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Key factors that influence households' tree planting behaviour

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Abstract

Despite a decrease in indigenous forests and a growing demand for tree products in developing countries, tree planting activities are not considerably expanding in Tanzania. In this paper, we analyse factors that influence households' tree planting behaviour, as well as the number of trees planted. Coast and Morogoro regions in the east of Tanzania were selected as the case, and data was gathered from 202 households in 11 villages in these regions where tree planting programmes have been or still are active. A Heckman model is used to analyse the factors that drive tree planting behaviour. Results indicate that households get wood energy from forest reserves (57%), in addition to their own planted trees (9.1%). Emperical findings show that the most important factors have significantly positive effects on households' tree planting behaviour, as well as the extent to which it was implemented. These factors include households' land sizes, households' awareness of tree planting programmes, tree planting for wood energy, and the age of the head of the household. The right/freedom to harvest and transport tree products, households' attitudes towards tree planting, and family size have significantly negative effects on households' tree planting behaviour. This paper is perhaps the first comprehensive study to analyse the factors that influence households' tree planting behaviour in Tanzania, and it uncovers results that are useful, even for other developing countries with similar conditions.

Keywords: Tree planting; wood energy; households; Tanzania.

1. Introduction

Over the last few decades, forest land cover has declined, and will continue to decline as a result of deforestation in developing countries (Sunderlin, 2005; Larson *et al*., 2013). Heavy dependence on forest products such as wood fuel and the growing need for poles and other forest materials for house construction cause severe deforestation in developing countries. It was found in Hosonuma *et al*. (2012) and Brockhaus *et al*. (2013) that small or large scale agriculture is one of the causes of deforestation in developing countries, followed by the felling of trees for timber and wood fuel. For example, for years there has been a substantial change in forest cover in Tanzania (see Figure 1).

Based on the results of a number of studies, we drew inferences of the possible benefits of forest products to households. Different studies have documented the importance of forest products for forest-dependent households (e.g., Lokina and Robinson, 2008; Gundimeda and Shyamsundar, 2012; Hansen *et al*., 2015). The demand for wood fuel and charcoal in particular is crucial to the survival of many households, and is unlikely to decline in the near future as an income supplement for these households (URT, 2006; Gundimeda and Shyamsundar, 2012). Empirical evidence shows that forest products for business provide different kinds of benefits, including topping up people's income, employment, and improvement of household livelihoods (Das, 2012). Das's findings suggest that forest products like charcoal and firewood offer more income and job opportunities to households than other fuel alternatives such as electricity, gas, and dryland salinity do and that they also, to some extent, contribute to the growth of the economy of Tanzania (Felix and Gheewala, 2011). According to Mwampamba (2007) and Felix and Gheewala (2011), wood fuel is consumed by approximately 80% of households in Tanzania.

However, we also noted that the consumption of forest products such as wood energy leads to deforestation (Msuya, 2011; Larson *et al*., 2013; Mwampamba *et al*., 2013). Whether or not wood energy consumption causes deforestation in developing countries, including Tanzania, remains up to debate (Chidumayo and Gumbo, 2013). Furthermore, there are contradicting views about the main factors that cause deforestation in these countries. In Tanzania,

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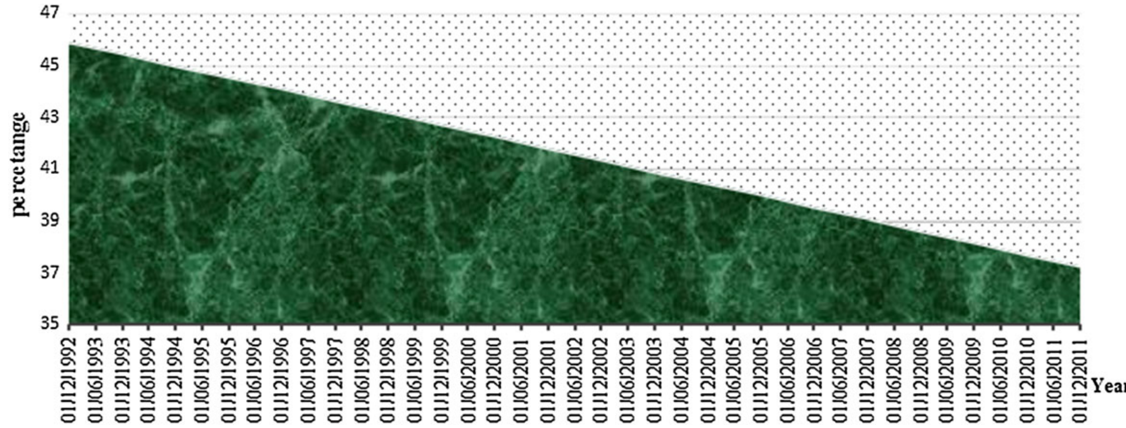

Figure 1. Tanzania forest land cover outlook (1992–2011).

more than 70% of forest harvests that cause deforestation are essentially used to meet household wood energy demand, and trees are usually harvested from open access forests and forest reserves (Msuya, 2011; URT, 2012). Although more than 50% of the forests are located in national reserves and protected areas (URT, 2012), their legal protection is very poor. It should be noted that illegal forest harvests that lead to the loss of forest cover take place in all of the country's protected forest areas (Robinson *et al*., 2006). Currently, the deforestation rate remains high, and is estimated to be about 1.1% of the total forest areas cleared per annum in Tanzania (URT, 2012). According to Hardin's theory (1968), a natural resource is over-harvested if it is non-excludable. The conventional theory of common-pool resources assumes that open access resources generate a highly finite predictable supply, and that where the actors in the market do not formally interact, they usually end up exhausting the resources (Ostrom, 2002).

Mwampamba *et al*. (2013) noted that the main cause of deforestation is the heavy dependence on natural forest resources for wood energy and sale by poor people. Khan and Khan (2009) found that wood energy extracted from the forest is the major cause of deforestation. In this study, we found that the dependence on forests (e.g., 57% extracted from reserve forests) for wood energy may lead to deforestation. Nevertheless, Arnold and Persson (2003) indicate that deforestation caused by the felling of trees for wood fuel is not clearly known, most likely because the information available is inadequate. The findings by Allen and Barnes (2005) indicate that in the short term, deforestation is due to agricultural expansion, and that over the long term it substantially correlates with wood harvesting for fuel.

See Figure 1[1] for the trend of change in the percentage of the distribution of land with forest cover in Tanzania. Land covered with forest is designated as land with both natural and planted trees of at least 5 m in situ. Data from the World Bank excludes "tree stands in agricultural production systems (for example, in fruit plantations) and trees in urban parks and gardens" (World Bank, 2013).

Deforestation has led different researchers and policymakers to find and develop alternative interventions and solutions to it in developing countries. One possible solution to deforestation is to find alternative sources of energy such as liquefied petroleum gas (LPG) and electricity (Mwampamba, 2007). However, this solution does not currently appear to be economically feasible. Despite the perceived failure by Tanzania to find an alternative source of energy, it is indisputable that deforestation is a critical problem in the country. Deforestation has resulted in a scarcity of wood energy in the country, and therefore it is among the reasons for many households' tree planting interventions at both the community and household levels. Thus, examining households' tree planting behaviour as a solution to the country's wood energy scarcity is an issue of considerable interest to both us and policymakers.

Although tree planting seems to be an alternative solution to deforestation (Chazdon, 2008), empirical findings on households' tree planting behaviour remain inadequate in their transfer of knowledge to policymakers in a way that is consistent with the available obtained evidence in Tanzania. Despite the government of Tanzania, along with the support of the Norwegian Agency for Development Cooperation (NORAD) introducing tree planting programmes (MNRT, 2013), achieving this goal requires factors that motivate individual households' behaviour towards tree planting. Regardless of tree planting programmes that were established in 1999/2000 (Malimbwi and Zahabu, 2008) and the New Forest Policy of 1998 and Forest Act No. 14 of 2002, recognizing the role of various stakeholders, including local communities, tree planting has not been successful in the country (Kindo *et al*., 2010). We argue that households' behaviour regarding tree

[1] In this context, wood fuel refers to wood sources harvested from stems, branches, and other parts of a tree and its quantities measured in cubic volume (CUM, solid volume units).

planting depends on several social, cultural, economic and technological factors in line with the intervention designed to stimulate planting practices, and these factors need to be understood and are critical to the achievement of tree planting programmes (Cooke *et al.*, 2008). Microeconomic theories appreciate the role of an individual household's tree planting when inspired, which may lead to forest recovery, rather than a common property right practice (Robinson *et al.*, 2006). Abebaw *et al.* (2012) suggest that the planting of fast growing trees by households could significantly contribute to the fight against deforestation.

As noted earlier, there is not enough empirical analysis on the factors that influence households' tree planting behaviour and its intensity in Tanzania. Thus, the current study has been undertaken to bridge this gap. It intended to answer the following questions: What determines households' tree planting behaviour? What is the extent of the tree planting? And what are the most important factors that a household considers when deciding to plant a particular type of tree species?

We structured this paper as follows: Section 2, which presents a theoretical and empirical overview of the study; Section 3, which describes the methodology of the study; Section 4, which presents the empirical results of the study; and Sections 5 and 6, which entail a brief discussion of the study, thus concluding the paper.

2. Literature review

In this paper, it is relevant to review and look at the effects resulting from a decrease in forest stocks, which have been the most important variable in forest-dependent households. The point of interest in this context is the factors that influence household behaviour when faced with forest resource scarcity. For example, changes from actual forest product collection behaviour to tree planting have affected household socio-economic welfare. Households have to forego more of some other resources due to forest resource shortages, and resources such as labour and time spent in order to obtain the forest resources. However, this needs to be weighed against factors influencing household tree planting behaviour under various theoretical and empirical settings, including the neoclassical utility and profit maximization model (Lancaster, 1975). Understanding the theory of household behaviour and tracing the relationship among institutions, market forces, household decisions, and forest stocks is empirically important in raising a value position and predicting the process of the study (Royse, 2008).

2.1. Theoretical reviews

In a number of studies, households' tree planting behaviour has been investigated and analysed under different theoretical frameworks. On one hand, employing neoclassical theory, Amacher *et al.* (2004) examined households' investment in tree planting behaviour for different purposes. Further, Cooke *et al.* (2008) applied neoclassical theory to discuss households' tree planting behaviour, based simultaneously on utility and profit maximization factors. Furthermore, Bluffstone *et al.* (2008) investigated households' tree planting behaviour using utility maximization theory, identifying different factors influencing tree planting behaviour. It has, however, been reported by Josh and Arano (2009) that the utility in question can only be observed through a set of determinants. Thus, households' decisions to plant trees is assumed to represent their utility maximization behaviour (Louhichi *et al.*, 2013). On the other hand, Mahapatra and Mitchell (2001) have used a number of theories to examine the factors that influence households' tree planting behaviour, which include the theory of economic constraints.

The theories reviewed have been developed for the purpose of analysing the behaviour of households in rural settings, in an effort to invest in tree planting in the long term. In a more specific study, Besley (1995) has analysed investment incentives and property rights linkages using theoretical models. According to Shively (2000), the utility maximization model has been used to investigate households' tree planting behaviour in situations such as those in which expected returns and changes in the price of trees are important determinants for tree planting patterns. Other works that have dealt with the factors for households' tree planting behaviour include the work of Simmons *et al.* (2002). This work has analysed the factors and market incentives that influence people's tree planting behaviour.

Other studies have looked into the relevance of non-separable models in relation to households' tree planting behaviour. Such studies indicate that tree planting involves the discrete choice of whether or not to plant trees, as well as how many trees to plant, as a continuous variable based on consumption (Gebreegziabher and Kooten, 2013). Therefore, households simultaneously maximize their utility based on consumption and production decisions (Gerber *et al.*, 2014).

In the study areas, households primarily employ family labour in tree planting, without using hired labour. Thus, the market wage rate of primarily family labour depends on the shadow wage of returns from the tree planted products. Therefore, the use of shadow wages makes households non-separable, which implies that the decision to plant trees does not depend on production alone, but also on factors that affect consumption decisions. For example, some of these factors include perceptions about tree planting, the right to transfer tree products for trade or domestic use, and policy tools designed to match household utility (Amacher *et al.*, 2004; Mekonnen and Damte, 2011). According to de Janvry and Sadoulet (2006), when a household's decisions regarding production are affected by its decisions regarding consumption, a household is said to be non-separable.

It is a well known fact that in developing countries, rural households are subjected to market failures (de Janvry and Sadoulet, 2006). Under market failures of on-farm products, risk averse households allocate more labour to non-farm activities, believing that they will generate some income through such activities (Wang *et al*., 2012). However, increased off-farm income of households is likely to reduce household size (farm labour) for tree production, and subsequently cause a direct effect on household tree planting and consumption behaviour under the non-separabilty perspective in farm household behaviour theory (Liang *et al*., 2012).

Therefore, the theoretical framework used in this study is based on the studies by Besley (1995), Shively (2000), Cooke *et al*. (2008) and Gebreegziabher and Kooten (2013), which are directly related to the current study, for they also analysed households' tree planting behaviour. Besley (1995) used three theoretical arguments to discuss the relationship between property rights and investment incentives. The first argument was based on traditional views, and emphasised people's right to own and use resources. The second argument had to do with investment incentives and property rights and their relationship with the credit market, and the third argument was about investment incentives and property rights and the gains made from trade. This paper uses the first and third arguments. This approach is considered appropriate to situations in which farmers plant trees and the laws governing transfer rights relating to the planted trees are not well-defined, as is the case with Tanzania. If there were clear transfer rights of products from planted trees to the markets, the cost of transactions could be lowered, which would possibly influence household tree planting behaviour significantly.

2.2. Empirical review

There are a number of empirical studies that have looked into several determinants of a household's tree planting behaviour and the types of trees planted (Bluffstone *et al*., 2008; Mekonnen and Damte, 2011). Mekonnen and Damte (2011), analysing tree planting and its intensity by household, found that the availability of resource endowments, household characteristics and institution-related factors influenced households' tree planting behaviour. Different empirical studies indicate that motivational monetary factors represent the households' utility (Poppenborg and Koellner 2013), which in turn influences households' tree planting behaviour (Bluffstone *et al*., 2008; Duesberg *et al*., 2013; Gebreegziabher and Kooten, 2013; Sikor and Baggio, 2014; Ashraf *et al*., 2015; Duan *et al*., 2015). However, some empirical studies found that financial incentives do not influence tree planting behaviour, rather that perceptional and value factors play a vital role in influencing it (Duesberg *et al*., 2013; 2014; Meijer *et al*., 2015). Many of these studies analysed data using discrete choice models.

Employing the Heckman model, the study by Sikor and Baggio (2014) indicates that household assets, expected income, statutory law, and loans have positive influences on households' tree planting. Carroll *et al*. (2011) and Ashraf *et al*. (2015) point out that the decision to plant trees is influenced by policy tools designed to match households utility, which include a tree planting programme, grant and tree planting subsidies, pricing of tree products and income incentives. A large number of studies support the influence of income incentives on households' tree planting behaviour (Gyau *et al*., 2014; Wunder *et al*., 2014; Belcher *et al*., 2015; Cobbinah, 2015; Kibria *et al*., 2015).

According to Frayer *et al*. (2014) and Ashraf *et al*. (2015), the size of land holding as a resource was the primary determinant of tree planting on 'former' cropland by households. Other studies like Jenbere *et al*. (2012) and Meijer *et al*. (2015) found that size of land holding is positively correlated with households' tree planting behaviour, whereas household size/family labour inputs have been found to significantly but negatively influence tree planting behaviour (Jenbere *et al*., 2012). A large household size has been suggested to have a high dependent ratio. In an attempt to match with consumption pressure, households tend to allocate available labour to off-farm activities for more income (Danquah, 2015). This result contradicts the results of several other studies where family size is found to have positive and significant effect on tree planting behaviour, for example that of Gebreegziabher *et al*. (2010).

Mekonnen and Damte (2011) found that experience or age of household heads and the level of education of the head have significant influence on tree planting behaviour. Also, Mahapatra and Mitchell (2001) indicate that the market price of forest products is among the most important factors influencing households' decision to plant trees. According to Mekonnen and Damte (2011), awareness of tree planting obtained from programmes was found to correlate positively and significantly with tree planting, as it was also reported by Gyau *et al*. (2014). The study by Jenbere *et al*. (2012) found that 96% of households planted the eucalyptus species because they were influenced by the existence of tree planting programmes in the area they studied.

Duguma and Hager (2010) assessed wood plant diversity and found that several species of trees planted in a household's plot correlated with the level of education of the household's head, the distance from state-owned forests and the household's assets. The distance a household travels to collect wood for fuel and adequate accessible trees from state forests influences tree planting in households. This suggests that physical and economic scarcity/

adequacy of wood energy influences households' tree planting behaviour (Sood and Mitchell, 2011).

In Tanzania, different studies have reviewed and acknowledged the importance of tree planting as a solution to deforestation. Nevertheless, the studies (e.g., Mwampamba, 2007; TaTEDO, 2009) did not execute an empirical study that could provide useful information about households' tree planting behaviour, and the extent to which devised policies motivate it. Furthermore, Mwampamba (2007) surveyed 244 households in six regions to determine threats to forests in the county. Overall, the results revealed that wood energy consumption was among the main cause of deforestation. Similarly, other studies found this to be the case (Bonnington *et al*., 2007; Msuya, 2011; Mwampamba *et al*., 2013).

Most of the previous studies have focused on the effects of wood fuel consumption on forests, with the result that very little information about households' tree planting behaviour and the factors that determine such households' tree planting behaviour. Against this background, it was of interest to study and determine factors potentially associated with the extent of households' tree planting behaviour.

3. Methodology

This study focused on different study sites in Tanzania: Kibaha District, located 40 km west of Dar es Salaam; Rufiji District, located 178 km south of Dar es Salaam, Coast Region, and Morogoro Rural and Kilombero Districts, located 169 km west of Dar es Salaam in the Morogoro Region (NBS, 2011). These regions of the country were selected as the case, and the data was gathered from households in these regions, where tree planting programmes have been or still are active. Furthermore, the regions are near Dar es Salaam, the country's largest city and commercial centre, where tree products are traded, mostly in the form of charcoal.

3.1. Econometric model

By considering household response to tree planting behaviour as a parameter only observed as an indicator of discrete choice and extent (number of trees planted) of household tree planting, the response is likely to be a source of sample selection bias (see Wooldridge, 2001). If the households that plant trees are not randomly sampled from a population, factors that influence their tree planting behaviour may not be observed (Abebe *et al*., 2008). Wooldridge (2009) noted that selection bias arises when a sample is not randomly selected.

However, other studies have pointed out that selection bias may result from a sampling frame design (Luka and Peracchi, 2007; González-Sepúlveda and Loomis, 2010). For example, if one interviews people who engage in charcoal making as their source of income and asks them how many times a month they produce charcoal, those who do so every week are much more likely to be included in the sample than those who do so every 6 months. In addition, selection bias may also arise from non-response or incorrect response. For example, households that say they do not plant trees may sometimes be those with a few trees that are planted in their plots, but which they do not regard as planted. Finally, selection bias may arise due to self-selection (Wooldridge, 2002), as household heads may select themselves on the basis of their individual characteristics. For example, one may select oneself to be a member of a certain programme (private or public) on the basis of one's level of education, tree planting knowledge or a high level of income.

According to Cameron and Pravin (2009), if a sample is selected on the basis of the value of dependent variables (yes = 1, no = 0), estimated coefficients will be biased when ordinary least squares (OLS) are used. In other studies where the outcome variable of interest is limited or binary in some way, OLS estimates are biased even asymptotically (Wooldridge, 2005). The outcome dependent variable of interest in this study is binary, because the potential outcome of interest arises either from households engaging or not engaging in tree planting. This is why the popular model OLS cannot be used in this study (Greene, 2012).

To meet the specific objectives of this study, we have employed a theoretical framework to discuss different binary choice modelling tools with specific significant features, including the tobit model, probit model, logit models, and propensity score matching model (Amemiya, 1985; Wooldridge, 2009). As already pointed out, this study uses the Heckman selection model because it takes into account the random inverse Mills ratio that is generated from the first stage of probit model estimation. This study examines two kinds of decisions that households make, that is, whether or not to plant trees and the extent to which to plant them.

According to Heckman (1979), the two decision choices are based on an univariate normality assumption, and take into account sample selection endogeneity bias (Puhani, 2000). The Heckman model is robust, and corrects possible selection bias (Wooldridge, 2009). The model treats a selection bias as an omitted variable problem (Vella, 1999; Bushway and Piehl, 2001).

The model under consideration is comprised of the probit equation (selection Equation 2) that relates to households' decision whether or not to plant trees, and the equation that relates to the intensity or magnitude of tree planting (outcome Equation 1). The model is expressed as:

$$y_1 = x_1\beta_1 + u_1, \tag{1}$$

$$y_2 = x_2\beta_2 + v_2, \tag{2}$$

Where y_1 stands for the number of trees planted and y_2 represents the propensity to decide whether or not to plant trees. Where x is a vector of explanatory variables and $u_1 v_2$ are error terms independent of x with zero mean (exogeneity) and constant variance.

In deriving a simple correlation assumption, Heckman (Wooldridge, 2002) assumes that y_1 is observed only when $y_2 = 1$, while (y_2, x) are always observed. He also assumes that error terms (u_1, v_2) have a bivariate normal distribution. It follows, thus, that $E(u_1/v_2 = \gamma v_2)$ (linearity hold), where $v_2 \sim$ normal (0, 1) and γ is the covariance between u_1 and v_2 when var $(v_2) = 1$.

Determining a selection equation with the main assumption that a household's decision whether or not to engage in tree planting is the function of different factors represented by utility maximization, as described in the review of theoretical frameworks in Section 2.1. In the Heckman model, the sample selection bias arises when the error term (residual v_2) in Equation 2 correlates with the residual in Equation 1 (u_1), and thus $\gamma \neq 0$. By deriving an expected outcome, y_1 variable is conditional to an observable x variable $E(y_1/x_2 y_2) = 1$. Thus, we have $E(y_1/x, v_2) = x_1\beta_1 + E(u_1/x, v_2)$. But if the error (u_1, v_2) term does not correct with x then we have $E(y_1/x, v_2) = x_1\beta_1 + E(u_1/v_2))$. Where linearity assumption holds $E(u_1, v_2)$, then we have

$$E(y_1/x, v_2) = x_1\beta_1 + \gamma v_2. \tag{3}$$

When $\gamma = 0$ then we have $E(y_1/x, v_2 = E(y_1/x) = E(y_1/x_1) = x_1\beta_1$. In this case, there is no sample selection problem. If $\gamma \neq 0$ then we have $E(y_1/x, v_2) = E(y_1/x_1 \neq x_1\beta_1)$ problem. To solve this problem, we employ an iterated expectation of outcome as $E(y_1/x_1, y_2 = 1) = E[E(y_1/x, v_2)/x_2, y_2 = 1$.

If we recall Equation 3, then we have:

$$E(y_1/x, y_2 = 1) = E[(x_1\beta_1 + \gamma v_2)/x, y_2 = 1]$$
$$E(y_1/x, y_2 = 1) = x_1\beta_1 + \gamma E(v_2/x, y_2 = 1)$$
$$E(y_1/x, y_2 = 1) = x_1\beta_1 + \gamma\omega(x, y_2 = 1)$$
$$\text{where as } \omega(x, y_2 = 1) = E(v_2/x, y_2 = 1),$$
$$\text{Prob}\,((y_1 = 1) = \vartheta(x\delta_2)), \text{ and prob}\,((y_1 = 0) = \vartheta(1 - x\delta_2)),$$

where β is a confident vector and φ is a cumulative distribution function (CDF) of the standard normal distribution, it follows then that for a subsample where $y_1 = 1$ the conditional expectation of y_1 is given by $E(y_1/x, y_2 = 1) = x_1\beta_1 + E(u_1/v_2 \geq -x\delta_2)$. A useful result is obtained if $x\delta_2$ follows the normal standard distribution with a mean that is equal to zero and a variance that is equal to one, and thus $E(x\delta_2/x\delta_2 > c = \frac{\theta(x\delta_2)}{1-\vartheta(x\delta_2)}$. Here, c is a constant and θ-denotes the standard normal probability density. However, the residual is not standard normal because the variance is not essentially equal to one. In order to standardize the residual, it makes sense dividing and multiplying through with the standard, and transforming the residual so that it becomes a standard normal. After doing this, we can write the function as:

$$E(u_1/v_2 \geq -x\delta_2 = \frac{\theta(-x\delta_2)}{1-\vartheta(-x\delta_2)}$$
$$E(u_1/v_2 \geq -\delta_2 = \sigma\frac{\theta(x\delta_2/\sigma)}{\vartheta(x\delta_2/\sigma)} \equiv \lambda(x\delta_2)E(u),$$

where $\lambda(x\delta_2)$ is the inverse Mills ratio, thus it follows that the fourth equation with a binary discrete dependent variable was employed using the probit model. The inverse Mills generated by estimating the selection equation was added into a continuous dependent variable in the outcome equation (the number of trees planted). The OLS regression, in which the expected value of y_1, is the dependent variable and x_1 and $\lambda(x\delta_2)$ are the explanatory variables, along with the product of the covariance of the error term, makes Equation 3 to be expressed as:

$$E(y_1/x, v_2) = x_1\beta_1 + \gamma\lambda(x\delta_2). \tag{4}$$

Hence, this expression clarifies that the OLS regression y_1 on x_1 omits the term $\lambda(x\delta_2)$. When the model is used directly on data gathered from a sample, the residual of the main (outcome) equation always correlates with the residual in the selection equation, and thus leads to biased estimates of the parameter β_1. Nevertheless, the probit estimation of β_1 usually leads to inconsistent estimates, unless of course u_1 and v_2 error terms are uncorrelated.

3.2.. Data description

The present study analysed data collected from a survey of 202 rural households in 11 villages. We employed a purposive sampling of villages with tree planting programmes, as well as those without programmes. We also used probability sampling procedure to select a sample size of households from two subgroups (one group involved households that planted trees, and the other consisted of those that did not plant trees). Each household had an equal chance of being selected. The primary data was obtained using two approaches. First, through a pilot study, information on the districts and villages where tree planting was done was obtained from the Ministry of Natural Resources and Tourism. Other information was acquired from various tree planting programmes and non-governmental organizations (NGOs), such as the Tanzania Forest Research Institute (TAFORI) and the World Wide Fund (WWF) for Nature–Tanzania. Then, we went to the districts and villages and gathered information from executive officers on the number of households that planted trees. We were told that 20–70 households from different villages have either planted or are planting trees. It was estimated that each village had 461 households. Finally, we randomly selected a sample size of 21 households from each subgroup in each village.

The data collected included the characteristics of households, namely, age, family size, various income sources and the level of education of the head. Also gathered was information on the sources of wood energy, the total size of the land owned by the particular household, the size of tree planted land, farm, household assets, and other assets. Likewise, we gathered information on household awareness of tree planting programmes. Specifically, the information gathered was about households that had planted or did not plant trees, the species of the trees planted, and the existence of tree planting programmes in the villages. Furthermore, data was collected on the perception of the household regarding tree planting, and the right or freedom to harvest and transport tree products from one point to another. Table 1 provides a summary of the different variables considered in this study.

All the aforementioned factors were selected on the basis of the literature reviewed from previous studies as in Section 2.2, as well as from the actual situation in the field. However, factors such as the market price of trees, tree planting as a long term investment and the opportunity cost of the labour used in tree planting were not included in this study due to a lack of, irrelevant or incomplete information from respondents.

4. Results and discussion

Table 2 summarises the variables used in the study, and presents the average and percentage of the results. The main sources of wood energy in the area studied include forest reserves or protected forests, open access forests, and planted trees, together respectively supplying nearly 57.0, 33.9 and 9.1% of wood energy. The results indicate that, on average, households walk about 6 km to fetch firewood in the open access forests.

The total size of a farm and the land in which trees are planted are about 6 and 2 acres, respectively. Only about 9% of the households that engage in tree planting and were interviewed about tree planting information obtained from programmes said they were not aware of any tree planting programme. They said, however, that they got such information from friends, while 45% of the households planted trees because they were aware that such programmes existed in their areas. Fifty-four percent of the respondents reported that they or their ancestors had planted trees of any age on their private lands, something that causes those households who do not plant trees to be an important econometric problem. For those who planted trees, the number of trees planted is about 24 trees per household, with a large disparity between households.

There are six common tree species planted by the households in the areas studied, namely Eucalyptus, Acacia, Albizia Lebeck, Senna Siamea, Casuarina, and Cedrela Ordorata. Senna Siamea accounts for 64% of all the tree species planted in the areas, followed by Eucalyptus (55%). For the percentages of the other tree species, see Table 2.

4.1. The descriptive analysis of households' tree planting statistics

4.1.1. Responses relating to the main purpose of planted trees

The respondents were asked to rank the first/main and second uses of the trees they plant. The respondents said that the first/main purpose of planting a particular tree species was for timber (51%). They also said they planted trees for wood fuel (36%) and poles (13%). In the subsequent equation, which required households to rank the second purpose of planting trees, they ranked wood fuel (51%) as the second purpose, followed by timber (38%) and poles (11%) see Figure 2.

Table 1. Summary of the factors used in the regression model

Variable names	Definition of variables	Unit of variables
hhage	Age of household head as decision-maker	Continuous
HHsize	Size of household in individuals (family size)	Continuous
PerceTreePL	Perception of household towards tree planting (it takes the value ranges from very favourable (+3) to very unfavourable (−3)	Continuous
HHawstreplPM	Household head or any member aware of tree planting programme = 1, 0 otherwise	Dummy
LwoodergINC	Natural log of income of the household earned from wood energy source	Continuous
hhedu	Years of formal education of the head of the household	Continuous
LhhgrsINC	Natural log of household gross income per capita in adult equivalent unit (AEU)	Continuous
hhfarmsize	Total farm size in acres owned by the household	Continuous
hhplantree	Household engages on tree planting score 1, 0 otherwise	Dummy
LasizeplaTr	Land size planted trees by household (acres)	Continuous
RigfharvTP	Right or freedom to harvest and transport trees product (s) from on-farm tree planting to the market: yes = 1, no = 0	Dummy

Table 2. Summary of statistical variables used in the study (202 respondents)

Variables	Mean (%)	Std. dev.	Min	Max
Age of the household head	49.050	11.385	25	90
Education of the household head as a decision-maker (years)	5.421	3.583	0	15
Household size (family size)	5.361	1.321	2	9
Total land size in acres owned by the household	5.590347	3.494	1	20
Land size planted trees by household (acres)	2.109	1.988	0.25	6
Tree planting for wood energy (yes = 1, no = 0)	0.633	0.483	0	1
Gender of household male	166 (82%)	—	—	—
Household awareness on tree planting programme (yes = 1, no = 0)	45%	—	—	—
Household awareness or involvement in any programme(s)				
Percentage of households surveyed that engage in tree planting	54%	—	—	—
Main source of energy				
a. Forest reserve	57%	—	—	—
b. Open access forest	33.9%	—	—	—
c. Own planted trees from private land	9.1%	—	—	—
Distance to the source of energy				
a. Forest reserve (km)	2	0.8075	1	4
b. Open access forest (km)	6	8.9318	6	28
Most reported exotic tree species usually planted for wood energy, timber and pole (% of responses by tree species)				
Eucalyptus Spp	55	60*	—	—
Acacia Spp	45	49*	—	—
Albizia Lebeck	32	35*	—	—
Senna Siamea Spp	64	70*	—	—
Casuarina	23	25*	—	—
Cedrela Odorata	28	30*	—	—
Number of trees planted/grown	24.921	38.394	0	218
Total value of household assets per capita (AEU)	465,669	593,789	80,000	7,571,563
Income of households from off-farm activities (yes = 1, no = 0)	57%	n = 155	—	—
Income of household from wood energy source	65%	—	—	—
Income from petty trade	20%	—	—	—
Other sources	15%	—	—	—
Log of household gross income per capita in adult equivalent unit (AEU) in Tsh	13.162	0.39868	12.1607	15.0329

Note: US$ = 1630 Tshs during the survey time period.
*Implies frequency of response by number of respondents on the tree species planted in the areas studied.

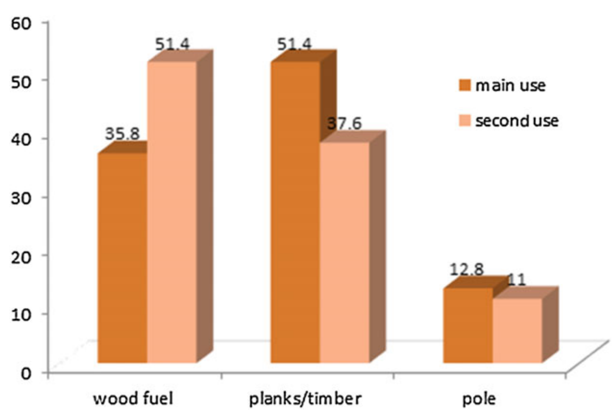

Figure 2. Main and second purpose of planting trees in Tanzania. *Source*: Survey 2013.

4.2. Regression results of Heckman model

The empirical regression results, using the Heckman model, are set out to determine the households' tree planting behaviour, as well as its intensity. As we are aware that the Heckman model involves the OLS model in its stages, we begin with OLS analysing of itself, because it provides a bridge between the traditional approach and econometrics (Greene, 2012). When the errors are serially uncorrelated, the OLS estimator is consistent and applicable in the investigation of issues that are cross-sectional in nature, as in this case. Nevertheless, the OLS model treats explanatory variables as fixed, while the Heckman approach treats explanatory variables as random and stochastic. Thus, the OLS model is likely to predict unintended results, especially in advanced variable settings, as in the setting of the present study, where the error terms are unlikely to be serially uncorrelated. Usually the model imposes unrealistic restrictions on people's behaviour, and thus renders itself irrelevant.

Regression analysis results that reflect the effect of each variable on the predicted probability are presented in Table 3. The OLS regression analysis shows that is 0.41. This suggests that the low highlights the model prediction error and calls for further investigation. The prediction is consistent with our expectation that if OLS omits the term λ, it may lead to an inconsistent estimation of (β). The statistical significance of inverse Mills term $\lambda(x\delta_2)$ justifies the OLS inconsistency as well. Furthermore, the inverse Mills term suggests that OLS may not be an appropriate model where there is selection bias (Marchenko and Genton, 2012), thereby suggesting the relevance of the Heckman model to this study.

The Heckman model's results are interesting in the sense that an estimated correlation coefficient is statistically significant. Based on the findings, the likelihood ratio (LR) test implies that the two questions estimated in the model are not independent. Thus, we cannot reject the alternative hypothesis that is not equal to zero. In addition, it is evident that an overdispersion and unobservable heterogeneity are present since δ is positive and significant. In our analysis, we estimated the model without exclusion restrictions, with the assumption that the identification of the model rests on the non-linearity of the inverse Mills ratio, and without the inclusion of another variable in the selection equation that is not in the outcome equation (Mekonnen and Damte, 2011).

The results from the selection equation indicate that the explanatory variables that are most associated with tree planting include farm sizes, households' awareness of tree planting programmes, the right/freedom to harvest and transport tree product(s) from the farms to the market, and household sizes. However, the explanatory household gross income factor did not have any significant effect on households' tree planting behaviour, although it was positive.

We used the age of household heads, tree planting for wood energy production, and households' perception of tree planting activities to determine the number of trees planted. These variables have a significant impact on the extent (number) of trees planted, contrary to what is found in the households' tree planting behaviour equations. In both equations, farm or land sizes, households' awareness of tree planting programmes, the right/freedom to harvest and transport trees product(s) from the farms to the market, and households' sizes were all statistically significant, with positive and negative coefficients. The findings are discussed below.

5. Discussion

Discussion of the results is executed as follows. First, we discuss the descriptive statistics presented in Table 2. Second, our discussion is guided by econometric techniques. We use these techniques to identify the correlates of households' tree planting behavour, as well as the extent to which trees are planted. Third, we discuss the marginal effects found in the selection equation and in the outcome equation variables, which measure the effect of exogenous variables on the probability of a particular choice (planting or not planting trees and the number of trees planted).

Despite the existing tree planting constraints, which inhibit tree planting programmes in Tanzania (Kindo *et al*., 2010), on average a household planted about 25 trees, with a large variation across households. We found six common tree species planted in the areas we studied, namely Eucalyptus, Acacia, Albizia Lebeck, Senna Siamea, Casuarina, and Cedrela Ordorata (Table 2). Most of the households planted Eucalyptus (55% responses by tree species) because of several uses, including for timber and energy for trade and domestic consumption, as compared to the uses of the other species. However, the responses relating to the planting of Senna Siamea species accounted for about 64% of all of the responses. This could be explained by the fact that this species has various local names, including *mijohoro*, *misaji*, and *michongoma*. The low number of trees planted could be explained by the nearby forest reserves, which are relatively easily accessible for households, especially in comparison to the establishment of their own tree sources. Another explanation could be due to the shortage of land size and seedling availability.

During the survey, it was observed that the households lacked proper seeds, especially after the programmes came to an end. This was one of the major challenges they faced. This observation is different from the findings in the study by Gebreegziabher and Kooten (2013), in which the government supported regional nurseries as the main sources of seedlings for all species for wood energy.

The local seeds were reported to have a low genetic gain in size and volume for wood energy (charcoal), timber and poles. Observation shows that the size and volume gain of trees is one of the factors that motivate households to plant trees for various usages. Therefore, the low genetic gain in size and volume reduces the probability that households could plant trees using local seeds when proper seeds are not attainable.

Household awareness of tree planting in Tanzania is largely raised by NGOs and tree planting programmes. About 45% of the households interviewed got information about tree planting activities from tree planting programmes. Only 9% of the households acquired such information from other sources, including friends. This is consistent with findings of an earlier study (Jera and Ajayi, 2008), which documents the importance of household awareness of tree planting in influencing household tree planting behaviour. Tree planting programmes influence households' decisions to plant trees in the areas studied. The results (Table 2) indicate that very few households

Table 3. Results of the sample selection Heckman model of the determinants of tree planting

Variables	OLS	Heckman maximum likelihood (ML)	
Outcome equation	*Coeff.*	*Coeff.*	Marginal *effect*
RigfharvTP	−10.655*** (3.773)	−10.338** (5.926)	−0.534*** (0.0752)
hhage	0.394 (0.184)	0.574** (0.309)	0.0081** (0.003)
hhfarmsize	1.738*** (0.663)	0.788*** (0.399)	0.059*** (0.015)
TrplwoodEnerg	18.659*** (5.228)	22.072*** (7.599)	0.218*** (0.107)
LwoodergINC	−0.802 (0.792)	−0.346 (1.153)	−0.0278 (0.017)
HHawstreplPM	25.3532*** (5.353)	0.023** (0.003)	0.510** (0.186)
LhhgrsINC	−2.981 (5.919)	8.841 (9.342)	0.029 (0.164)
hhedu	−0.431 (0.5477)	1.209 (0.897)	0.009 (0.012)
PerceTreePL	−2.121 (1.424)	−5.400** (2.598)	−0.510*** (0.086)
HHsize	−0.2102** (0.103)	−2.934*** (0.753)	−0.091*** (0.035)
Constan	−0.6259 (4.438)	−93.382 (131.185)	—
Selection equation			
RigfharvTP	−0.235*** (0.072)	−0.806*** (0.313)	−0.343*** (0.102)
hhage	0.004* (0.002)	0.018 (0.011)	0.006 (0.003)
hhfarmsize	0.022*** (0.008)	0.117*** (0.043)	0.045*** (0.014)
TrplwoodEnerg	0.047 (0.062)	0.415 (0.323)	0.159 (0.117)
LwoodergINC	−0.015 (0.009)	−0.066 (0.051)	−0.028 (0.019)
HHawstreplPM	0.457*** (0.070)	1.51688*** (0.292)	0.511*** (0.086)
LhhgrsINC	0.048 (0.074)	0.033 (0.317)	0.014 (0.1947)
hhedu	0.006 (0. 007)	0.046 (0.031)	0.009 (0.012)
PerceTreePL	−0.017 (0.017)	−0.038 (0.079)	−0.029 (0.031)
HHsize	−0.051** (0.022)	−0.210** (0.104)	−0.092** (0.045)
Constant	−0.447 (1.016)	−1.166 (4.378)	—
ρ	—	−0.751***	—
σ	—	3.566***	—
Heckman's λ: *LR* test of indep. eqns χ^2 (9)	ρ = 0: χ^2 (1) = 25.9***	−22.4935*** (6.64710)	—

Note: Standard error in parentheses. Set initial value of corr and std deviation.
*Indicates statistically significant at the 10% level or more, ** indicates statistically significant at the 5% level or more, and *** indicates statistically significant at the 1% level or more.

engage in tree planting without the programmes' sensitization.

Furthermore, the respondents ranked wood energy (51%) as the second purpose for planting trees, after timber production. This may be due to the fact that wood energy is the main source of energy used for cooking and heating and is a source of income for most households in Tanzania in general, as well as in the areas studied in particular. For instance, about 65% of the respondents said that they engage in felling trees for domestic energy consumption and trade (Table 2).

5.1. Determinants of households' tree planting behaviour

The dependent variables in the Heckman model were estimated to analyse the determinants of a household's tree planting behaviour, whether or not the household planted trees (1 = yes, 0 = no). We estimate the model depending on whether or not the dependent variable represents a household that planted trees. As concluded by Duesberg *et al.* (2014), the results indicate that policy-related factors, the right/freedom to harvest and the transport of tree products from the farms to the market and households' awareness of tree planting programmes are likely to influence their tree planting behaviour. The right/freedom to harvest and transport tree products from the farms to the market has a statistically significant effect on households' tree planting behaviour, but with a negative sign. This suggests that households continue to view tree planting as an insecure opportunity, probably because of prohibitive and weak regulations that attempt to limit the freedom and right in question. Although legally there is no published prohibitive information about the freedom in question in the areas surveyed, as per these findings there is reason to believe that there could be little freedom for the households to harvest and transport their tree products. The results indicate that a unit increase in such a right or freedom affects households' tree planting behaviour by 34.3%. To generate determinant explanatory variables, we coded the responses as 1 if a respondent said that there was the right/freedom to harvest and transport tree products from the farms, and 0 if otherwise. Another policy-related determinant variable is household awareness of tree planting programmes.

This kind of awareness has a positive and statistically significant effect on households' tree planting behaviour at a 1% level of significance. It is therefore clear from the findings that households with better knowledge about the short and long-term benefits of having trees and about how the programmes or the country's policies could favour them are more likely to plant trees in the areas studied. In other words, a unit increase in awareness increases the possibility of planting tress by 51%. Although programmes observed belong to NGOs whose objective is to conserve the environment, these organizations nonetheless implicitly approach the communities by giving them incentives such as free seeds. This suggests that institutional coordination and clear information about the need of trees and types of trees required in each area can have a positive influence on households' tree planting behaviour, as also highlighted by Frayer *et al*. (2014). The results are interesting in that the same factors are not necessarily the most important to both households' tree planting behaviour and number of trees planted.

Another determinant of households' tree planting behaviour is the size of the land a household owns. The size of the land positively influenced a household's tree planting behaviour. This suggests that once the decision to plant trees is made, land tenure becomes important to the households in the areas studied. A unit increase in the amount of land a household owns increases the household's propensity to plant trees by 4.5%. This implies that households with large farmland are more likely to plant trees than households with a small tract of land or no land. Similarly, Ashraf *et al*. (2015) shows a positive correlation between the size of landholdings and tree planting behaviour of households.

Some household characteristics, such as age and level of education, did not have a significant influence on their tree planting behaviour. Family sizes, however, negatively and significantly (P 0.045) affected households' tree planting behaviour, and similar results were shown by Danquah (2015). The marginal effect results of the model indicate that increasing the size of a household by one person is likely to decrease the possibility of households' tree planting by 21%. This result is consistent with the argument that when the size of a family increases, usually through an additional number of children, parents redivide a piece of land among all their children after they grow up, in an effort to help them get a start in life. As a result, the size of the land is reduced and the probability of tree planting in favour of crop production is reduced as well. Tree planting is likely to be given little weight when the size of land falls short. However, this finding is different from the findings of various previous studies, which indicated that more trees were planted when family sizes increased (Duguma and Hager, 2010; Gebreegziabher and Kooten, 2013).

5.2. *Determinants of the number of trees planted*

In this subsection, we discuss determinants of the number of trees that the households planted. The results indicate that some variables have a statistically significant positive effect on the number of trees planted, and that other variables have a statistically significant negative effect on the extent of trees planted. The variables that have a statistically significant positive effect on the number of trees planted included the size of the land owned by a particular household, the household's awareness of tree planting programmes, tree planting for wood energy production, and the age of the head of a household. The factors that have a negative influence on tree planting, which are statistically and significantly correlated with the number of trees planted, included the right/or freedom to harvest and transport tree product(s) from the farms to the market, households' perception of tree planting activities, and a household's size.

As indicated in Table 3, the size of the farm that a household owned is positively correlated with both the household's trees planting behaviour and the number of trees planted. This implies that households with large pieces of farm or land are more likely to plant many trees than those with small pieces of land. The marginal effect revealed that a one-unit increase in the size of a farm increases the probability in the number of trees planted by a household by 5.9%. Similarly, Danquah (2015) and Ashraf *et al*. (2015) conducted studies in Ghana and India, and found that farm size had a significantly positive influence on tree planting behaviour and its extent. Likewise, raising household awareness of tree planting programmes increases the number of trees planted by 51%. In general, this finding suggests that if households know the importance of planting trees, many trees will be planted in the areas studied. We argue here that the presence of tree planting programmes and NGOs could raise the number of trees planted in Tanzania.

The results also suggest that tree planting for wood energy positively influenced households' decisions to plant many trees on their farms. Although the main source of wood energy is forest reserves (57%), it appears that regulations have some positive effect on tree planting for wood energy in the areas studied. For example, the respondents were asked whether there were any restrictions on the resources found in forest reserves. In response to the question, they said that there were restrictions on such resources. Likewise, the distance between the villages and open access forests (6–28 km) could also have some positive influences on planting of trees for energy production, as demonstrated by Köhlin and Parks (2001).

The findings indicate that there is a negative correlation between households' perceptions of tree planting activities and the number of trees planted. The findings show that a one-unit increase in households' perceptions of tree planting activities reduces the possibility of trees being planted in the areas studied by 51%. In line with a theoretical framework by Besley (1995), one possible explanation for this phenomenon might be that the right/freedom to harvest tree products from the farms reduces the probability of the households to plant trees on their land by 53%. Moreover, the regulatory measures taken in the areas in focus force the households to sell their products through intermediaries or middlemen, for the procedure they have to follow in order to get official permits is both costly and bureaucratic.

6. Conclusion and policy implications

This paper is perhaps the first comprehensive study analysing factors that influence households' tree planting behaviour in Tanzania, and provides results that are useful for policymakers both in Tanzania and in other developing countries with similar conditions. A Heckman model is undertaken to analyse the factors that drive tree planting behaviour. Some conclusions can be drawn from the analysis in this study.

First, the findings show that the main source of wood energy in the areas studied is forest reserves or protected forest areas, supplying nearly 57%. Perhaps this reflects a weak enforcement of the regulations on forest reserves. In the present context of forest-dependent households, strengthening the restrictions on forest reserves would lead to increased wood energy consumption from farms by more than 9.1%. The results also show that the main purpose of planting trees is the production of timber, followed by the production of wood for energy. Second, there are factors that are important and have a statistically significant effect on tree planting behaviour, including the right/freedom to harvest and transport tree products from the farms to the market, households' awareness of tree planting programmes, the size of the land owned by households and family sizes. Third, the efforts to promote tree planting behaviour should focus on the right/freedom to harvest and transport tree products to the market, household awareness of tree planting programmes, and the size of the land owned by households. Other factors to consider include the availability of both proper seedlings and preferred tree species. For example, we believe that if there were a clear and ensured transfer right of products from planted trees to the markets, households could view tree planting as a secure business, which possibly would significantly influence tree planting behaviour. Therefore, we recommend that the forest policy that appears to permit the sale of forest products be reviewed for practical purpose.

Finally, our findings suggest that unless an alternative feasible tree planting policy that merges well with variables that have significant effects on household tree planting behaviour is found, it is likely that negative tree planting behaviour, including deforestation resulting from the felling of trees for timber and for wood energy will continue. This study also highlights the need for several interesting research areas for future studies. For example, a study for designing a policy instrument for encouraging people to plant trees in their areas could be undertaken. Another study may analyse household perceptions regarding the planting of trees for wood energy.

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References

Abebaw, D., Kassa, H., Kassie, G.K., Lemenih, M., Campbell, B., Teka, W., 2012. Dry forest based livelihoods in resettlement areas of Northwestern Ethiopia. *Forest Policy and Economics*, 20(1): 72–77.

Abebe, W., Puskur, R., Karippai, R.J., 2008. Adopting an improved box hive in the Atsbi Wenberta District of Eastern Tigrai Zone, Tigrai Region: Determinants and financial benefits. IPMS Working Paper No. 10. Addis Ababa.

Allen, U.C., Barnes, D.F., 2005. The causes of deforestation in developing countries. *Annals of the Association of American Geographers*, 75(2): 163–184.

Amacher, G.S., Eesado, L., Hyde, W.F., Osorio, A., 2004. Tree planting in Tigray, Ethiopia: The importance of human disease and water microdams. *Agroforestry Systems*, 60(3): 211–225.

Amemiya, T., 1985. *Advanced Econometrics*. Harvard University Press, Cambridge, MA.

Arnold, M., Persson, R., 2003. Reassessing the fuelwood situation in developing countries. *The International Forestry Review*, 5(4): 379–383.

Ashraf, J., Pandey, R., de Jong, W., Nagar, B., 2015. Factors influencing farmers' decisions to plant trees on their farms in Uttar Pradesh, India. *Small-Scale Forestry*, 14(3): 301–313.

Belcher, B., Achdiawan, R., Dewi, S., 2015. Forest-based livelihoods strategies conditioned by market remoteness and forest proximity in Jharkhand, India. *World Development*, 66(2015): 269–279.

Besley, T., 1995. Property rights and investment incentives: Theory and evidence from Ghana. *Journal of Political Economy*, 103(5): 903–937.

Bluffstone, R., Boscolo, M., Molina, R., 2008. Does better common property forest management promote behavioral change? On-farm tree planting in the Bolivian Andes. *Environment and Development Economics*, 13(2): 137–170.

Bonnington, C., Weaver, D., Fanning, E., 2007. The use of teak (Tectona grandis) plantations by large mammals in the Kilombero Valley, southern Tanzania. *African Journal of Ecology*, 47(2): 138–145.

Brockhaus, M., Gregorio, M.D., Mardiah, S., 2013. Governing the design of national REDD+: An analysis of the power of agency. *Forest Policy and Economics*, 49(2014): 23–33.

Bushway, S., Piehl, A., 2001. Judging judicial discretion: Legal factors and racial discrimination insentencing. *Law Society Review*, 35(4): 733–764.

Cameron, A.C., Pravin, K.T., 2009. *Microeconometrics Using Stata*. Stata Press, College Station, TX.

Carroll, M.S., Ní Dhubháin, Á., Flint, C.G., 2011. Back where they once belonged? Local response to afforestation in County Kerry, Ireland. *Sociologia Ruralis*, 51(1): 35–53.

Chazdon, R.L., 2008. Beyond Deforestation: Restoring Forests and Ecosystem Services on Degraded Lands. *Science*, 320(5882): 1458–1460.

Chidumayo, E.N., Gumbo, D.J., 2013. The environmental impacts of charcoal production in tropical ecosystems of the world: A synthesis. *Energy for Sustainable Development*, 17(1): 86–94.

Cobbinah, P.B., 2015. Local attitudes towards natural resources management in rural Ghana. *Management of Environmental Quality*, 26(3): 423–436.

Cooke, P., Köhlin, G., Hyde, W.F., 2008. Fuel wood, forests and community management evidence from household studies. *Environment and Development Economics*, 13(1): 103–135.

Danquah, J.A., 2015. Analysis of factors influencing farmers' voluntary participation in reforestation programme in Ghana. *Forests, Trees and Livelihoods*, 24(3): 176–189.

Das, N., 2012. Impacts of participatory forestry program on sustainable rural livelihoods: Lessons from an Indian province. *Applied Economic Perspectives and Policy*, 34(3): 428–453.

Duan, W., Lang, Z., Wen, Y., 2015. The effects of the sloping land conversion program on poverty alleviation in the Wuling mountainous area of China. *Small-Scale Forestry*, 14(3): 331–350.

Duesberg, S., Dhubháin, Á.N., O'Connor, D., 2014. Assessing policy tools for encouraging farm afforestation in Ireland. *Land Use Policy*, 38(2014): 194–203.

Duesberg, S., O'Connor, D., Dhubháin, Á.N., 2013. To plant or not to plant—Irish farmers' goals and values with regard to afforestation. *Land Use Policy*, 32(2013): 155–164.

Duguma, A.L., Hager, H., 2010. Woody plants diversity and possession, and their future prospects in small-scale tree and shrub growing in agricultural landscapes in central highlands of Ethiopia. *Small-Scale Forestry*, 9(2010): 153–174.

Felix, M., Gheewala, S.H., 2011. A review of biomass energy dependency in Tanzania. *Energy Procedia*, 9(2011): 338–343.

Frayer, J., Sun, Z., Müller, D., Munroe, D.K., Xu, J., 2014. Land use policy analyzing the drivers of tree planting in Yunnan , China , with Bayesian networks. *Land Use Policy*, 36(2014): 248–258.

Gebreegziabher, Z., Mekonnen, A., Kassie, M., Köhlin, G., 2010. *Household Tree Planting in Tigrai*. Environment for Development. Discussion Paper Series. EfD DP, Northern Ethiopia. pp. 10–01.

Gebreegziabher, Z., Kooten, G.C., 2013. Does community and household tree planting imply increased use of wood for fuel? Evidence from Ethiopia. *Forest Policy and Economics*, 34(1): 30–40.

Gerber, N., Nkonya, E., von Braun, J., 2014. Land degradation, poverty and marginality. Available at http://link.springer.com/chapter/10.1007/978-94-007-7061-4_12 (accessed April 2015).

González-Sepúlveda, J.M., Loomis, J.B., 2010. Do CVM welfare estimates suffer from on-site sampling bias? A comparison of on-site and household visitor surveys. *Agricultural and Resource Economics Review*, 39(3): 561–570.

Greene, W.H., 2012. *Econometric Analysis*, 7th edn. Prentice Hall, Upper Saddle River, NJ.

Gundimeda, H., Shyamsundar, P., 2012. Forests, sustainability andpoverty in India. *Environment and Development Economics*, 17(03): 373–378.

Gyau, A., Smoot, K., Kouame, C., Diby, L., Kahia, J., Ofori, D., 2014. Farmer attitudes and intentions towards trees in cocoa (Theobroma cacao L.) farms in Côte d'Ivoire. *Agroforestry Systems*, 88(6): 1035–1045.

Hansen, C.P., Pouliot, M., Marfo, E., Obiri, B.D., Treue, T., 2015. Forests, timber and rural livelihoods: Implications for social safeguards in the Ghana-EU voluntary partnership agreement. *Small-Scale Forestry*, 14(4): 401–422.

Hardin, G., 1968. The tragedy of the commons. *Science*, 162(3859): 1243–1247.

Heckman, J.J., 1979. Sample selection bias as a specification error. *Econometrica*, 47(1): 153–161.

Hosonuma, N., Herold, M., Fries, R.D., Brockhaus, M., Verchot, L., Angelsen, A., Romijn, E., 2012. An assessment of deforestation and forest degradation drivers in developing countries. *Environmental Research Letters*, 7(4): 12.

de Janvry, A., Sadoulet, E., 2006. Progress in the modeling of rural households' behavior under market failures. In: de Janvry, A., Kanbur, R. (Eds.), *Poverty, Inequality and Development: Essay in Honor of Erik Thorbecks* (Vol. 1). Springer, New York. pp. 155–181.

Jenbere, D., Lemenih, M., Kassa, H., 2012. Expansion of eucalypt farm forestry and its determinants in Arsi Negelle District, South Central Ethiopia. *Small-Scale Forestry*, 11(3): 389–405.

Jera, R., Ajayi, O.C., 2008. Logistic modelling of smallholder livestock farmers' adoption of tree-based fodder technology in Zimbabwe. *Agrekon*, 47(3): 379–392.

Josh, S., Arano, K., 2009. Determinants of private forest management deci-sions: A study on West Virginia NIPF landowners. *Forest Policy and Economics*, 11(2): 118–125.

Khan, S.R., Khan, S.R., 2009. Assessing poverty–deforestation links: Evidence from Swat, Pakistan. *Ecological Economics*, 68(10): 2475–2734.

Kibria, A.S.M.G., Inoue, M., Nath, T.K., 2015. Analysing the land uses of forest-dwelling indigenous people in the Chittagong Hill Tracts, Bangladesh. *Agroforestry Systems*, 89(4): 663–676.

Kindo, A.I., Mndolwa, M.A., Edward, E., Chamshama, S.A.O., 2010. Performance of four-year-old Australian and Papua New Guinean Acacia species/provenances at Kongowe, Kibaha, Tanzania. *Southern Forests*, 72(1): 13–22.

Köhlin, G., Parks, P.J., 2001. Spatial variability and disincentives to harvest: Deforesta-tion and fuelwood collection in South Asia. *Land Economics*, 77(2): 206–218.

Lancaster, K., 1975. The theory of household behavior: some foundations. *Annals of Economic and Social Measurement*, 4(1): 5–21.

Larson, A., Brockhaus, M., Sunderlin, W.D., Babon, A., Dokken, T., Pham, T.T., Awono, A., Huynh, T., 2013. Land tenure and REDD+: The good, the bad and the ugly. *Global Environmental Change*, 23(3): 678–689.

Liang, Y., Li, S., Feldman, M.W., Daily, G.C., 2012. Does household composition matter? The impact of the Grain for Green Program on rural livelihoods in China. *Ecological Economics*, 75(C): 152–160.

Lokina, R.B., Robinson, E.J.Z., 2008. Determinant of the effectiveness of participatory forest management in Tanzania. Paper presented at the European Association of Environmental and Resource Economists, Gothenburg, Sweden.

Louhichi, K., Paloma, G.S., Belhouchette, H., Allen, T., Fabre, J., Fonseca, M.B., Chenoune, R., Acs, S., Flichman, G., 2013. *Modelling Agri-Food Policy Impact at Farm-Household Level in Developing Countries. FSSIM-Dev.* In: Louhichi, K., Paloma, G.S., (Eds.), *European Commission, Joint Research Centre, Institute for Prospective Technological Studies*. European Union, pp. 1831–9424.

Luca, G., Peracchi, F., 2007. A sample selection model for unit and item nonresponse in cross-sectional surveys. CEIS Tor Vergata - Research Paper Series, Vol. 33 , No. 99. Available at: http://ssrn.com/abstract=967391

Mahapatra, A.K., Mitchell, C.P., 2001. Classifying tree planters and non-planters in a subsistence farmingsystem using a discriminant analytical approach. *Agroforestry Systems*, 52(1): 41–52.

Malimbwi, R.E., Zahabu, E.M., 2008. Woodlands and the charcoal trade: The case of Dar es Salaam City. *Working Papers of the Finnish Forest Research Institute*, 98(1): 93–114.

Marchenko, Y.V., Genton, M.G., 2012. A Heckman selection model. *Journal of the American Statistical Association*, 107(497): 304–317.

Meijer, S.S., Catacutan, D., Sileshi, G.W., Nieuwenhuis, M., 2015. Tree planting by smallholder farmers in Malawi: Using the theory of planned behaviour to examine the relationship between attitudes and behaviour. *Journal of Environmental Psychology*, 43(1): 1–12.

Mekonnen, A., Damte, A., 2011. Private tree and household assets and determinant of tree-growing behaviour in rural Ethiopia. EfD Discussion Paper Series 11-14. Resources for the Future and Environmental for Development, Washington, DC and Gothenburg.

MNRT, 2013. Ensure the full participation of local communities, NGOs and the private sector in conserving and managing natural resources for the benefit of the present and future generation, Vice President's

Office, Division of Environment, United Republic of Tanzania, Dar es Salaam.

Mwampamba, T.H., 2007. Has the woodfuel crisis returned? Urban charcoal consumption in Tanzania and its implications to present and future forest availability. *Energy Policy*, 35(8): 4221–4234.

Mwampamba, T.H., Ghilardi, A., Sander, K., Chaix, K.J., 2013. Dispelling common misconceptions to improve attitudes and policy outlook on charcoal in developing countries. *Energy for Sustainable Development*, 17(2): 75–85.

Msuya, N., 2011. Environmental burden of charcoal production and use in Dar es Salaam, Tanzania. *Journal of Environmental Protection*, 2(10): 1364–1369.

NBS, 2011. National accounts of Tanzania mainland 2000–2010. Available at www.nbs.go.tz , accessed on May 2015.

Ostrom, E., 2002. Common pool resources and institutions: Toward a revised theory. In: Gardner, B., Rausser, G. (Eds.), *Handbook of Agricultural Economics*. Elsevier, Amsterdam. pp. 1315–1339.

Poppenborg, P., Koellner, T., 2013. Do attitudes toward ecosystem services determine agricultural land use practices? An analysis of farmers' decision-making in a South Korean watershed. *Land Use Policy*, 31: 422–429.

Puhani, P.A., 2000. Puhe Heckman correction for sample selection and its critique. *Journal of Economic Surveys*, 14(1): 53–68.

Robinson, E.J.Z., Albers, H.J., Williams, J.C., 2006. Spatial and temporal modeling of community non-timber forest extraction. CSAE Working Paper 03.

Royse, D.D., 2008. *Research Methods in Social Work*, 5th edn. Thomson Higher Education, Belmont, CA.

Shively, E.G., 2000. Economic policies and the environment: the case of tree planting on low-income farms in the Philippines. *Environment and Development Economics*, 3(1): 83–104.

Sikor, T., Baggio, J.A., 2014. Can smallholders engage in tree plantations? An entitlements analysis from Vietnam. *World Development*, 64: S101–S112.

Simmons, C.S., Walker, R.T., Wood, C.H., 2002. Tree planting by small producers in the tropics: A comparative study of Brazil and Panama. *Agroforestry Systems*, 56(2): 89–105.

Sood, K.K., Mitchell, C.P., 2011. Household level domestic fuel consumption and forest resource in relation to agroforestry adoption: Evidence against need-based approach. *Biomass and Bioenergy*, 35(1): 337–345.

Sunderlin, W.D., Angelsen, A., Belcher, B., Burgers, P., Nasi, R., Santoso, L., Wunder, S., 2005. Livelihoods, forests, and conservation in developing countries: An Overview. *World Development*, 33(9): 1383–1402.

TaTEDO, 2009. *Sustainable Charcoal Production for Poverty Reduction in Tanzania (Some Issues and Options). Some Selected Experience from TaTEDO'S Work on Improved Charcoal Production Practices*. Bioenergy for Sustainable Development in Africa, Brussels.

URT, 2006. *Study to Establishing Mechanism for Payments for Water Environmental Services for the Rufiji River Basin in Tanzania*. Economic Research Bureau University, Dar es Salaam.

URT, 2012. *National Forestry Resources Monitoring and Assessment*. Ministry of Natural Resources and Tourism, Dar es Salaam.

Vella, F., 1999. Estimating models with sample selection bias: a survey. *Journal of Human Resources*, 33(1): 127–169.

Wang, C., Pan, S., Qin, L., 2012. Effects of off-farm work on farm household production choices. Selected Poster Prepared for Presentation at the International Association of Agricultural Economists (IAAE). Triennial Conference, Foz do Iguaçu, Brazil, 18-24 August 2012.

Wooldridge, J.M., 2001. *Econometric Analysis of Cross Section and Panel Data*. The MIT Press, Cambridge, MA.

Wooldridge, J.M., 2002. *Econometric Analysis of Cross Section and Panel Data*. The MIT Press, Cambridge, MA.

Wooldridge, J.M., 2005. Simple solutions to the initial conditions problem indynamic, nonlinear panel-data models with unobserved heterogeneity. *Journalof Applied Econometrics*, 20(1): 39–54.

Wooldridge, J.M., 2009. Hurdle and "selection" models. Michigan State UniversityBGSE/IZA Course in Micro-econometrics.

World Bank, 2013. Tanzania National Panel Survey data AGRODEP. Available at http://go.worldbank.org/ U6O4OFC7U0 (accessed 25 May 2013).

Wunder, S., Börner, J., Shively, G., Wyman, M., 2014. Safety nets, gap filling and forests: A global-comparative perspective. *World Development*, 64: S29–S42.