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Use of biochar for increased crop yields and reduced climate change impacts from agricultural ecosystems: “Chinese farmers’ perception and adoption strategy”

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Biochar is a carbon-rich product from pyrolysis of biomass at relatively low temperatures in a closed system with limited oxygen. The product has been shown to have economic and environmental benefits, ranging from improved soil moisture retention for carbon sequestration, reduced pollution and dependence on inorganic fertilizers. Additionally, biochar can be produced on-farm by small scale farmers using locally made stoves as well as on industrial scale in bioenergy plants. Chinese government is fast tracking commercial production of biochar based fertilizers from pyrolysis of crop straw. However, most of the work on biochar is confined to universities and other research institutions mainly through field trials. Yet, without understanding of farmers’ roles as the main stakeholders in generation and use of this innovation, use of biochar is unlikely to be effective. Using survey data collected in the Henan region, Central China where major biochar industries are located, this study assesses farmers’ perspectives and adoption decisions on the use of biochar in agricultural production. A binary logit model is used to analyze the factors influencing biochar adoption. Higher probabilities of adopting biochar are observed among farmers with more contact with extension officers and other sources of information, higher levels of education, credit access and those belonging to farmers’ groups. Furthermore, the perceived positive aspects of biochar increased the probability of biochar adoption. These results strongly suggest that, government interventions in these areas are needed to realize the full potential of biochar production and use by farmers’.

Key words: Biochar adoption, logit model, smallholder farmers’, agriculture, China.

INTRODUCTION

As China strives to ensure sustainable food production for the increasing population, it is faced with the challenge of reducing land degradation and greenhouse gas emissions of which agriculture is a major contributor (Chen and Zhang, 2010). Chinese farming is characterized by higher yielding, greater external-inputs and agricultural technologies which have played a considerable food production (Kibue et al., 2014; Tong et al., 2003). This result in increased greenhouse gas emissions, pesticide residues, environmental degradation,
salinity, and reduced biodiversity (Gomiero et al., 2011; Lichtfouse et al., 2009). Additionally, more than 600 million tons of crop straw generated annually (Liu et al., 2008), presents a huge challenge of bio-wastes management. Farmers are skeptical of returning the straws to the soil due to concerns of pest control and labor input (Li et al., 2013; Kibue et al., 2014). Therefore, most farmers are compelled to burn the crop straws in the fields (Kibue et al., 2014). These rampant burning activities aggravate the environmental situation as it results in release of pollutants such as carbon dioxide (CO$_2$), carbon monoxide (CO), nitrogen oxides (NOx), and trace amounts of sulphur dioxide (SO$_2$) (Gadde et al., 2009). These pollutants in turn accelerate global warming and cause health problems (Mishra and Shibata, 2012). Moreover, the burning process reduces soil nutrient availability and nutrient turnover (Wang et al., 2010) and consequently reducing crop yield. These consequences have propelled both farmers and the government to start looking at strategies of managing the bio-wastes. One option that is being supported nationally is conversion of agricultural bio-wastes to value-added products such as biochar and/or renewable energy (MF-SBEMOA, 2012).

Biochar is a carbon-rich product from pyrolysis of biomass at relatively low temperatures in a closed system with limited oxygen (Lehmann and Joseph, 2009). It differs from common charcoal in that it is primarily produced for use as soil amendment aimed at improving soil productivity and enhancing soil carbon storage (Lehmann and Joseph, 2009). Biochar has a number of economic and environmental benefits, ranging from increased yields, reduced pollution and dependence on fertilizers, improved soil moisture retention to carbon sequestration. Beneficial effects of biochar have been reported through intensive research in the laboratory and field experiments in China (Liu et al., 2010; Zhang et al., 2010, 2012; Laslari et al., 2013) and elsewhere (Whitman and Lehmann, 2009; Mulcahy et al., 2013; Joseph et al., 2013).

Biochar can be produced on-farm by small scale farmers using locally made stoves (Whitman and Lehmann, 2009) as well as on large scale in bioenergy plants (Wang et al., 2013). Furthermore, the Chinese government is fast tracking commercial production of biochar from pyrolysis of crop straw under the national project of green energy with agricultural bio-wastes (MF-SBEMOA, 2012). In addition, biochar based fertilizers from pyrolysis of crop straw are being developed nationwide (Pan et al., 2011). However, the role of farmers, who are the main stakeholders in generation and use of this innovation, has not been adequately addressed. Besides, for adoption of biochar to be effective, policy makers require an understanding of elements that motivate farmers to use biochar innovation. Farmers adoption of biochar will not only solve the problem of waste management but will also confer environmental benefits. The aim of this study is therefore to assess the factors that may influence biochar adoption.

Adoption of innovations

The uptake of new technologies or agricultural practices has attracted considerable interest over the years. Hence, there is a vast literature on the adoption and diffusion of technologies in agriculture (Feder, 1985). The uptake of biochar innovation follows adoption and diffusion process similar to other agricultural technologies. In order to explain what influences the adoption of new technologies, several researchers have examined the influence of various determinants on adoption decisions. These studies show that technology adoption or disadoption is largely dependent on a technology’s capacity to meet social expectations (Frey et al., 2012; Reimer et al., 2012), and adopters’ perceptions of all the technical, cultural and economic costs, and benefits of the innovation (German et al., 2006; Kiptot et al., 2007; Rogers, 2003; Khan et al., 2008; Frey et al., 2012). Farmers’ perceptions of a technology may be influenced by farm size, age and gender (Marenya and Barrett, 2007; Mwirigi et al., 2009; Gachango et al., 2015). Several adoption studies yield evidence on the importance of information access and particularly the role of informal information sources and social networks (German et al., 2006; Frey et al., 2012; Kibue et al., 2016). Besides, farmers’ educational background is critical for adoption. For instance education and training greatly increased the likelihood of initial uptake of polythene mulch, contour cultivation, sweet chestnut, and intercropping in china (Subedi et al., 2009). The role of extension in bridging the gap between new innovations and actual uptake by the farmers is underscored. Rahman (2003) and Mariano et al. (2012) have shown that adoption is higher for farmers with contacts with extension agencies working on technologies. Other factors may impede adoption of a technology, for example: loss of social status for being associated with negative outcomes of a technology and lack of access to credit facilities (He et al., 2007; Mariano et al., 2012) and lack of economic incentives (Shi et al., 2008).

In the current study, it is expected that farmer-specific characteristics have a positive relationship with the adoption of biochar innovation. More educated farmers are in a better position to evaluate the relevance of new technologies. It is expected that farmers with off farm income are more financially capable to invest in technologies than poor farmers. Farmers who own bigger farm sizes are more likely to adopt biochar technologies than farmers owning small sizes of land because they can afford to devote sections of their lands to experiment the innovation. Since smallholder farmers often have insufficient capital to invest in a new innovation, availability of credit will encourage technology adoption.

Farmers receiving extension services, those attending
on-farm demonstrations of new technologies, seminars and workshops, and farmers having positive attitudes towards gathering information and with high frequency of contact with information sources are also expected to adopt biochar. Lastly, if farmers consider the innovation beneficial and they are perceptive about climate change, they are likely to adopt it.

MATERIALS AND METHODS

Study area

The study area is located in Xieji Township (34°31’11”N115°28’33”E), Liangyuan district, Shangqiu Municipality, Henan province, China. The area lies on the North China Plain, easternmost region of Henan province. It is mostly flat, with elevations ranging from 30 to 70 m (98 to 230 ft), and has a monsoon-influenced humid subtropical climate with four distinct seasons. The annual average temperature is 14.1°C (57.4°F). Precipitation mainly occurs from June to September. The region is characterized by highly fertile soil and convenient irrigation facilities that greatly help the production of crops and other plants. The most important agricultural products are wheat, maize, cotton, sesame, vegetables, fruit, tobacco, and livestock. The region hosts major biochar trial fields managed by Nanjing Agriculture University and Sanli New Energy Company, a key biochar producer in China. Most of the biochar feedstock is provided by the farmers, who give their crop straw for free to Sanli company, while others exchange it for biochar. Field experiment trials have been undertaken on salt affected land in Xieji village (Lashari et al., 2013) and more trials are ongoing.

Sampling questionnaire and field survey

The study is based on a regional survey of factors influencing biochar adoption by farmers in Xieji municipality, which was conducted between April and May, 2013. The sampling frame constituted households in three villages where biochar companies are located since significant numbers of farmers knowledgeable and/or using biochar, necessary for an empirical analysis, can be found in this area. A total of 287 households were randomly sampled (Marshall, 1996) for interview. A standard questionnaire was formulated in English and translated into Chinese by a native bilingual English speaker who also back-translated it to ensure accuracy. The Chinese version of the survey tool was then pre-tested in a different site and necessary adjustments made before the actual survey. The dataset contained information on: (1) Farmers socioeconomic characteristics (farm size, age and level of education), (2) Contact with sources of biochar information and perceived benefits of biochar innovation, and (3) Access to credit facilities. Before the commencement of interviews, respondents were thoroughly briefed about the purpose of the study and asked if they were willing to participate. After giving consent, all interviews and discussions were recorded (Bordens and Abbott, 2008). The questionnaire was administered face to face by 4 enumerators each spending approximately 30 min to interview each farmer. The dependent variables are shown in Table 1.

Binary choice model

Most of the technology choices that farmers consider in their decision making are of a ‘use or not use’ nature. Similarly, respondents-farmers were asked whether they used biochar or not. The aim was to investigate which factors influence the decision process and by how much each factor affects the farmers’ choice. As in most empirical studies, the observed yes/no decision to use biochar technology is viewed as the outcome of a binary choice model. Two models, logit and probit are widely used. They differ from each other only in the assumption about the functional form of F. This happens when sample sizes were large and certain extreme patterns are observed in the data (Chambers and Cox, 1967). The models assume that a variable Y has only two possible outcomes, in this case, adopt and not adopt. They also assume a discrete vector of regressors X, which are assumed to influence the outcome Y, in this case factors that influence farmers’ decision to adopt biochar (Table 1). The observations (adopt or not adopt) are the outcome of the binary choice model, meaning each farmers choice to adopt is a dummy variable defined as:

\[ y_i = \begin{cases} 1 & \text{if the farmer adopts biochar} \\ 0 & \text{if the farmer does not adopt biochar} \end{cases} \]

This study adopts a logit model. This model has been used in similar studies (Burton et al., 1999; Bryan et al., 2009; Läpple and Rensburg, 2011; Mariano et al., 2012). All the equations used in this work have been derived and modified from Greene (1997). The parameters of farmers’ decision to adopt or not adopt biochar are defined by latent variable \((U_i^*)\), that is, related to factors that influence the farmers’ decision (\(X_i\)):

\[ U_i = X_i \beta + \epsilon_i \quad i = 1, 2, 3, ..., N \]

where \( \beta \) is a vector of adoption parameters and \( \epsilon_i \) is a random error term. The observed pattern of adoption is then represented by the dummy variable \((y_i)\) where these observable values of \((X)\) are related to \(y^*\) :

\[ y_i = \begin{cases} 1 & \text{if } U_i^* > 0, \text{ otherwise } y_i = 0 \end{cases} \]

The probability that a farmer adopts biochar is:

\[ P[y_i = 1] = P(\epsilon_i > -X_i \beta) = 1 - F(-X_i \beta) = F(X_i \beta) \]

where \( F \) is the cumulative distribution function (CDF). The \( \beta \) parameter can be estimated using maximum likelihood ratio. Using the logit model, the farmers’ probability of adopting biochar can be predicted as:

\[ P_i = P[y_i = 1] = \frac{\epsilon_i^X \beta}{1 + \epsilon_i^X \beta} \]

The maximum likelihood estimates of the model can be used to predict the probability that a farmer adopts biochar based on his/her characteristics, estimate change in probability for change in farmers’ characteristics \(X_i\). For instance if the farmer changes the frequency of obtaining advisory information from \(X_a = 1\) to \(X_a = 2\), then, the change in probability of adapting changes can be computed as:

\[ P = F(\beta_0 + \beta_1 X_a + \beta_2 X_2 + ... + \beta_k X_k) - F(\beta_0 + \beta_1 X_a + \beta_2 X_2 + ... + \beta_k X_k) \]
Table 1. Definition of variables and their measurement.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition and measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Age of the farmer. Measured in years</td>
</tr>
<tr>
<td>Gender</td>
<td>Sex of the respondent. Measured in percentage and described as 1 if male, and 0 otherwise</td>
</tr>
<tr>
<td>Education</td>
<td>Highest level of schooling attained by the farmer. 1= none, 2= primary, 3= Secondary, 4= College. 1 if educated, and 0 otherwise</td>
</tr>
<tr>
<td>Farm size</td>
<td>Total agricultural area of the farm measured in Chinese Mu</td>
</tr>
<tr>
<td>Off farm income</td>
<td>Proportion of farmers earning income from other sources. If the farm household has an off-farm income=1, =0 otherwise,</td>
</tr>
<tr>
<td>Info frequency</td>
<td>Mean number of times of consultation with source of information on biochar</td>
</tr>
<tr>
<td>Contact with extension services</td>
<td>Proportion of farmers in contact with extension worker. 1 if the farmer access to advice from extension workers; 0 otherwise</td>
</tr>
<tr>
<td>Belonging to association</td>
<td>Proportion of farmers belonging to farmers associations. 1 if the farmer belongs to a farmers association; 0 otherwise</td>
</tr>
<tr>
<td>Info seeking attitudes</td>
<td>Attitudes towards seeking information. Rated on a scale of 1-5. Higher value = higher interest in information gathering</td>
</tr>
<tr>
<td>Access to credit facilities</td>
<td>Proportion of farmers obtaining credit. 1 if the farmer has access to credit; 0 otherwise</td>
</tr>
<tr>
<td>Perceived benefits of biochar use</td>
<td>Proportion of farmers viewing biochar innovation as beneficial. 1 if the farmer views biochar use as beneficial; 0 otherwise</td>
</tr>
</tbody>
</table>

The estimates of marginal effects, that is, the effect of a unit change in $X_i$ if all other factors are held constant, on the farmer’s probability to adapt can be shown as:

$$
\frac{\Delta P_i}{\Delta X_i} = \frac{\partial P_i}{\partial X_i}
$$

Data analysis

Two hundred and eighty responses were used for analysis since 7 respondents declined to be interviewed. Analysis was done using Statistical Package for the Social Science (SPSS) version 16.0. Descriptive statistics were used to summarize the data. The data were tested for their reliability through scale creation process (using a ‘reliability analysis’; Alpha = 0.77). The value of computed Cronbach alpha was 0.421 (unweighted variables) and 0.306 (weighted variables). Analysis of factors that influence farmer’s adoption of biochar was done using the logit model. In order to derive the magnitude of the impact of the independent variables on the probability of adoption, marginal effects at the mean for continuous variables and for a change from zero to one for dummy variables were estimated (Greene, 1997).

RESULTS

Descriptive statistics

Table 2 shows the descriptive statistics of the variables for adopters and non-adopters of biochar technology and the total sample. The results show that most farmers had attained secondary school education. Most farmers had mean age of farmers to be 49 years, owned 11 Chinese Mu of land, relied purely on agriculture as the only sources of income and perceived biochar as beneficial. The table further reveals that compared to non-adopting farmers, adopting farmers had more contact with extension workers, sought information more frequently, had other sources of income and have higher level of education among others. Besides the conventional sources of information (print and electronic media), most farmers (46%) sought information from fellow farmers, 22% did not seek information anywhere, 13% from friends and family members, 12% from extension officers, and 7% from nearby field demonstration stations.

Results of logit model

The estimated coefficients of the parameters and the marginal effects in the binary logit model are shown in Table 3. The chi-squared test statistic is significant at the 5% level. The power of prediction of the estimated model is 0.702. The estimated marginal effects indicate that for every unit increase in the variables, the probability of biochar adoption increases by: farm size (8%), frequency of gathering information (6%), credit access, information gathering attitudes and contact with extension officer (5%) each, farmers education and belonging to farmers
Table 2. Descriptive statistics for variables; adopters (N=84), non adopters (N=196) and total farmers (N=280).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Biochar adoptors Means (St. dev)</th>
<th>Biochar non-adoptors Means (St. dev)</th>
<th>Total sample Means (St. dev)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of household head</td>
<td>49.48 (16.02)</td>
<td>48.78 (13.02)</td>
<td>48.93 (12.51)</td>
</tr>
<tr>
<td>Gender (% males)</td>
<td>68 (0.55)</td>
<td>63 (0.66)</td>
<td>65 (0.45)</td>
</tr>
<tr>
<td>Education of HH head (level)</td>
<td>3.47 (0.99)</td>
<td>2.82 (0.97)</td>
<td>3.17 (1.09)</td>
</tr>
<tr>
<td>Farm sizes (Chinese Mu)</td>
<td>13 (0.77)</td>
<td>11 (0.91)</td>
<td>11.83 (1.09)</td>
</tr>
<tr>
<td>Off farm income (%)</td>
<td>39 (0.48)</td>
<td>19 (0.87)</td>
<td>23.80 (1.00)</td>
</tr>
<tr>
<td>Frequency of obtaining information (count)</td>
<td>3.80 (0.86)</td>
<td>1.99 (1.57)</td>
<td>2.74 (1.72)</td>
</tr>
<tr>
<td>Contact with extension services (count)</td>
<td>2.80 (1.71)</td>
<td>1.64 (1.89)</td>
<td>2.17 (2.69)</td>
</tr>
<tr>
<td>Information seeking attitudes (level)</td>
<td>3.3 (1.62)</td>
<td>2.70 (1.79)</td>
<td>3.07 (1.97)</td>
</tr>
<tr>
<td>Access to credit facilities (%)</td>
<td>37 (0.08)</td>
<td>18 (2.23)</td>
<td>27 (1.01)</td>
</tr>
<tr>
<td>Belonging to farmers associations (%)</td>
<td>43 (0.81)</td>
<td>27 (1.91)</td>
<td>35.6 (1.27)</td>
</tr>
<tr>
<td>Perceived benefits of biochar (%)</td>
<td>65 (0.42)</td>
<td>38 (0.81)</td>
<td>57.2 (0.70)</td>
</tr>
</tbody>
</table>

Table 3. Results of logit model (N=280)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficient</th>
<th>Marginal effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of household head</td>
<td>0.200</td>
<td>0.860</td>
</tr>
<tr>
<td>Education of household head</td>
<td>0.001**</td>
<td>0.040</td>
</tr>
<tr>
<td>Gender</td>
<td>0.607</td>
<td>0.503</td>
</tr>
<tr>
<td>Farm sizes</td>
<td>2.36**</td>
<td>0.082</td>
</tr>
<tr>
<td>Off farm income</td>
<td>0.741</td>
<td>0.161</td>
</tr>
<tr>
<td>Information frequency</td>
<td>0.997**</td>
<td>0.061</td>
</tr>
<tr>
<td>Contact with extension services</td>
<td>0.864**</td>
<td>0.049</td>
</tr>
<tr>
<td>Belonging to association</td>
<td>0.329**</td>
<td>0.040</td>
</tr>
<tr>
<td>Information seeking attitudes</td>
<td>0.216**</td>
<td>0.045</td>
</tr>
<tr>
<td>Access to credit facilities</td>
<td>0.735**</td>
<td>0.054</td>
</tr>
<tr>
<td>Perceived benefits</td>
<td>1.630**</td>
<td>0.0271</td>
</tr>
<tr>
<td>Likelihood ratio</td>
<td></td>
<td>0.70228</td>
</tr>
<tr>
<td>Pseudo R- square</td>
<td></td>
<td>.4180</td>
</tr>
</tbody>
</table>

** Test statistics is significant at the 0.05 level.

association (4%)-each and perceived benefits (3%). As expected biochar adoption is influenced by farmer’s formal education, farm size, contact with extension services, frequency of gathering information, access to credit, farmers associations, perceptions that biochar is beneficial, and information seeking attitudes. However, off farm income had no influence on biochar adoption.

With regard to information availability, the results in Table 3 show that belonging to a group, association with access and diffusion of information increase the likelihood of biochar adoption. Farmers who are in more contact with extension services are also more likely to adopt biochar innovation. In line with this, better attitudes towards seeking information and high frequency of obtaining information more also plays an important role for the adoption decision. The findings are in line with results of previous studies on technology adoption that identify informal information exchange between peers to be an important determinant of technology diffusion (Montalvo, 2003; German et al., 2006; Frey et al., 2012) and that contact with information, farmers’ associations as well as farmers’ attitudes toward actively seeking information influence adoption decisions (He et al., 2007; Mariano et al., 2012).

With respect to socioeconomic characteristics, Table 3 also shows that household head’s education levels, farm sizes and perceived benefits of biochar have a likelihood to influence biochar adoption. In line with He et al. (2007), Marenya and Barrett (2007), and Mwirigi et al. (2009), education has positive influence on adoption. Farmers who have higher levels of education are more able to embrace an innovation that can enhance their livelihoods by easing farm management cost. Similarly, farmers with bigger farm sizes are likely to adopt biochar because they can devote some section of their farms for trials. On the contrary, due to their vulnerability in an event of crop failure or any other eventuality, the farmers with small farm sizes are likely to watch and learn from other
farms about the outcome of the innovation rather than take the risk of taking up the innovation. This observation is corroborated by other studies on adoption (Marenya and Barrett, 2007; Mwirigi et al., 2009).

Farmers’ perception of biochar innovation as beneficial influences its adoption. This is for the reason that the adoption results in social or economic gains. This is in agreement with other adoption studies (German et al., 2006; Kiptot et al., 2007; Khan et al., 2008; Frey et al., 2012; Rogers, 2003) that perceived benefits of an innovation influences its adoption. Finally, as expected, access to credit facilities influences farmers’ likelihood of biochar adoption. This is because the farmers are able to meet costs of adoption. This observation is in line with Shi et al. (2008), that lack of economic incentives and lack of credit facilities (He et al., 2007; Liu and Huang, 2013) are barriers of adoption.

DISCUSSION

Biochar innovation is relatively new and the focus of the research by universities has been on field trials with little extension from agricultural departments. Subsequently, few agricultural extension experts have received detailed training or written information about the method of production, application and potential benefits. First and foremost, this presents a gap in information diffusion which, in other similar studies, has been blamed for limiting the widespread use of information (Hansen et al., 2011). Additionally, lack of knowledge among extension officers has been blamed for poor adoption of organic agriculture and communication failure (Wheeler, 2008).

Social ties among the farmers belonging to groups and the perception that biochar innovation can offer them a solution to manage their crop residues by converting them to a value-added product with other benefits is indicative of adoption. Besides, it is established, in the same region by Li et al. (2013) that farmers find crop residues as a big challenge because of increased labor and chemical inputs to kill insects and pests attracted by the residues. This is well corroborated by similar studies that show that adoption is dependent on farmers recognition that an innovation is beneficial and can meet social expectations (Frey et al., 2012; Reimer et al., 2012; D’Antoni et al., 2012) belonging to social groups facilitates spread of information and social learning (Rahman, 2003; Mariano, 2012).

Having confirmed the factors that influence biochar adoption and the vast literature on beneficial use of biochar and its large scale production in China, this study seeks to discuss some policy perspectives based on the findings.

Information/Awareness

As revealed by the survey data, information is key to adoption of biochar. As such, the government should ensure that farmers are in constant contact with each other. These extension officers should be equipped with both technical and application aspects of biochar. Successful agricultural extension can help to overcome the gap between newly invented technologies and changes in the farmer’s field. That is, extension specialists supply farmers with the required knowledge, thus assisting in a shift to more efficient production techniques and thereby enhancing the diffusion process of technologies (Birkhaeuser, 1991). Hence, the farmers will have the advantage of not only using biochar but also establishing onfarm biochar production. Biochar can be produced on-farm by small scale farmers using locally made stoves (Whitman and Lehmann, 2009).

Incentives for farmers to give some land for demonstrations and trials

The government should encourage more farmers in the region to devote some sections of their land for on-farm trials and demonstrations. Few farmers in this region have devoted some portions of their land for biochar field trials that are managed by Nanjing Agriculture University and Sanli New Energy Company, a key biochar producer in China. This acts as a capacity building initiative by bringing research and innovations to the farmers and empowering them to learn practically and acquire technical skills. Studies associate farmers with contacts with extension agencies working on technologies and for those belonging to farmers’ groups to higher adoptions (Rahman, 2003; Mariano et al., 2012).

Education

Government should liaise with higher institutions of learning to develop short courses to meet farmers’ needs and also to keep the extension officers updated with the latest developments in their fields. In addition to short courses, research institutions should be facilitated to conduct more workshops for farmers. Of great importance also, the government should take advantage of existing social groups and networks and non-governmental organizations to educate and train farmers on new and best practices in agriculture.

Credit facilities and incentives

Lack of affordable credit facilities and lack of incentives remain a huge barrier to adoption of innovations. This is because given the inherent risks in agricultural projects, the lending bodies (micro finances, saving cooperatives, banks, etc). A study of farmers access to credit (Corpuz, 2008) finds that lending processed are complicated by farmers lack of collaterals, high transaction cost and
interest rates among others. To attempt to solve this problem, the government should create a fund specifically for smallholder farmers to make them access their agricultural needs. The government could also negotiate lending rates with the lenders to make it affordable for the farmers and in return waive some taxes for the specific lenders. Finally, the government should give incentives and relevant technical support to the big companies that manufacture biochar.

**Conclusion**

Biochar innovation is a relatively new innovation whose beneficial impacts in agriculture are known to few farmers. This study shows that biochar adoption is influence by individual farmer’s characteristics and institutional factors, a fact consistent with adoption literature.

Based on the estimated marginal effects, farm sizes and information-related variables have the biggest impact on technology adoption. This makes it imperative to involve farmers as major stakeholders in trials and other developments in agricultural matters. In addition, the government should invest in efficient ways of communicating with farmers besides exploiting the social groups. For instance, through training more extension workers and intensifying media campaigns to educate the farmers on new ideas. This is of paramount importance because precise and timely information will help farmers make important decisions to adopt innovations. In regard to farm sizes, government should work closely with researcher to develop high yielding varieties and high value crops that can give satisfactory returns under the farm sizes. A follow-up survey is important to provide a more comprehensive analysis of farmers’ behavior in adopting new technology over a longer period of time.

**CONFLICT OF INTERESTS**

The author has not declared any conflict of interests.

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