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Production efficiency of charcoal producers in Odeda local government area, Ogun State, Nigeria

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Abstract
This study examined the production efficiency of charcoal producers in Odeda local government area of Ogun-state, Nigeria. Multistage sampling technique was adopted and data were collected from 80 respondents using structured questionnaire. Descriptive statistics was used to analyse socio-economic characteristics of the respondents and Stochastic Production Frontier (SPF) to evaluate the technical (TE), allocative (AE) and economic (EE) efficiency of the respondents and to identify factors affecting efficiency. The results revealed that the respondents were all male with mean age of 40.9 years, married- (78.8%) and average household size of 5 persons. Primary education was predominant (80%), mean years of experience (18 years), method of production was earthen only with mean household annual income of ₦717,929.38. A total of 16 hard wood species in ten families were identified for charcoal production. Leguminosae family with five species (31%) recorded the highest number of species. The mean TE, AE and EE were 0.8136, 0.8134 and 0.9998, respectively. The SPF estimates showed that Tree volume was negatively significant ($p<0.1$), Labour and fuel were positively significant ($p<0.01$) and ($p<0.05$) respectively. The gamma (γ) value of 91.76% indicates variation in output due to differences in technical efficiency. In relation to AE, Cost of trees and Wage rate were positively significant ($p<0.01$), Cost of fuel was negatively significant ($p<0.05$) while the Cost of transporting logs was insignificant ($p>0.1$). Conclusively, there is opportunity for increasing production by 18.6% using better technique to reduce inefficiency. Forest policy should ensure conservation and sustainable production through extension services.
Keywords: Earthen method, Income, Wage rate, Technical efficiency, Forest policy.

Introduction

Charcoal is a carbonaceous material obtained by heating wood or other organic matter in the absence of air called pyrolysis, which is, heating of wood or other substances in the absence of oxygen (Adeniyi, 1995; Ressenelear, 2009). It is usually an impure form of carbon as it contains ash. The resulting soft, brittle, lightweight, black, porous material resembles coal (FAO, 2010).The processes of charcoal production (FAO, 2011a) were documented with livelihood activities associated with the processes such as logging, kiln processing, packaging and transportation. Thus, charcoal contributes to the sustenance of the rural population. Charcoal has been used since the earliest times for a range of purposes including art and medicine, but by far its most important use has been as a metallurgical fuel. Charcoal is the traditional fuel of a blacksmith's forge and other applications where an intense heat is required. Consequently, charcoal became an export commodity across the globe, with a large market in Europe and Asia. Top five major importers are Germany-9%, China-8%, Malaysia-8%, Japan-7%, Republic of Korea-6% and others-62% (Ghilardi and Steierer, 2011). World charcoal leading producers are Paraguay-12%, India 11%, Indonesia-11%, Somalia-5% and others-51%. These producers accounted for 4% of global wood charcoal export. Other charcoal producers are Brazil, Nigeria, Ethiopia and Congo Republic. Thus, present charcoal production in Nigeria is far below world least producer and therefore charcoal producers in Nigeria need to redouble efforts for identification among committee of nations producing wood charcoal.

Price as a factor in charcoal production is significant, therefore the price of charcoal serves as a catalyst in production. Charcoal price varies, it ranges from \$170 - \$300/ton. Tropical Africa accounts for 70% of the market as source of foreign exchange. The market is all year round with a slight drop between July and September (Essiet, 2009; The Consulting, 2011). However, it is surprising to note that in year 1904, Nigeria's consumption of fuel wood and charcoal was the third highest in Africa but this has changed due to civilization and technology. The importance of charcoal in Nigeria (Kalu and Izekor, 2007) was reported in Benin City (Edo State) and the study noted that charcoal was used for cooking, roasting of suya, maize, yam and cocoyam, black smiting and bronze casting.

According to Kammen and Lew (2005), half of the world's population uses biomass fuel for cooking and by 2011, 280 million m3 in round wood (Charcoal) were produced at global level. The charcoal was consumed worldwide, with third world countries accounting for nearly all the consumption while Africa alone accounted for 50%. Thus, there was extensive use of charcoal in Southeast Asia involving 16 countries, including India, Indonesia, Philippines, Pakistan, Nepal and Myanmar.

By conducting production efficiency analysis of charcoal production in Nigeria, it is possible to identify further areas of input use that can improve the output of charcoal producers. This helps to evaluate whether there is the need for improvement in processing method or knowledge of the producers in terms of skills and conservation issues for sustainability. In other words, since production efficiency refers to utilization of production factors in the most efficient way, the factors will therefore show the contribution of the input to output and consequently welfare. This study bases its analysis on input-oriented Data Envelopment Analysis (DEA) (Charnes et al, 1981). Thus in an input/output relationship it is possible to show how resources endowment can be reduced for a given output level. However, this study is equally interested in identifying socioeconomic factors influencing charcoal production efficiency; it therefore follows recent developments in non parametric frontier modelling. This study utilized small sample and therefore the efficiency results could be biased as obtainable from DEA model. The objectives of this study are: to describe the socio-economic characteristics of the respondents, identify the method and input adopted in production and estimate technical, allocative and economic efficiencies of the respondents.

Methodology

The study area

The study was carried out in Odeda local government area, Ogun State, Nigeria. The local government is one of the twenty local governments in Ogun State. Its headquarters is located about 10 kilometres from Abeokuta, the State capital. It has an extensive landmass mostly grass and with an area of 126, 345km² and a population of 99,115 people (NBS, 2009). It shares boundaries with Ibarapa and Iddo local governments in Oyo State. The area has three major zones:

- Odeda zone: the settlements include: Odeda, Osiele, Solalu, Oluga, Olugbo, BaaleOgunbayo, BalogunItesi, Eweje farm settlement.
- Ilugun zone: Settlements here are Ilugun, Olodo, Okiri, Ojule, Apesin, Akonko, Olokemeji, KugbaAjagbe.
- Opeji zone: Settlements here include Obantoko, Adao, Alabata,Adeyemi, Opeji, Sanusi and Obete.

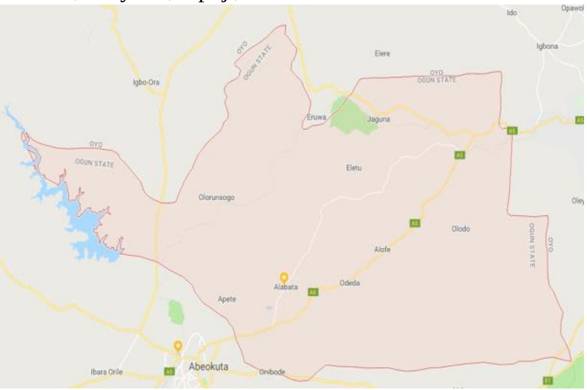

Figure 1. Map of Odeda Local Government

Sampling procedure and data collection

Multistage random sampling technique with a 3-stage design was adopted to select 80 respondents;

Stage 1: Division of Odeda local government into three (3) strata based on existing political divisions within the local government.

Stage 2: Purposive selection of villages/settlements noted for charcoal production based on reconnaissance survey

Stage 3: Simple random selection of households/respondents noted for charcoal production from selected villages (Table 1).

Table 1. Sampling plan of the study

ZONES	SETTLEMENTS	Households
Opeji	Alabata	15
	Adao	10
	Sanusi	5
	Adeyemi	7
	Opeji	15
	Solalu	8
Odeda	Olugbo	5
	Olodo	3
Ilugun	Olokemeji	12
	TOTAL	80

Source: Field survey, 2013

Data analysis

The data collected were analysed using both descriptive statistics and econometric method using Stochastic Production Frontier Approach.

The descriptive statistics include the use of frequency tables, means, percentages and standard deviation to describe the socio-economic characteristics of the respondents, tree species used in production of charcoal and the technology (method) adopted in the production of charcoal.

The Stochastic Production Frontier Approach was used to estimate the technical, allocative and economic efficiencies of charcoal producers and to identify the factors that affect efficiency of charcoal production in the study areas.

The Stochastic Production Frontier Approach

The production technology (method) of a firm was specified by the Cobb Douglas production frontier function (Farrell, 1957; Abdulahi and Eberlin, 2001; Coelli, et al, 2002 ;Barmon, 2013; Karimov et al, 2014) which is specified as follows:

$$LogY= \beta_o + \beta_1 \log X_1 + \beta_2 \log X_2 + \beta_3 \log X_3 + \epsilon \quad (1)$$

Where; Y = Natural logarithm

Y = Quantity of charcoal produced (tonne)

X_1 = Volume of trees used to produce a tonne of charcoal (m^3)

X_2 = Labour (Man days)

X_3 = Quantity of fuel per production (litres)

ϵ = error term which is equal to $V_i – U_i$; V_i represents stochastic effects outside the producers control (e.g. weather), measurement errors, and other statistical noise while $U_i$is technical inefficiency of the producers.

$\beta_{1-}\beta_3$ = Parameters to be estimated

Technical efficiency:The Technical efficiency is specified as follows:

$$T= \alpha_0 + \alpha_1 G_1 + \alpha_2 G_2 + \alpha_3 G_3 + \alpha_4 G_4 + \alpha_5 G_5 \qquad (2)$$

Where; T = Technical efficiency

G_1 = Age (Years)

G_2 = Marital status (dummy) Married=1, otherwise=0

G_3 = Household size (number)

G_4 = Level of education (Years)

G_5 = Experience (Years)

Cost Efficiency

The Cost function is specified as follows:

$$LogY = \beta_o + \beta_1 \log X_1 + \beta_2 \log X_2 + \beta_3 \log X_3 + \beta_4 \log X_4 + \epsilon (3)$$

Where; Y = Total cost of production (₦)

X_1 = Cost of trees used to produce a tonne of charcoal (₦)

X_2 = Cost of transporting trees that produce a tonne of charcoal (₦)

X_3 = Wage rate (hired labour) per production (₦)

X_4 = Cost of fuel that produce a tonne of charcoal (₦)

Allocative Efficiency: The production level, Allocative Efficiency(AE) was obtained by the inverse/reciprocal of Cost Efficiency (CE) calculated from the above equation, i.e.AE= 1/CE

Economic efficiency: EE = TE*AE(4)

Decision criteria: AE = 1, implies efficient allocation of resources; AE>1, underutilization of resources and AE<1, overutilization of resources (Adinya et al., 2010; Adinya, 2011b).

Results and discussion

The socio-economic characteristics of the respondents are summarised in Table 2. The data revealed that all the respondents were male. This is line with the findings of Kwasi et al (2012) that reported on commercial charcoal production in Upper West Region, Ghana. The production of charcoal requires a combined effort of strong individuals and it is tedious. Consequently, women hardly engage in strenuous forestry activities (FAO, 1987). The distribution by age shows that age 31-40 years (49%) recorded the highest number of respondents and age 51-60 years (5%) recorded the lowest. The average age of the respondents was 40.5years which indicates that they were adults within the active working age group. This is in agreement with the findings of Adinya et al (2012). On marital status, 17.5% were single, 78.8% married and 3.8% were divorced. This indicates that majority were married with responsibility to cater for their household. On household size, majority (1-5) recorded 75% and 6-10 recorded 25%. The mean household size was 5. This aligns with Baland et al, (2004) that reported on the positive relationship of labour input into farming.

Table 2. Distribution of respondents by socio-economic characteristics

Characteristics	Frequency	Percentage	Mean	Standard deviation
Gender				
Male	80	100.0		
Age (years)				
21-30	6	7.4		
31-40	36	44.9		
41-50	34	42.5	40.5	6.533
51-60	4	5.0		
Total	80	100.0		
Marital status				
Single	14	17.5		
Married	63	78.8		
Divorced	3	3.8	1.86	0.443
Total	80	100.0		
Household size				
1-5	60	75.0		
6-10	20	25.0	4.9	1.818
Total	80	100.0		

Source: Field survey. 2013.

Table 3 shows the distribution of the educational level,experience, source of water and type of road.Educationally,primary education was predominant (80%), secondary 18.8%, tertiary 1.2%.This is in agreement with the findings of Huynh and Mitsuyasu (2011) on rice production in Vietnam. On years of experience, 11-20years recorded the highest (61.2%) and 31-40 recorded the lowest(1.2%).This indicates that majority have experience in the business.On source of water, pipe- borne recorded 1%, Bore-hole 7%,and Stream 72%. This indicates that majority, (72%) relies on stream water. The type of road indicates that majority of the roads (61.2%) were tarred but failed indicatinginfrastructural deficit in the villages.

Table 3. Distribution of the respondents by other socio-economic characteristics

Characteristics	Frequency	Percentage	Mean/Mode
Educational level			
Primary	64	80.0	Primary
Secondary	15	18.8	
Tertiary	1	1.2	
Total	80	100.0	
Experience (years)			
1-10	8	9.8	
11-20	49	61.2	
21-30	22	27.3	18yrs
31-40	1	1.2	
Total	80	100.0	
Source of water			
Pipe borne	1	1.2	
Bore-hole	7	8.8	
Stream	72	90.0	Stream
Total	80	100.0	
Type of road			
Tarred	10	12.5	
Tarred but damaged	49	61.2	Tarred but damaged
Un-tarred but motorable	21	26.2	
Total	80	100.0	

Source: Field survey, 2013.

Table 4 shows further distribution of the respondents by other socio –economic profile. The distribution by source of funds indicates thatmajority, (90%) sourced fundpersonallyand through co-operative (10%). The type of houses indicate rural environment with majority (51.2%) of the houses built with Mud and metal roofing sheets. Bamboo hut and thatched roofing, 8.8% while Mud, plastered and metal roofing was 40%. On annual income, majority (70.4%) earned ₦250,000-₦749,000, ₦750,000-₦1,249,000 (23.3%), ₦1,250,000-₦1,749,000 (3.8%) and ₦1,750,000 and above(1.2%). The mean annual income was ₦717,929.38. This agrees with Ottu-Danquah (2010) that reported on livelihoods and welfare of charcoal producers. Technologically,earthen method was adopted for charcoal production(a traditional method of production) based on Indigenous Knowledge System. On labour, respondents relied mainly on hired family labour.

Table 4. Distribution of respondents by other socio-economic characteristics-contd

Characteristics	Frequency	Percentage	Mean/Mode
Nature of house			
Mud plus Iron roofing sheet	41	51.2	Mud plus
Mud, plastered plus Iron roofing	32	40.0	
Bamboo hut house and thatched roofing	7	8.8	
Total	80	100.0	

Source of fund			
Personal	72	90.0	Personal
Co-operative	8	10.0	
Total	80	100.0	
Annual income (₦)			
250,000-749,000	57	70.4	
750,000-1,249,000	19	23.3	
1,250,000-1,749,000	3	3.8	₦717,929
≥1,750,000	1	1.2	
Total	80	100.0	
Method adopted in production			
Kiln method	0	0.0	
Earthen method	80	100.0	Earthen method
Total	80	100.0	
Type of labour (operation)			
Family labour	0	0.0	
Hired labour	80	100.0	Hired
Total	80	100.0	

Source: Field survey, 2013.

Table 5 shows the tree species used in charcoal production. A total of sixteen species were identified in nine families. Leguminosae with five species recorded the highest number of species and sub family Papilionaceae with three species had the highest number among the sub-families of leguminosae.

Table 5. Summary of tree species used for charcoal production

S/n	Botanical name	Family	Local name	Source
1	*Margaritaria discoidea*	Euphorbiaceae	Asasa	Farmland
2	*Vitellaria paradoxa*	Sapotaceae	Emi	Farmland
3	*Pterocarpus erinaceus*	Leguminosae: Papilionaceae	Apepe	Farmland
4	*Anogeisus leiocarpa*	Combretaceae	Orin dudu	Free areas
5	*Distemonanthus benthamianus*	Leguminosae: Caesalpinaceae	Ayan	Free areas
6	*Cleistopholis patens*	Annonaceae	Apako	Free areas
7	*Albizia lebbeck*	Leguminosae: Mimosaceae	Ayunre	Farmland
8	*Milicia excelsa*	Meliaceae	Iroko	Free areas
9	*Lophira lanceolata*	Ochnaceae	Ekki	Forest
10	*Blighia sapida*	Bignoniaceae	Isin	Free areas
11	*Alstonia boonei*	Apocynaceae	Ahun	Forest fringes
12	*Azadirachta indica*	Meliaceae	Dongoyaro	Free areas
13	*Haplormosia monophylla*	Leguminosae: Papilionaceae	Akoriko	Forest
14	*Dalbergia sissoo*	Leguminosae: Papilionaceae	Ojiji	Free areas
15	*Psidium guajava*	Myrtaceae	Guava	Farmland
16	*Guarea cedrata*	Meliaceae	Olofun	Free areas

Source: Field survey, 2013

Estimating the technical efficiency

Table 6 shows technical efficiency of respondents. Tree volume was negatively significant ($p<0.1$), Labour and fuel were positively significant ($p<0.01$) and ($p<0.05$) respectively. This implies that 1% increase of Labour and fuel would increase output of charcoal by 0.7294 and 0.5983unit respectively, while 1% increase in tree volume will decrease the output by 1.1338unit. Also,socio-economic characteristics of the respondents were notsignificant in the production ofcharcoal and so do not influence the quantity of charcoal produced. The gamma (γ) value indicates the relative magnitude of the variance, δ2 associated with technical inefficient effects. That is 91.76% output variation of charcoal was due to differences in technical efficiency. The Likelihood ratio was 5.305, significantly different from zero.

Table 6. Technical Efficiency of Charcoal producers

Variable	Co-efficient	T-ratio
Constant	1.7437	1.9266
Tree volume	-1.1338	-1.6916*
Labour	0.7294	6.5434***
Fuel	0.5983	2.1145**
Inefficiency		
Constant	0.3138	0.8117
Age	-0.0011	-0.1083
Marital status	-0.0148	-0.0502
Household size	-0.0617	1.1265
Educational level	0.0077	0.4538
Experience	0.0075	0.5039
Sigma-squared (δ)	0.0433	0.9749
Gamma (λ)	0.9176	1.0591
log likelihood function	40.32	
Likelihood ratio test (LR)	5.305	

***significant at 1%; ** significant at 5%; * significant at 10%
Source: Field survey, 2013.

*Cost efficiency***:** This was used to estimate allocative efficiency. Table 7 shows cost efficiency of the respondents. The cost of trees and wage rate were positively significant ($p<0.01$), Cost of fuel negatively significant ($p<0.05$) while the cost of transporting logs was insignificant ($p>0.1$). This implies that 1% increase in cost of tree and Wage rate will increase output by 0.0944unit and 0.7371 respectively while 1% increase in cost of fuel would decrease output by 0.0725.The gamma (γ) value indicates the relative magnitude of the variance, δ^2 associated with allocative inefficient effects. That is 1% variation in output of charcoal among was due to differences in allocative efficiency. The estimated sigma squared was significantly different from zero ($p< 0.01$).This indicates a good of fit and the correctness of the specified distributional assumption of the composite error term. The Likelihood ratio was 14.027, significantly different from zero.

Table 7. Cost Efficiency of charcoal producer

Variable	Co-efficient	T-ratio
Constant	5.9978	15.5523
Cost of trees	0.0944	3.3512***
Cost of transportation	0.0409	1.5155
Wage rate	0.7371	22.1749***
Cost of fuel	-0.0725	-2.2234**
Sigma-squared (δ)	0.0056	6.5006***
Gamma (λ)	0.0010	6.8256
log likelihood function	100.67	
Likelihood ratio test (LR)	14.027	

***significant at 1%; ** significant at 5%
Source: Field survey, 2013.

Distribution of Respondents by Technical Efficiency in the Study Area

Table 8 shows respondents distribution by technical efficiency. The analysis reveals technical efficiency range of between 0.80 – 0.89 as the highest, 33.8%; 0.70 – 0.79 and ≥0.90 have the same percentage of 25% each while 0.50 – 0.59 had the least percentage of 1.25%.

Table 8. Distribution of Respondents by Technical Efficiency in the Study Area

Range	frequency	percentage	cumulative percentage
0.50 - 0.59	1	1.25	1.25
0.60 - 0.69	12	15.0	16.2
0.70 - 0.79	20	25.0	41.2
0.80 - 0.89	27	33.8	75.0
≥0.90	20	25.0	100.0
Total	80	100.0	

Source: Field survey, 2013.

Comparison of the Efficiencies of the respondents in the Study Area

Table 9 shows comparison of Technical Efficiency, Allocative Efficiency and Economic Efficiency. Allocative efficiency has a mean of 0.9998 approximately 1.0, which implies efficient allocation of resources. The Technical efficiency has a mean of 0.8136 which describe how they combine different set of inputs to maximize their output. Respondents obtained 81.4% of potential output. Thus, in the short run, production may be increased by 18.6% by adopting most efficient technique (technology) to reduce inefficiency and increase resource productivity. The economic efficiency has a mean of 0.8134 that is 81.3% economic efficiency.

Table 9. Comparison of the Efficiencies

Efficiency	Range	Min	Max	Mean	Std. dev
Allocative Efficiency (AE)	.0003	.9997	1.000	.9998	.0001384
Technical Efficiency (TE)	.4112	.5573	.9685	.8136	.1033696
Economic Efficiency (EE)	.4109	.5573	.9682	.8134	.1032995

Source: Field survey, 2013.

Conclusion

This study reveals the production efficiency of charcoal producers and identifies socioeconomic factors contributing to efficiency in the study area. The respondents had 81.4% technical efficiency and 81.3% cost efficiency. Thus, technical efficiency can increase by 18.6% and cost efficiency by 18.5% with the adoption of new technology. Suggestions include high literacy level along with better production technology (kiln method) to allow female participation in charcoal production. Forest policy must promoteextension services to educate respondents on farm forestry for conservation and sustainable production.

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