off the effect of grain contamination, in Nigeria Naira)

Consequently,

Weed Loss Effect = YL + PP (6)

where YL and PP are as previously defined.

Efficiency analysis of weed control technology in rice-based farming systems

Efficiency is the maximization of output input ratio. There are three components of efficiency namely; technical, allocative and economic efficiency. **Technical efficiency (TE)** is the measure of effectiveness in which maximum output is obtained from a given combination of inputs i.e., the ability to operate on the Production Frontier). Technical efficiency assumes the essential nature of output of goods and services to remain unchanged and focus on reducing the cost of input for production. **Allocative efficiency (AE)** refers to the situation where resources are given in profit maximizing sense so that the marginal value products of resources are equal to their unit prices. **Economic efficiency (EE)** combines technical and allocative efficiencies. Perfect technical and allocative efficiency implies that the firm is maximizing profit and minimizing cost for a given level of output i.e., operating on the expansion path (Ojo, 2003).

Conceptually, the i^{th} rice farm technology is represented by a stochastic production frontier as follows:

$$Y_{ii} = f(X_i \beta) + \varepsilon_i \tag{7}$$

Y_i denotes output of the i^{th} rice farm; and X_i is a vector of actual input quantities used by the i^{th} farm, including weed control herbicides and manual labour; β is a vector of parameters to be estimated and ε_i is the composite error term (Aigner *et al.*, 1977, Meeusen and Vanden Broeck, 1977), defined as:

$$\varepsilon_i = V_i - U_i \tag{8}$$

V_i is assumed to be independently and identically distributed $N(0, \sigma V^2)$ random errors, and U_i U_ls is a non negative random variables, associated with technical inefficiency in rice production, assumed to be independently and identically distributed and truncations (at zero) of the normal distribution with mean μ and

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variance, σU^2 (/N(μ,σμ²/). The maximum likelihood estimation of equation (7) provides estimators for β and variance parameters, $\sigma^2 = \sigma v_i^2 + u_i^2$ and $Y_i = \sigma u^2 / u^2$. Subtracting V_i from both sides of equation (7) yields.

$$\bar{Y} = Y_i - V_i = f(X_i\, \beta) - \mu_i \quad (9)$$

where Y_i is the observed output of the i^{th} farm, adjusted for the stochastic noise captured by V_i. Equation (9) is the basis for deriving the technically efficient input vector and for analytically deriving the dual cost frontier of the production function represented by equation (7).

For a given level of output Y_i, the technically efficient input vector for the i^{th} farm, X_i^t is derived by simultaneously solving equation (9) and the input ratios $X_1/Xi = K_i$ (i >1), where K_i is the ratio of observed inputs X_1 and X_i. Assuming that the production function in equation (7) is self-dual (e.g. Cobb-Douglas), the dual cost frontier can be derived algebraically and written in a general form as follows:

$$C_i = h(W_i, Y_i, \alpha) \quad (10)$$

where C_i is the minimum cost of the i^{th} farm associated with output, Y_i. W_i is a vector of input prices for the i^{th} farm and α is a vector of parameters. The economically efficient input vector for the i^{th} farm X_i^e is derived by applying shepherd's lemma and substituting the firm's input prices and output level into the resulting system of input demand equation:

$$\delta C_i = X^e_K (W_i, , Y_i, \phi);\ K= 1, 2,\ldots m \text{ inputs} \quad (11)$$

where Φ is a vector of parameters. The observed, technically efficient and economically efficient costs of production of the i^{th} farm are equal to W_iXi, $W_1X_1^t$ and, $W_iX_i^e$. The convectional ways of measurement of costs are compute technical (TE) and Economic (EE) efficiency indices for the i^{th} firm as follows:

$$TE = \underline{W_iX_i^t}\, W_iX_i \quad (12)$$

$$EE = \underline{W_iX^e_i}\, W_iX_i \quad (13)$$

Following Farrell (1957), the Allocative efficiency (AE) index can be derived from Equations (6) and (7) as follows:

$$AE_1 = EE = \underline{W_iX^e_i}\, W_iX_i \quad (14)$$

Thus the total cost or economic inefficiency of the i^{th} firm ($W_iX_i^t$ - $W_iX_i^e$) can be decomposed into its technical (W_iXi- $W_iX_i^{t)}$ and Allocative ($W_iX_i^t$ - $W_iX_i^e$) components and it can also be measured in a non parametric approach. Under this approach, data envelopment analysis (DEA) (Charnes *et al*., 1978) is used to derive technical, scale, allocative and economic efficiency measures.

METHODOLOGY

The study area

The area of study was Obafemi-Owode Local Government Areas (LGAs) of Ogun State, Nigeria. The State comprises of four (4) divisions, namely Egba, Ijebu, Remo, and Yewa, out of Obafemi-Owode LGA forms major rice-growing area of the State, belonging to Egba. Ogun State is in the South-western zone of Nigeria. It is bounded in the West by the Republic of Benin, in the East by Ondo State, in the North by Oyo State and in the South by Lagos State and the Atlantic Ocean. The average rainfall in Ogun State ranges between 1250mm and 1800mm with a slight bimodal rainfall distribution which peaks in June and October, which largely supports the production of rice and other arable crops. Average temperature and average relative humidity range from 24-32^{0}c and 80-90%, respectively.

Data, source and method of collection

Primary data were collected for this study using structured questionnaires and focus interview methods through a stratified random sampling technique. Responses to the researcher's questions depended largely on memory recall of the farmers, since information was sought on the rice cropping activities of the 2008 cropping season. A single rain-fed cropping regime (extending between May and October 2008) was covered in this study. Relevant information from journal materials and statistical publications were also accessed. Data relating to socio-economic characteristics, types of weed encountered in the 2008 cropping season, details of weed control inputs and cost, crop production input and output estimates were obtained from the rice farmers among other variables.

Sampling technique

Obafemi-Owode was purposively selected from among the 20 LGAs in Ogun State due to the predominant concentration of rice farmers in the area. Simple random selection was consequently carried out to select at least 60% of the major rice-growing communities within LGA to make up the sampling frame for this study. This resulted in the selection of Obafemi, Ogunmakin, Oba, Ofada, Mosunmore, Marako, Ayiwere, Owode to represent the LGA. Finally, a total of 95 respondents were interviewed from the LGA out of which 7 did not give complete information, resulting in the 88 questionnaires used for this study.

Estimating weed control expenditure on rice farms

The control cost of weed was determined from the survey, which includes the average manual weeding labour costs, the herbicide costs (pre-emergent and post-emergent herbicide) and treatment (or application) costs on rice farms cultivated in the 2008 cropping season. The costs were determined as follows, following (ABARE, 1999):

$$CC = MWC + HC$$

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where

CC = Total control cost (Nigeria Naira/ Ha)

MWC = Manual weeding cost (Nigeria Naira / Ha)
HC = Herbicide costs (Nigeria Naira / Ha)

Herbicide costs were computed as:

HC = $\sum$NAM (P_e+ P_0+ Tr)

where

HC = Herbicide cost (Nigeria Naira / ha)
N = Number of times farm were treated with herbicides
A = Farm size (Ha)
P_e = Total cost of farm pre-emergence herbicide (Nigeria Naira)/ annum
P_0 = Total cost of farm post-emergence herbicide (Nigeria Naira / annum)
Tr = Treatment / application cost per time (Nigeria Naira / manday)
M = Total quantity of labour utilized on herbicide application (manday)

Although the need for control weeds that germinate prior to crop planting is important to tillage costs, there are other reasons for tillage. Consequently, it is assumed that 75% of all tillage costs are attributable to weed control (ABARE, 1999).

Stochastic frontier production model

The stochastic frontier production model was specified to estimate technical efficiency and its determinants in weed controlled rice production in the study area.

According to Tzouvelekas *et al*. (2001), the production technology of the farmers assumes to be specified by Cobb-Douglas Frontier production function (Wadud *et al.*, 2000) that is defined by:

$$\mathrm{Ln}Y_{1i} = \mathrm{Ln}\beta 0 + \beta_1 \mathrm{Ln}x_{1i} + \beta_2 \mathrm{Ln}x_{2i} + \beta_3 \mathrm{Ln}x_{3i} + \beta_4 \mathrm{Ln}x_{4i} + \beta_5 \mathrm{Ln}x_{5i} + \beta_6 \mathrm{Ln}x_{6i} + \beta_7 \mathrm{Ln}x_{7i} + V\text{-}U$$

where

Y_{1i} = Rice output (Kg)
X_{1i} = Hectares of land cultivated to rice
X_{2i} = Quantity of seed planted (Kg)
X_{3i} = Hired labour (number)
X_{4i} = Household labour (number)
X_{5i} = Quantity of fertilizer (Kg)
X_{6i} = Cost of weed control (both manual weeding and herbicide) (₦)
X_{7i}= Number of farmland (number)
V_i = Non-negative truncation at zero or half normal distribution with N (U, δ U^2)
U_i = Technical inefficiency effect which are assumed to be independent.

The Inefficiency model in the weed-controlled rice production system is given as:

$$U_i = \theta_0 + \theta_1 \sum_{i=1}^{n} Z_i + e_i$$

where

U_i = Measure of technical inefficiency in weed controlled rice farms
Z_i = variables hypothesized to explain technical inefficiency in the weed controlled rice production systems, including:

Z_1 = Age of farmers (year)
Z_2 = Years of formal education (year)
Z_3 = Year of experience in rice farming (year)
Z_4 = Variety of rice cropped (1= Improved; 0 = Local)
Z_5 = Gender of farmer (1= male, 0 = female)
Z_6 = Weed control technology (1 = use of herbicide, 0 = manual weeding)
Z_7 = Frequency of weed control (numbers).

RESULTS AND DISCUSSIONS

Common weeds of rice farm in the study area

Ten weeds were identified on rice farm plots in Obafemi-Owode Local Government Area. The major weeds associated with rice in the study area are mainly grasses. The farmers preferred the use of selective herbicides which they reported to have found more relevant to their case in the area. Manual weeding was also used as a follow-up to herbicide for total eradication of weeds especially where weed infestation was severe. The identified weeds are listed below according to their increasing order of control difficulty, as reported by the rice farmers thus: Guinea grass (*Panicum maximum*); Broom weed (*Sida acuta*; Stubborn grass (*Eleucine indica*); Carpet grass (*Anonopus compressus*); Centro (*centrocema pubenscen*); Tridax (*Tridax procumbens*); Amaranth (*Amarathus spinosus*); Pig weed (*Boeshatia diffusa*); Goat Weed (*Agerantum conyzoides*) and Water leaf (*talinium triangulare*).

Weed control expenditure

Table-1. Estimates of weed control expenditure.

Cost item	**Weed control cost** (Nigeria naira per hectare)
Manual weeding	51,600.00
Herbicide	20,950.00
Tillage	8,550.00
Total cost of weed eradication	80,100.00
Mean farm size = 4.37 Ha	

Source: Computed from survey data, 2009

The average amount spent on rice farm in the study area on manual weeding was ₦51, 600.00 / ha while the average cost of weed control using herbicide (both pre-emergence and post-emergence) was ₦20, 950.00 / ha. The average amount spent on tillage activities (mainly ploughing and ridging) was ₦8, 550.00 / ha. This resulted in total weed control expenditure of ₦80, 100.00 / hectare.

Technical efficiency estimates

As presented in Table-2, land, hired labour, and fertilizer are statistically significant at 1% probability level, while herbicide and number of farm land cultivated to rice are statistically significant at 5% and 10% level of significance, respectively. Other hypothesized variables have no significant effect on rice output. The coefficients of all the variables are positive except for hired labour and organic fertilizer which have negative coefficients. This implies a reduction effect on rice output with an increasing usage of hired labour and organic fertilizer. This is likely to be as a result of the subsistence level of rice production in the area, even though many households are involved in rice production. The general Likelihood Ratio Test for rice production was 5.424.

Table-2. Stochastic production frontier for rice production in the study area.

Variable	Coefficient	t-value
Constant	6.014	6.1013
Land	7.405*	0.6015
Hired labour	- 6.300*	- 0.0154
Household labour	0.180	0.1526
Seed	0.207	0.2991
Fertilizer	-6.010**	-0.0126
Herbicide	2.433**	0.0170
Number of farmland	1.919***	0.0061
Diagnosis statistics sigma square	0.926	
Gamma	0.00232	0.001
Log of likelihood function	-19.87	-17.46
LR test	5.414	

Source: Computed from survey data, 2009
Figures in parenthesis are the t-values
* 1% significant level; ** 5% significant level; *** 10% significant level

Sources of inefficiency in rice production systems

Estimates of technical inefficiency of rice production are presented in Table-3. Only the frequency of manual weeding significantly increases the inefficiency level on rice farm, showing that cost of manual weeding has much negative effect on the overall output level of rice. Age, gender, educational status of the farmers, variety of rice planted and weed control technology do not significantly influence the level of technical inefficiency, against *apriori* expectation. This might be due to level / rate of rice production in the country generally. For example, Sanzidur (2006) observed that farmers with no education incurred significantly higher losses and recorded significantly low level of profit when compared with those with higher level of education.

Table-3. Determinants of technical inefficiency.

Inefficiency variables	Coefficient	t-value
Constant	0.0295	0.042
Age	0.0359	0.104
Gender	0.0133	0.281
Education	-0.0040	-0.047
Years of experience	-0.0053	-0.175
Variety of rice	-0.0189	-0.013
Weed control technology	-0.0058	-0.084
Frequency of manual weeding	-0.0785*	-3.131

Source: Computed from survey data, 2009
Figures in parenthesis are the t-values
* 1% significant level; ** 5% significant level; *** 10% significant level

Technical efficiency estimates of rice farms

The frequency distribution of the technical efficiency estimates is presented on Table-4.

Table-4. Technical efficiency of rice farmers.

Class interval	Frequency	Percent distribution
60 – 64	5	5.7
65 - 69	11	12.5
70 - 74	26	29.5
75 - 79	29	33.0
80 and above	17	19.3
Total	88	100.0
Minimum = 61	Mean = 78	Maximum = 99

Source: Computed from survey data, 2009

33% of the rice farmers are efficient at 75 - 79%, followed by the 70 - 74% (29.5% of farmers). The tables showed that majority of the farmers in Obafemi-Owode Local Government Area are efficient from 70% and above, approaching the technology frontier.

CONCLUSIONS AND RECOMMENDATIONS

Rice farmers in the study area display high level of technical efficiency, even though they operate at subsistence level of production. Educational level of the farmers does not necessarily contribute to their production efficiency as reported in literature. It was recommended that the local rice farmers should be motivated to use more of improved technologies that may increase their level of production as well as the cost incurred on tillage and manual weeding. Furthermore, the farmers should be more educated on the appropriate use of fertilizer as excess of it was found to be detrimental to rice production output.

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