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# ENVIRONMENTAL AND WELFARE EFFECTS OF LIVELIHOOD DIVERSIFICATION OF CHARCOAL PRODUCERS IN OKE-OGUN, OYO STATE, NIGERIA

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**Abstract**

*Charcoal production over the years has contributed to deforestation and environmental degradation which could affect its sustainability. Seasonality of production also makes livelihood diversification important for the producers' wellbeing. Hence, the environmental and welfare effects of livelihood diversification of charcoal producers were investigated. The study showed that 71.4% of the respondents diversified into other agriculture and non-agricultural activities. The diversification index was 0.61. With the poverty line of ₦189,023.10, 56.1% of the charcoal producers had poor welfare status (poor). The disaggregation showed that 55.7% and 43.3% of the charcoal producers that diversified and respondents that did not diversify had good welfare status, respectively. Most of the respondents with good welfare-status (non-poor) diversified into poultry, crop farming, fish farming and artisanal work (54.6%, 57.4%, 88.9%) while those that engaged in artisanal work (carpentry, bricklaying and painting among others) were poor. The average quantity of wood used per month was 89337.6kg wood (equivalent of 3.9hectares) per month to produce 8933.76kg of charcoal. Age, household size and years of experience of respondents were factors that influenced extent of livelihood diversification. Livelihood diversification positively improved respondent's welfare. Based on the large hectares of wooded land cleared for charcoal production monthly, relevant NGOs should embark on campaigns on the negative effects deforestation. Also, the Federal Government officials should mandate the Ministry of Commerce and Industry to encourage charcoal producers to engage in other economic activities through training and loan disbursement in different enterprises in order to reduce pressure on forest trees and by extension global warming.*

**Keywords:** Livelihood diversification, charcoal producer, per capita expenditure, welfare status, Herfindahl index

## 1.0 Introduction

The evolution of human society has rested on the sustained interaction between man and his natural environment. Hence, natural resources are materials and substances occurring in nature which can be exploited for economic gain. They are resources that exist without any action of humankind (gifts of nature) which are either renewable or non-renewable, such as mineral, water, forest and atmospheric resources. The abundance of natural resources continues to be a key component of the world economy, especially in developing countries that depend on them for a considerable part of their Gross Domestic Product - GDP (World Energy Council, 2004; Adesopo and Asaju, 2004; Hailu and Kipgen, 2017). Natural resources, especially forests represent important sources of livelihoods for many in developing countries through the provision of timber and non timber products such as charcoal.

Charcoal is a carbonized wood and has recently increased in importance due to growth in the rate of its use among households. The increasing popularity of charcoal is especially pronounced in Africa where production increased by around 30% between 2004 and2009 (Aabeyir *et al.*, 2016). High level of charcoal usage can be explained by many advantages of its use (as regards energy content, transportation and air pollution) when compared to firewood. According to African Review of Business and Technology (2006), Charcoal is mainly produced from tropical hard wood, although there are other sources like coconut shell. The process of production is called Pyrolysis; that is, burning of wood under high temperature in the absence of air. Charcoal is a primary cooking fuel for urban households in most developing countries (GIZ, 2014a), and it is also used in small-scale businesses such as restaurants, bakeries and street food stands. Charcoal is preferred to fuel wood in urban areas because it is easier to transport. Fuel wood is also used mostly in rural areas. Charcoal is more commercialized than fuel wood, and the nature of charcoal markets typically means that charcoal production is more likely to lead to the overexploitation of wood resources. Charcoal and fuel wood have different greenhouse gas emission patterns. In Southwestern Nigeria, charcoal production contributes to poverty alleviation and also ensures food security among average households. As an economic activity, it generates employment and income for the people. Most times, charcoal producers undertake the operations illegally without government license or permit. Apart from its utilization as a source of energy and means of livelihood for the populace, the role charcoal production in environmental degradation is enormous. Literature on charcoal production stating the quantity of trees and the size of land cleared to obtain the raw material is scanty. This is important in order to know the extent of forest destruction attributed to charcoal production. According to Africa Energy Outlook (2019), deforestation is a serious consequence of the unsustainable harvesting of fuel-wood, mainly driven by inefficient charcoal production.

Aside from the disruption of production activity during rainy season, Jamala *et al.* (2013) opined that production, local sales and export of charcoal during the raining season could be rejected by buyers because of the high moisture content (more than 10%) that usually characterizes the charcoal produced during this period. Charcoal, because of it uses, is a seasonal product in some clime while in others they require it all year round. The seasonality in its production is a major problem to producers' welfare. Due to this reason, most charcoal producers diversify to other livelihood activities such as farming, artisanal work, government work and private work among other economic activities to complement their income during rainy season when production is almost zero. The livelihoods concept is in understanding how the poor draw upon a range of different assets and activities as they seek to sustain and improve their wellbeing. The array of livelihood strategies employed depends on the level and the kind of resources. Capital is livelihood assets available to them (Ayantoye *et al.,* 2011). Bezu *et al.* (2012) opined that livelihood diversification is generally accepted as desirable and a key focus of poverty reduction strategies in developing countries. Therefore, livelihood diversification simply means the process by which households construct an increasingly diverse portfolio of activities and assets in order to survive and to improve their standard of living. The concept of livelihood diversification has rapidly gained ground as an approach to poverty reduction in poor countries according to Khatun and Roy (2012). But due to the following challenges such as seasonality, risks, stress, health issues, environmental effect, policy restrictions and so on in charcoal production, diversification has been seen as a desirable option as well as coping strategies to spread out the risk for improved and sustainable welfare. Given the adverse effect of seasonality on the welfare of charcoal producers, the following research questions are raised:

i. What are the other economic activities charcoal producers engaged in?
ii. Why are the charcoal producers engaging in other economic activities?
iii. What is the extent of livelihood diversification among the charcoal producers?
iv. What factors influence livelihood diversification among the respondents in the study area?
v. What is the implication of charcoal production on the environment?
vi. What proportion of the charcoal producers with diversified income has good welfare?
vii. What is the impact of livelihood diversification on respondents' welfare?

Various studies have analyzed livelihood diversification (Ashraf *et al.*, 2008; Gertler *et al.*, 2008; Awotide *et al.*, 2012; Abildtrup *et al.*, 2014 ; Gebrehiwot , 2015; Adenuga *et al.*,2016), but they do not capture the impact (participation effect) using propensity score matching. Therefore, this study seeks to find out the impact of income from other economic activities engaged-in by the charcoal producers in Oke-Ogun on their welfare bearing in mind the almost zero production of charcoal during the raining season. The study sets out to empirically determine whether income from other economic activities serve as palliative measure or not for the sustainability of producers' welfare during off season.

**Theoretical framework and literature review**

Sustainable livelihood concept supports this study. Fisher *et al*. (2013) opined that Sustainable livelihood is a holistic and multidimensional approach that acknowledges the complexities entrenched in rural livelihoods. A livelihood can be considered sustainable when it "can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation; and which contributes net benefits to other livelihoods at the local and global levels and in the short and long-term(Chambers and Conway, 1992). Charcoal production has been an age-long economic activity despite the obstruction of production activities during the rain. The shocks of no production during the rains are addressed over the years through the adoption of various palliative measures.

In literature, several analytical tools have been used in impact studies: Randomized Control Trials (RCT) (Awotide *et al.*, 2012; Adenuga et *al*., 2016). The method of RCT is expensive and has the problem of ethical issues especially with human beings (more pronounced in medicine). It has the problem of attrition and interviewee's non-response. Regression discontinuity (RD) is another impact assessment tool (Levy *et al.*, 2007; Filmer, 2009). According to Moss (2016), regression discontinuity design utilizes data that might otherwise be disregarded. The estimated effects of RD design are only unbiased if the functional form of the relationship between the treatment and outcome is correctly modeled. Difference in difference (Galiani *et al.*, 2005; Ditella, 2009; Islam, 2017). Time invariant limits the use of difference in difference. Instrumental variable (Angrist, 2001; Abadie, 2003); the weakness is the choice of the instrument which is a key issue in the implementation of instrumental variable. It is often difficult to find an observable variable that satisfies assumption, in which case instrumental variable is of no practical use. Endogenous switching regression (Adela and Aurbacher, 2018; Ahmed *et al.,* 2017; Gazali *et al.,* 2016); models with endogenous switching can be estimated with one equation at a time either by two-step least square or maximum likelihood estimation which are inefficient (Lokshin and Sajaia, 2004).

This study utilized Propensity Score Matching following Deheija and Wahba (2002); Liebenehm *et al.* (2009); Juliet and Price (2014); Wu *et al.* (2017), Ahmed *et al.* (2017). The analytical too (PSM) contributes to the more precise estimation of treatment response. Thus, the propensity score could be currently recommended as a standard tool for investigators trying to estimate the effects of treatments in studies where any potential bias may exist (Littnerova *et al.*, 2013). It helps to adjust for initial differences between the two groups by matching each of livelihood diversifier unit to a non-livelihood diversifier unit based on similar observable characteristics (Rosenbaum and Rubin, 1983). Hence, the selection bias is accounted for in measuring the impact of diversifying livelihoods on welfare.

Welfare can be measured either from income or consumption expenditure perspectives. However, it is advised to measure welfare based on consumption expenditure in less-developed countries. This is because a household's income is hard to measure in less-developed countries as much of it comes from self-employment (Ahmed *et al.*, 2017). According to Getahun and Villanger (2015), data on household income are likely to be understated compared to consumption expenditures. For instance, households may not remember everything they have sold, or money they have earned, within a year. They may also be unwilling to reveal their entire income for fear of taxation (Meyer and Sullivan, 2003). Poverty status was used as proxy for welfare of respondents based on per capita expenditure in this study. The two-third of the mean monthly per capita expenditure was used as the poverty line. Charcoal producer with per capita expenditure above the poverty line were categorized as having good welfare while producers below the poverty line were categorized as having poor welfare (Meyer and Sullivan, 2003).

Some of the methods used in literature to measure the extent of livelihood diversification/degree of the concentration of income from different sources include composite entropy index (Anna, 2002; Daniel and Johnson, 2004) and Margalef index (Iglesias-Rios and Mazzoni, 2014). Composite Entropy Index composition involves subjective judgment while Margalef index results are different if densities are used instead of total numbers. Shannon (Sabyrbekov, 2019; Xuhuan *et al.*, 2020) and Simpson (Magurran, 1988; Awotide *et al.*, 2012; Bernard *et al.*, 2014) combine richness and evenness components into a single measure. Herfindahl-Hirschman Index (Adebayo *et al.*, 2009; Babatunde and Qaim, 2009) was used in this study. Unlike other methods for measuring livelihood diversification, Herfindahl-Hirschman Index has computational simplicity and requires relatively moderate data.

## 2.1 Analytical framework of PSM

Following Rosenbaum and Rubin (1983) as contained in Herzog (2014), the propensity score is given as:

$$\hat{p}(X_i) = \Pr(D_i = 1 | X_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where:
Pr measures the probability measures of selecting into treatment D conditional on observable predictors (covariates X) for each case i.

Assuming that the treatment can be measured dichotomously (D = 1 or 0), the average treatment effect (ATE) conditional on X is formalized as:

$$E(\Delta_i | X_i = x) = E[(Y_i | D_i = 1) - (Y_i | D_i = 0)] | X_i = x \ldots\ldots\ldots (2)$$

Where:
$E(\Delta_i | X_i = x)$ is the expected difference in the outcome
$Y_i$ between the treated ($D_i = 1$) and untreated ($D_i = 0$), controlling for observable factors ($X_i = x$) that predict treatment (D) selection.

Since livelihood diversification is focused typically on sustaining the welfare status of the charcoal producer, the counterfactual centers on the treated—that is, had they not been treated—and thus the Average Treatment Effect on the treated (ATT) is defined as:

$$E(\Delta_i | D_i = 1) = E[(Y_i | D_i = 1) - (Y_i | D_i = 0)] | D_i = 1, \ldots\ldots (3)$$

Since only the treated outcome (Yi| Di = 1) is observed for the treated, the untreated outcome (Yi| Di = 0) is derived from untreated cases with similar or identical chance of treatment selection as the treated based on observable characteristics (Xs).

## 3.0 Methodology

### *3.1 Description of the study area*

The study was carried out in Oke-Ogun, Oyo State. Oke-Ogun is made up of ten (10) Local Government Areas (LGA), namely: Oorelope, Irepo, Olorunsogo, Saki East and West, Itesiwaju, Atisbo, Iwajowa, Kajola and Iseyin. Oke-Ogun is located on latitude 6°08 north of the Equator and 3°00 east of Greenwich Meridian. The annual rainfall varies between 700 -1100 mm. The agro-ecology is rainforest/derived savannah by virtue of this; it encourages the growth of trees like mahogany, obeche and acacia among others which serve as the raw material for charcoal production. The dry and wet seasons commence from November to March and while the wet season starts from April to October, respectively. Average daily temperature ranges from 25°C to 35°C almost throughout the year (Britannica, 20018). Crop farming and charcoal production are main occupations of the residents. Crop farming is populated by small scale farmers who are identified in the state as major producer of arable crops (Sanusi and Salimonu, 2006). The major crops grown in this area include: yam, maize, cassava, cashew, watermelon and cash crops.

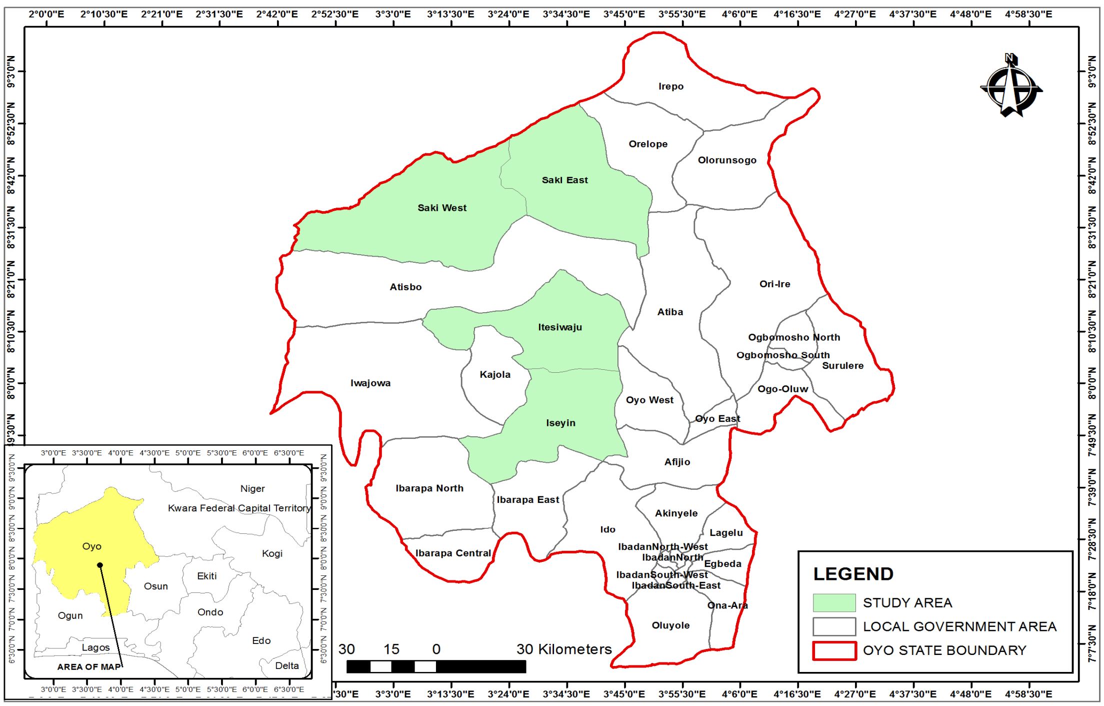


**Figure 1: Map of Oyo State showing the study Area**

### *3.2 Sample selection and data collection*

A three-stage sampling technique was used in selecting the respondents (charcoal producers) for the study. The first stage involved a purposive selection of four (4) LGAs (Saki – West, Saki – East, Itesiwaju and Iseyin ) from the ten LGAs that make up Oke-Ogun. The selected four LGAs are known for charcoal production in Oyo State (Salami and Brieger, 2010; Ogundare, 2007). In the second stage seven charcoal producing towns with large quantity produced per day (Iseyin, Saki, Baba ode, Okaka, Ipapo, Otiri, and Otu) that cut across the four LGAs towns were purposively selected. In the last stage, charcoal producers were randomly selected from the towns, proportionate to size, using the list of charcoal producers obtained from the township associations. The breakdown of the membership number and the randomly sampled number are

Iseyin (80:40), Saki (76:38), Baba Ode (53:27), Okaka (88:44), Ipapo (46:23), Otiri (56:28) and Otu (68:34). Data were collected from the respondents with the aid of questionnaire. The data collected included the socio-economic characteristics of the charcoal producers (age of respondents, production experience, educational status of the respondents, household size, marital status), other economic activities engaged in, charcoal output (in sacks) per week, income from charcoal, membership of cooperative, reasons for diversification, food and non-food expenditure per week/month. Two hundred and thirty-four (234) questionnaires were administered. Two hundred and eighteen (218) were returned to time while two hundred and ten (210) returned questionnaires were good enough for analysis.

### 3.4 *Data analysis*

Data were analyzed using descriptive statistics to profile the socio-economic characteristics of respondents in the study area. Foster, Greer and Thorbecke (FGT), Herfindahl-Hirschman diversification index, Tobit regression and Propensity Score Matching method (PSM) was also used to achieve the objective of the study. Following Nguyen and Winters (2011) and Morgan and Robb (1981), the categorized household size and age of respondents were used. The detail of each analytical tool is shown below:

*Estimation of quantity of charcoal produced and the size of land cleared for trees*

The equivalent quantity of wood cleared in the forest to produce charcoal is computed based on 25 tons of wood per ha (FAO, n. d; In Pari, 2000). The 25 tons of wood per hectare is equivalent to 22727.27kg of wood per hectare. The equivalent of wood to charcoal produced is computed using 1kg of charcoal equal 10kg of wood (Stassen, 2002; Habermehl, 2007; GIZ HERA, 2016).

*Foster, Greer and Thorbecke (FGT)*

This was measured using the annual total expenditure (food and non-food) of respondents in the study area to calculate the mean per capita expenditure in other to obtain the poverty line. The poverty line was used to generate the welfare status of the respondents. FGT is expressed as:

$$P_\alpha = \frac{1}{n}\sum_{i=1}^{m}\left(\frac{z-y_i}{z}\right)^\alpha, \alpha \geq 0 \text{ .......... (4)}$$

Where:

$P_\alpha$ represents poverty index

$zi$ represents poverty line (2/3 of mean per capita expenditure) of charcoal producers

$m$

$n$ represents number of total sampled population

$y_i$represents per capita expenditure in increasing order for all household in time period *t*

$\alpha$ represents poverty aversion parameter that takes values of 0,1 or 2

$z - y_i$ represent poverty gap of the *ith* household in time period t

$\frac{z-y_i}{z}$represent poverty gap ratio at time period *t*

The headcount index is obtained by setting the $\alpha = 0$, $\alpha = 1$, the yield poverty gap index, and $\alpha = 2$, yield the poverty severity.

*Herfindahl-Hirschman Diversification Index (HHDI)*

This index was used to measure the extent of livelihood diversification of each of the respondent. It is calculated as the sums of squares of income shares from each income sources. HHDI is estimated using:

$$HHDI = \sum_{i=1}^{n} Si^2 \text{ …….. (5)}$$

$$S = \left[\frac{C_1}{TI}\right]^2 + \left[\frac{C_2}{TI}\right]^2 + \left[\frac{C_3}{TI}\right]^2 + \left[\frac{C_4}{TI}\right]^2 + \left[\frac{C_5}{TI}\right]^2 \text{ .................(6)}$$

Where:

i= 1, 2, 3,…, n,

HHDI represents Herhindahl-Hirschman Index

$C_i$ represents income from each economic activity of each respondent

$S_i$ represent share of income source of economic activities

TIi represents total income from all the economic activities engaged each respondent engaged in

**Tobit regression**

The factors that influenced respondents' extent of livelihood diversification were determined using Tobit regression. The continuous dependent variable (diversification index) was truncated at zero. The Tobit regression model (Tobin, 1958) is given as:

$$Y = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + a_4X_4 + a_5X_5 + a_6X_6 + a_7X_7 + a_8X_8 + a_9X_9 + a_{10}X_{10} + a_{11}X_{11} + a_{12}X_{12} + a_{13}X_{13} + \mu_i .......(7)$$

Where:
Y represents livelihood diversification index for each respondent (0<Y<1)
$X_1$ represent household size 1-4 of respondents
$X_2$ represents household size 5-8 of respondents
$X_3$ represents age 27-36 (years) of respondent
$X_4$ represents age 37-46 (years) of respondent
$X_5$ represents age 47-56 (years) of respondent
$X_6$ represents age 57-66 (years) of respondent
$X_7$ represents age 67 above (years) of respondent
$X_8$ represents sex of respondent (male =1, female=0)
$X_9$ represents marital status (married = 1, others =0)
$X_{10}$ represents membership of charcoal Association
$X_{11}$ represents per capita expenditure of respondents
$X_{12}$ represents charcoal production experience (years)
$X_{13}$ represents years of education
$\alpha_n$ represents coefficient
$\mu_i$ represents error term

*Propensity score matching method (PSM)*

To estimate the propensity score, standard probability model used is a logit regression model. The nearest neighbor matching method was used to match. Nearest to neighbor matches uses the propensity score of similar individuals in the treated and control group to construct the counterfactual outcome. For the logit model used in estimating the propensity score is given as:

$$\log it(p) = \log\left(\frac{p(y=1)}{1-(p=1)}\right) = \beta_0 + \beta_1K_1 + .....\beta_nK_n ............(8)$$

The dependent variable (Y) = Diversified=1, Non-Diversified=0)
The breakdown of independent variables (K) is given as follows:
$K_1$ represents household category 1-4
$K_2$ represents household category of 5-8
$K_3$ represents age (year) category of 17-26
$K_4$ represents age (year) category of 27-36
$K_5$ represents age (year) category of 37-46
$K_6$ represents age (year) category of 47-56
$K_7$represents sex of respondent
$K_8$represents marital status of respondents
$K_9$ represents years of education of respondents
$K_{10}$represents membership of association of respondents
$K_{11}$represents membership of association of respondents
$K_{12}$ represents per capita expenditure of respondent

The performance difference between treatment (diversified charcoal producer) and control groups (Charcoal producers that non-diversified) is estimated by the average treatment effect on the treated (ATT) in a second step. The true ATT, based on PSM, can be written as:

$$ATT_{PSM} = E_{p(x)}\{E(Y_1|Z=1, P(X)) - E(Y_0|Z=0, P(X))\}$$

Where:
$E_{P(X)}$ represents the expectation with respect to the distribution of propensity score in the entire population of charcoal producers. The true ATT indicates the mean difference in knowledge test scores between diversified and non-diversified charcoal producers, who are identical in observable characteristics and adequately weighted by a balanced probability of participation. An adequate match of a participant with his counterfactual is achieved, as long as they are identical in their observable characteristics. In order to obtain such matched pairs three different matching methods that vary in terms of bias and efficiency are applied (Caliendo and Kopeinig, 2005). Firstly, nearest neighbor

Firstly, nearest neighbor matching (NNM) involves the selection of one non-diversified charcoal producer with the propensity score closest to that of the respective diversified charcoal producers. NNM will cause no concern as long as the distribution of propensity scores of the pair is similar (Smith and Todd, 2005). Secondly, radius matching (RM) involves all neighbors within a maximum propensity score distance (caliper), a priori defined. Here, poor matches through too distant neighbors are avoided (Dehejia and Wahba, 2002; Smith and Todd, 2005). Thirdly, kernel-based matching (KM), a non-parametric matching estimator, includes all individuals of the underlying sample of non-diversified charcoal producers and weights more distant observed characteristics among both groups down (Heckman *et al.*, 1997; 1998).Hence, kernel-based matching on all control units indicates a lower variance (Caliendo and Kopeinig, 2005). The third step is to check the matching estimators' quality by standardized differences in observables' means between diversified charcoal producers and non-diversified charcoal producers. The standardized difference in percent after matching represents, for a given independent covariate X, the difference in sample means in the diversified charcoal producer($\overline{X}_1$) and matched non-diversified charcoal producers ($\overline{X}_2$) sub-samples as a percentage of the square root of the average sample variances ($S_1^2$ and $S_0^2$) (Rosenbaum and Rubin, 1985):

$$SD = \left| 100 * \frac{\left(\overline{X}_1 - \overline{X}_2\right)}{\left[\left(0.5 * \left(S_1^2 + S_0^2\right)\right]^{\frac{1}{2}}} \right|$$

Although there exists no clear threshold of successful or failed matching, a remaining bias below 5% after matching is accepted as an indication that the balance among the different observable characteristics between the matched groups is sufficient (Diprete and Gangl, 2004; Caliendo and Kopeinig, 2005).

## 4.0 Results and discussion

### *4.1Socioeconomic characteristics of respondents*

The study showed that 71.4% of the respondents diversified into other economic activities such as poultry, fish, crop and other farming activities, artisanal work (carpentry, plumbing, painting, vulcanizing and trading among others), government and privately employed paid job (see Figure 2 and Table1). Majority of the respondents who diversified (27.62%), engaged in crop farming aside charcoal production, followed by artisanal work (13.33%) and employment in government establishment (11.90%).

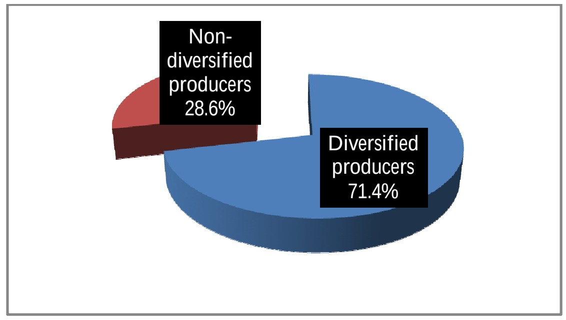


**Figure 2: Distribution of Respondents by Diversification Status.**
Source: Field survey (2018)

**Table 1: Distribution of respondents by economic diversification**

| Economic activities | Frequency | Percentage |
|---|---|---|
| Charcoal production only (No diversification) | 60 | 28.6 |
| Poultry farming | 20 | 9.52 |
| Fish farming | 5 | 2.38 |
| Crop farming | 58 | 27.62 |
| Other farming activities | 3 | 1.43 |
| Artisanal work | 28 | 13.33 |
| Government establishment | 25 | 11.90 |
| Private establishment | 11 | 5.24 |
| Total | 210 | 100 |

**Source: Author's computation from field survey (2018)**

The disaggregation of socioeconomic characteristics of the respondents based on livelihood diversification is presented on Table 2 and shows that more of male respondents were into other economic activities apart from charcoal production. Expectedly, majority of the married respondent (76.0%) engaged in other economic activities because of the need to sustain the welfare of the family all year round regardless of the season. On the whole, most respondents were within the household size of 1-4 members. The average household size of the respondents was 5 while the averages of household size for households with or without other economic activity were 5 and 5 respectively. These values are above the Oyo state (4.0) average household size (NBS, 2012). Keeping large family as a source of labour is a common occurrence in most rural enterprises; large family size contributes to high population growth which has been implicated as the bane of economic development in developing countries. According to Amjad (2013), high population growth reduces capital-labor ratio and savings. Table 2 further shows that majority of the respondents that engaged in other economic activities were within the age bracket of 52 - 61years. The average ages of respondents that diversified and those that did not diversify were 47.5years and 44.9years respectively. The study revealed that majority of the respondents had their ages below the average ages (positive skewness). Most respondents (24.7%) that diversified their livelihood had primary school education while 22.0% had Ordinary National Diploma/National Certificate of Education. Respondents that diversified had the highest percentage of respondents without formal education (20.7%). The effect of this may manifest in the planning of operation, marketing, sourcing of information and ignorance on the impact of deforestation on the environment. Table 2further shows that 27.6% and 30.3% of the respondents with and without other economic activities produced 43 – 67 sacks of charcoal per month. This is equivalent of 1.5 - 2.3 tons per month (One sack is approximately 35kg). Averages of charcoal production per month for respondents with and without other economic activities were 279.6 sacks (9.8 tons) and 229.8 sacks (8.0 tons), respectively. The average quantity of charcoal produced per respondent was 8933.76kg per month regardless of their diversification status from equivalent of 89337.6 kg of wood. This implies that a respondent consumed 3.9 hectares of wood to produce charcoal on the average monthly. The total respondents (201) would have cleared 783.9hectares of trees to produce the needed charcoal per month. There is no gainsaying that clearing this size of land per month will cause enormous damage to the ecosystem in the study area (Sowunmi *et al.,* 2018). This affirms the role of charcoal producer in deforestation.

**Table 2: Socioeconomic characteristics of respondents by diversification**

| | **Diversified charcoal producers** | | **Non-diversified charcoal producers** | |
|---|---|---|---|---|
| **Sex** | **Frequency** | **Percentage** | **Frequency** | **Percentage** |
| Male | 77 | 51.3 | 35 | 58.33 |
| Female | 73 | 48.7 | 25 | 41.67 |
| **Marital status** | | | | |
| Single | 22 | 14.7 | 11 | 18.33 |
| Married | 114 | 76.0 | 44 | 73.33 |
| Separated /Divorced | 7 | 4.7 | 2 | 3.33 |
| Widow/Widower | 7 | 4.7 | 3 | 5.00 |
| **Educational status** | | | | |
| No formal education | 31 | 20.67 | 13 | 21.67 |
| Primary school | 37 | 24.67 | 17 | 28.33 |
| Secondary school | 31 | 20.67 | 11 | 18.33 |
| OND/NCE | 33 | 22.00 | 11 | 18.33 |
| HND/BSC | 15 | 10.00 | 6 | 10.00 |
| Postgraduate | 3 | 2.00 | 2 | 3.33 |
| **Household size** | | | | |
| 1-4 | 84 | 56.0 | 29 | 48.33 |
| 5-8 | 38 | 25.3 | 17 | 28.33 |
| 9-12 | 20 | 13.3 | 7 | 11.67 |
| Above 12 | 8 | 5.3 | 7 | 11.67 |
| **Age (year)** | | | | |
| 22 – 31 | 11 | 9.7 | 12 | 12.2 |
| 32 – 41 | 22 | 19.5 | 18 | 18.6 |
| 42 – 51 | 21 | 18.6 | 24 | 24.7 |
| 52 – 61 | 24 | 21.2 | 19 | 19.6 |

| | | | | |
|---|---|---|---|---|
| 62 – 71 | 17 | 15.0 | 16 | 16.5 |
| 72 and above | 18 | 15.9 | 8 | 8.2 |
| **Charcoal produced (sacks) per month** | | | | |
| 10 – 17 | 28 | 26.7 | 1 | 1.5 |
| 18 – 42 | 15 | 14.3 | 10 | 15.2 |
| 43 – 67 | 29 | 27.6 | 20 | 30.3 |
| 68 – 92 | 13 | 12.4 | 22 | 33.3 |
| 93 – 117 | 5 | 4.8 | 1 | 1.5 |
| 118 – 500 | 11 | 10.5 | 11 | 16.7 |
| 501 – 10000 | 4 | 3.8 | 1 | 1.5 |

**Source: Author's computation from field survey (2018)**

Table 3 shows the income distribution of respondents for charcoal only and other economic activities. Most of the respondents were within the monthly income ranges of ₦1000 – 210,000 and ₦10,000 – 150,000 for charcoal production (82.1%) and other economic activities (67.4%). Averages of monthly income were ₦173,967.75 and ₦143,488.87 for charcoal production and other economic activities, respectively. Moreover, income from other economic sources accounted for 26.1% of the total income of respondents in the study area.

**Table 3: Respondents' Monthly income distribution for charcoal and other economic activities**

| **Monthly income (₦) from charcoal** | | | **Monthly income (₦) from other economic activities** | | |
|---|---|---|---|---|---|
| **Income** | **Frequency** | **Percentage** | **Income** | **Frequency** | **Percentage** |
| 1000 - 210,000 | 165 | 82.1 | 10,001 - 150,000 | 58 | 67.4 |
| 210,001– 410,000 | 8 | 4.0 | 150,001– 290,000 | 21 | 24.4 |
| 410,001 – 610,000 | 25 | 12.4 | 290,001 – 430,000 | 3 | 3.5 |
| 610,001 -810,000 | 2 | 1.0 | Above 430,000 | 4 | 4.7 |
| 810,001 and above | 1 | 0.5 | **Total** | **86** | **100** |
| **Total** | **201** | **100** | | | |

**4.2 *Determination of welfare status of respondents***

The average per capita annual expenditure was ₦283, 537.50. The two-third of the average gave the poverty line of ₦189,023.10 of the respondents. This showed that 56.1% of the respondents had poor welfare (poor) while 43.9% had good welfare (non-poor) status. The disaggregation of welfare status of respondents based on participation in other economic activities revealed that 55.7% of the respondents had good welfare status. Further breakdown revealed that respondents engaged in poultry (54.6%), fish farming (57.4%), fishing and artisanal work (88.9%); crop farming and government work (94.1%) had good welfare status. Moreover, 43.3% of the respondents that did not diversify had good welfare status. The study showed that most respondents that engaged-in more than one economic activity apart from charcoal production had good welfare status (non-poor). Table 4 shows that majority (67.0%) of the respondents had per capita expenditure within the range of ₦10,383 – 317,471 and 1.6% were within the range of ₦931,650 - ₦1,238,741. The positive skewness (3.06) showed that majority of the respondent had per capita expenditure below the average.

**Table 4: Distribution of per capita annual expenditure of respondents**

| **Per capita expenditure (₦)** | **Frequency** | **Percentage** |
|---|---|---|
| 10383 – 317471 | 122 | 67.0 |
| 317472 – 624561 | 45 | 24.7 |
| 624561 – 931651 | 10 | 5.5 |
| 931650 – 1238741 | 3 | 1.6 |
| 1238742 – 1545831 | 0 | 0.0 |
| 1545832 – 1852921 | 1 | 0.5 |
| 1852922 – 2160011 | 1 | 0.5 |

| | | |
|---|---|---|
| **Total** | **182** | **100** |
| **Average per capita expenditure = ₦283, 537.50, Skewness = 3.06** | | |

**Source: Author's computation from field survey (2018)**

Table 5 shows the disaggregation of welfare status of respondents based on other economic activities respondents' engaged-in. The table reveals that respondents that were into poultry (54.6%), fish farming (57.4%), fishing and artisanal work (88.9%), crop farming and government work (94.1%) had good welfare status. Moreover, 42.6% and 68.0% of respondents that engaged in poultry farming and artisanal work respectively were poor. The study showed that most respondents that engaged-in more than one economic activity apart from charcoal production had good welfare status (non-poor).

**Table 5: Distribution of respondent's welfare status that engage in other economic activities**

| | Good welfare | | Poor welfare | |
|---|---|---|---|---|
| **Economic activities** | **Frequency** | **Percentage** | **Frequency** | **Percentage** |
| Poultry | 6 | 54.5 | 5 | 45.5 |
| Crop farming | 31 | 57.4 | 23 | 42.6 |
| Artisanal work | 8 | 32.0 | 17 | 68.0 |
| Government establishment | 6 | 46.2 | 7 | 53.8 |
| Private establishment | 0 | 0.0 | 4 | 100.0 |
| Fish and Artisanal work | 8 | 88.9 | 1 | 11.1 |
| Crop farming and Artisanal | 3 | 33.3 | 6 | 66.7 |
| Crop farming and Government establishment | 16 | 94.1 | 1 | 1.4 |
| Total | 78 | 100 | 64 | 100 |

### *4.3 Extent of livelihood diversification among respondents*

The result on the determination of the extent of livelihood diversification showed that 25.2% of the respondents had at most 0.5 diversification index while majority of the respondents (57.1%) had diversification index of ) 0.51 – 0.80. Also, 17.6% of the respondents were highly diversified (0.80–1.00). The average diversification index was 0.61 (moderate diversification). Respondents with the most diversified income sources had the highest index and those with the least diversified income had the smallest index. Only few of the respondents did not combine charcoal production with other economic activities. Apart from serving as source of income, it also serves as coping strategy for charcoal producers during the raining season when production is nil (see Table 6). The large number of the respondents that had moderate diversification index is in agreement with Ayantoye *et al.* (2017).

**Table 6: Distribution of livelihood diversification index**

| Herfindahl-Hirschman index | Extent of Livelihood Diversification | Frequency | Percentage |
|---|---|---|---|
| 0.00 | No-diversification | 60 | 28.6 |
| 0.31- 0.50 | Less Diversified | 41 | 19.5 |
| 0.51 – 0.80 | Moderately Diversified | 79 | 37.6 |
| 0.81 – 1.00 | Highly Diversified | 37 | 17.6 |
| **Total** | | **210** | **100** |

**Source: Author's computation from field survey (2018)**

### *4.4 Determinants of extent of livelihood diversification*

Table 7 shows the Tobit regression results of the determinants of extent of livelihood diversification among charcoal producers in the study area. The diagnostic result showed that log-likelihood was -12.35125; likelihood ratio (LR) chi-square test was 37.16 ($p<0.01$). This confirms that the model has a good fit. The result shows that out of thirteen independent variables used, six variables were significant at different levels. Specifically, household size of categories 1-4 and 5-8 persons had a positive relationship with the extent of livelihood diversification ($p<0.10$). This means that an increase in the households under these categories will increase the extent of livelihood diversification by 0.3 and 0.8 respectively. This may be attributed to the fact that there is pressure on resources in large households. This necessitates the need for other sources of income aside the main occupation of household head. However, the marginal effects of number of households' heads in the age categories of 27-36, 37-36 and 41-56 had a negative relationship with the extent of livelihood diversification contrary to expectation. This means that the more the respondents within the age brackets, the less will be the diversification into other economic activities. The more the respondents in these age categories, the less the diversification. Experience (years) in charcoal production had a positive relationship with the extent of livelihood diversification. This is in agreement with Sallawu *et al*. (2016) and Oluwatayo (2009) findings on similar studies.

**Table 7: Tobit regression results**

| Variable | dy/dx | Std. Error | z-value | p-value |
|---|---|---|---|---|
| Household size (category 1 – 4) | 0.8446996** | 0.3784029 | 2.23 | 0.027 |
| Household size (category 5 – 8) | 0.335582** | 0.1545876 | 2.17 | 0.031 |
| Age (category 27- 36) | -0.566334** | 0.2740421 | -2.07 | 0.04 |
| Age (category 37- 46) | -0.4147179* | 0.2260159 | -1.83 | 0.068 |
| Age (category 47- 56) | -0.1207357** | 0.2349356 | -1.96 | 0.052 |
| Age(category 57- 66) | -0.1207357 | 0.2301612 | -0.52 | 0.600 |
| Sex | 0.1030275 | 0.1304866 | 0.79 | 0.431 |
| Marital status | -0.1058152 | 0.1883714 | -0.56 | 0.575 |
| Charcoal association membership | -0.218476 | 0.288672 | -0.76 | 0.450 |
| Per capita expenditure | $7.77e^{-06}$ | $5.56e^{-06}$ | 1.4 | 0.164 |
| Years of experience in charcoal production | 0.261241** | 0.0129776 | 2.01 | 0.045 |
| Years of education | -0.005001 | 0.0105096 | -0.48 | 0.635 |
| Other membership of association | 0.2929671 | 0.2168752 | 1.35 | 0.178 |

Prob> chi2 = 0.0004
Log likelihood = -12.35125

Note: *, **, *** represent level of significance at 10%, 5% and 1% respectively

**Source: Author's computation from field survey (2018)**

### *4.6 Impact of livelihood diversification on welfare status of respondents*

To obtain the propensity score matching estimator, individual socioeconomic status was used to form matched pairs. Charcoal producers that diversify represent the treatment group while those that did not were the control group. Matching was done on the propensity score of treated group. The propensity score is the predicted probability of charcoal producers' livelihood diversification. This was estimated from the logit regression of charcoal producer; with or without livelihood diversification used as dependent variable. The model estimated was a good predictor. The value of chi-square statistics (14.75) is statistically significant (p<0.1). This implies that the significant predictors in the model are capable of predicting participation of charcoal producer in livelihood diversification (see Table 8).

**Table 8: Logit regression result**

| Variable | Coefficient | Z-value | P-value |
|---|---|---|---|
| Household size category 1-4 | 0.646 | 1.41 | 0.158 |
| Household size category 5-8 | 0.231 | 0.51 | 0.613 |
| Age category 17-26 | -1.474* | -1.85 | 0.065 |
| Age category 27-36 | -1.665** | -2.31 | 0.021 |
| Age category 37-46 | -1.523** | -2.28 | 0.023 |
| Age category 47-56 | -1.460** | -2.27 | 0.023 |
| Age category 57-66 | -1.172* | -1.79 | 0.073 |
| Sex of respondent | -0.128 | -0.41 | 0.684 |
| Marital Status | 0.275 | 0.63 | 0.528 |
| Years of education | 0.046 | 1.48 | 0.139 |
| Experience in charcoal production (year) | -0.003 | -0.15 | 0.88 |
| Per capita expenditure | 0.000016* | 1.84 | 0.066 |
| _cons \| | -0.278 | -0.25 | 0.802 |

Number of observation= 209, LR Chi2 (10) =14.75, Prob> chi2 = 03955, Pseudo $R^2$ = 0.0545 and Log likelihood=-127.84844

Note: *, **, *** represent level of significance at 10%, 5% and 1% respectively

**Source: Author's computation from field survey (2018)**

Table 9 shows that the average probability that a charcoal producer diversified into other income generating activities was 65% of the total charcoal producers sampled. This means that if a charcoal producer is to be selected at random out of 210 charcoal producers, the probability that the charcoal producers will diversify in order to increase the consumption expenditure is 65 percent or 0.65 (on a scale between 0 and 1).

**Table 9: Propensity score estimate**

| Variable | Observation | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Propensity score | 210 | 0.651 | 0.123 | 0.348 | 0.94523 |

**Source: Author's computation from field survey (2018)**

By forming matched pairs of observable similar treated and control groups, the matching methods eliminate the confounding effects of observable variables. This study used nearest-neighbor matching algorithm that matches treatment and control cases with similar propensity scores within the tolerance level. Table 10 shows how matching restricts the control groups in order to increase the similarity of the subsample of control groups that are directly compared with the treated groups. The table presents the average estimates of propensity scores of all the covariates before and after matching. The process of matching thus creates a high degree of "covariate balance" between the treatment and control groups that are used in the estimation procedure when the p-value is not within the significant level thus implying that there is no statistical difference between the means of the treated and control groups making the covariates statistically balanced for the estimation of impact analysis.

**Table 10: Propensity score matching and observed covariate balancing test estimates**

| **Variable** | | **Mean treated** | **Mean control** | **t-values** |
|---|---|---|---|---|
| Household size category 1-4 | U | 0.56738 | 0.50909 | 0.73 |
| | M | 0.56738 | 0.56738 | 0.00 |
| Household size category 5-8 | U | 0.24823 | 0.27273 | 0.35 |
| | M | 0.24823 | 0.31915 | -1.32 |
| Age category 17-26 | U | 0.11348 | 0.10909 | 0.09 |
| | M | 0.11348 | 0.85110 | 0.79 |
| Age category 27-36 | U | 0.18440 | 0.18182 | 0.04 |
| | M | 0.18440 | 0.15603 | 0.63 |
| Age category 37-46 | U | 0.24113 | 0.12727 | 0.77 |
| | M | 0.24113 | 0.3191 | -1.46 |
| Age category 47-56 | U | 0.18440 | 0.25455 | -1.09 |
| | M | 0.18440 | 0.19858 | 0.30 |
| Age category 57-66 | U | 0.15603 | 0.2000 | 0.33 |
| | M | 0.15603 | 0.19149 | 0.36 |
| Sex of respondent | U | 0.55319 | 0.52727 | 0.33 |
| | M | 0.55319 | 0.53191 | 0.36 |
| Marital Status | U | 0.75887 | 0.74545 | 0.20 |
| | M | 0.75887 | 0.68794 | 1.33 |
| Years of education | U | 8.55320 | 9.5273 | -1.09 |
| | M | 8.55320 | 8.2411 | 0.46 |
| Years of experience | U | 9.80850 | 9.0545 | 0.57 |

| | | | | |
|---|---|---|---|---|
| | M | 9.80850 | 0.007 | -0.19 |
| Other Association membership | U | 0.92908 | 0.94545 | -0.41 |
| | M | 0.92908 | 0.96454 | -1.33 |
| Charcoal association membership | U | 1.17730 | 1.0364 | 2.6 |
| | M | 1.17730 | 1.1489 | 0.64 |
| Per capita expenditure | U | 235.64 | 297.53 | -0.31 |
| | M | 234.64 | 83.34 | 1.50 |

**U= Unmatched M= Matched**

**Source: Author's computation from field survey (2018)**

The covariate balancing tests was used for matched and unmatched. The standardized mean difference in bias of about 11.9% decreased to about 8.8% when matched. As a result, the matching process decreased total bias by 26.1%. The likelihood ratio also showed that p-value when matched was statistically insignificant, and thus the joint significance of covariates was rejected (see Table 11). As noted by Rosembum and Rubin (1985); the difference after matching of the covariates should be balanced in both groups and hence no significant differences should be found, as against the expected differences when unmatched. In addition to this, The Pseudo $R^2$ reduced from 7.4% when unmatched to 4.6% when matched. It is expected that after matching, there should be no systematic differences in the distribution of the covariates between both groups and therefore the Pseudo $R^2$ should be fairly low (Sianesi, 2004). The outcome indicators showed that the proposed specification of the propensity score had a balanced distribution of covariates between charcoal producers that diversified and those that did not diversify.

**Table 11: Covariate balancing test**

| Matching Algorithm | Model Type | Pseudo $R^2$ Unmatched | Pseudo $R^2$ Matched | LR $\chi^2$ (p-value) Unmatched | LR $\chi^2$ (p-value) Matched | MSB Unmatched | MSB Matched | Total% \|bias\| reduction |
|---|---|---|---|---|---|---|---|---|
| NNM | Logit | 0.074 | 0.046 | 0.246 | 0.212 | 11.9 | 8.8 | 26.05 |

NNM represents Single Nearest Neighbour Matching, MSB = Mean Standard Bias

The common support graph in Figure 3 shows visual presentation of overlap of propensity scores between the treated and control groups. A larger proportion of overlap implies a good match of treated and control groups (Dehejia and Wahba, 2002). From the graph there is a considerable overlap of propensity scores between the treated and control cases, this implies that the match is good and balanced and satisfies the common support condition. From the figure, the upper half of the common support graph shows the propensity score distribution of Charcoal producers who diversified (treatment group), while the bottom half shows the propensity score distribution of those who did not diversify (control group).

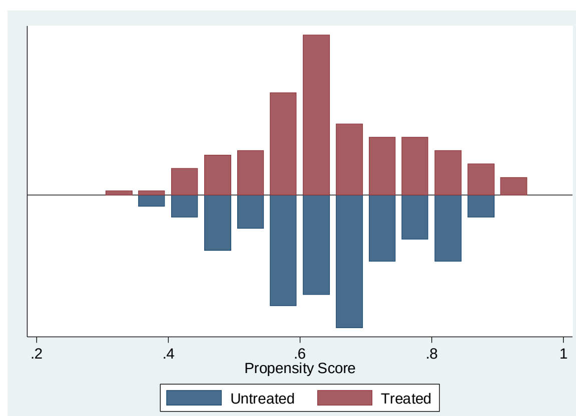


**Figure 3: Propensity score distribution and common support for propensity score estimation**

The Propensity-score matching is based on the idea of comparing the outcomes of the treated groups (charcoal producers that diversify into other income generating activities) with the outcomes of "equivalent" control groups (charcoal producers that did not diversify into other income generating activities). Since the two groups are comparable on all observed characteristics with the exception of treatment (diversification), the differences in the outcomes are attributed to the livelihood diversification strategy. Table 12 shows that estimated average effect of diversification (treatment) on the per capita consumption expenditure (outcome). The result shows that diversification had a positive impact on the per capita consumption expenditure of the charcoal producer that diversified into other income generating activities compared to producers that did not diversify. The result implied that diversification into other income sources increased per capital expenditure of respondents by ₦539.37 on the average.

**Table 12: Average impact estimates of propensity score matching of diversification on expenditure**

| Variable | Sample | Treated | Control | Difference | SE | t-value |
|---|---|---|---|---|---|---|
| **PCE** | Unmatched | 23615.27 | 23530.54 | 84.73 | 34.38 | 2.46** |
| | ATT | 23615.27 | 23075.90 | 539.37 | 97.49 | 5.53*** |
| | ATU | 23530.54 | 23107.60 | -422.94 | | |
| | ATE | | | 263.11 | | |

Note: ** means 5%, *** means 1% level of significance
N treated = 150, N control = 60
Nearest neighbor matching

## 5.0 Conclusion and recommendation

The positive impact of livelihood diversification on the welfare status of charcoal producers was affirmed by this study. Most respondents that engaged other economic activities aside charcoal production had good welfare status. Other economic activities they engaged-in were crop farming, poultry farming, fish farming, artisanal work, government and private paid jobs (trading, barbing, vulcanizing, painting, carpentry and bricklaying among others) to complement income from charcoal as well as to ward-off the negative effect of seasonality of charcoal production on the respondents' households welfare. The charcoal producers contributed substantially to deforestation based on the size of land cleared for trees per month. It is expected that through diversification into viable and sustainable economic activities, some of the charcoal producers may opt out of charcoal production. Encouraging charcoal producers to engage-in other economic activities by Ministry of Commerce and Industry and relevant NGOs will go a long way to enhance their welfare status and reduce pressure on forest trees.

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