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The Impact of Farm Forestry on Poverty alleviation and Food Security in Uganda

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Abstract

To address the problem of high rural poverty and food insecurity, government and international donors have funded on-farm plantation forestry projects as one of the tools for improving the welfare of rural communities. In the wake of climate change, on-farm plantation forestry has evolved to include carbon forestry, with the dual purpose of sequestering carbon and improving rural livelihoods. However, there is a dearth of empirical evidence regarding whether and under what conditions on-farm plantation forestry can deliver favorable livelihood outcomes.

Therefore, Propensity Score Matching (PSM) and endogenous switching regression models were used to estimate the average treatment effects of adopting eucalyptus and carbon forestry woodlots (under the planvivo system) on consumption expenditure per adult equivalent and daily calorie acquisition per adult equivalent. PSM and switching regression results consistently indicated that adoption of eucalyptus woodlots increased consumption expenditure by 32 and 28.3% respectively. PSM and switching regression results also indicated that adoption of eucalyptus woodlots increased calorie acquisition per adult equivalent by 36 and 13.1% respectively. Results also indicated that adoption of carbon forestry increased calorie acquisition per adult equivalent by between 22 and 26.9% but the impact on consumption expenditure per adult equivalent was mixed. The findings of this study provide empirical evidence that adoption of on-farm eucalyptus woodlots is an important pathway for smallholder farmers to escape poverty and improve food security. Similarly, adoption of carbon forestry woodlots under the planvivo system can improve food security. However, previous on-farm plantation forestry projects were not well targeted to the poor households.

Keywords: food security, on-farm, plantation forestry, poverty alleviation

1. Introduction

There has been a significant shift in focus from encouraging natural forest extraction to forest plantation establishment in many parts of the tropics (Angelsen & Wunder, 2003). Promotion of forest plantation establishment has included smallholder tree growing on-farm. On-farm plantation forestry, also known as farm forestry, has received enormous support from governments and their development partners (Food and Agriculture Organisation [FAO], 2011). The importance of farm forestry as a livelihood improvement strategy is highlighted by the higher poverty rates in most developing countries. It is estimated that more than 90% of the poor in sub-Saharan Africa live in the rural areas and they mainly depend on agricultural production as a source of livelihood (Oksanen *et al.*, 2003; Chamshama *et al*., 2004).

The key appeal of on-farm plantation forestry is that in addition to addressing environmental concerns such as deforestation and climate change, it is seen as a tool for improving the welfare of rural communities through supplying the wood products market (FAO, 2001; Ministry of Water Lands and Environment [MWLE], 2002). The assumption is that facilitating poor households to participate in farm forestry would improve their incomes and enable them to eventually escape poverty by producing products and services for home consumption as well as cash income (Oksanen *et al.*, 2003; Higman *et al*., 1999; Curtis & Race, 1998). Unlike commercial plantation forestry, on-farm plantation forestry can be adopted by small-medium scale farmers and therefore is seen as being more pro-poor.

The international expert consultation on the role of planted forests recognized that planted forests provided a diverse range of goods and services, including timber, fuelwood, non-wood forest goods, conservation, carbon sequestration, recreation, erosion control, rehabilitation of degraded lands and amenity enhancement (FAO, 1996; Cossalter & Pye-Smith, 2003). However, concerns have also been raised about the potential competition between farm forestry and other land use options available to rural households (Arnold, 2001). This is important given the long-term nature of tree growing, especially from the perspective of the poor (Oksanen *et al.*, 2003). Concerns have also been raised about the opportunity cost associated with displacement of other land uses (Pagiola *et al*., 2005; Corbera *et al*., 2007).

In the wake of climate change, on-farm plantation forestry has evolved to include carbon forestry where farmers grow trees to benefit from selling carbon credits (United Nations Framework Convention on Climate Change [UNFCCC], 2008). Afforestation/reforestation (AR) projects in clean development mechanism (CDM) and voluntary carbon market provide cash incentives for afforestation and reforestation activities in rural communities (Nelson & de Jong, 2003; Smith & Scherr, 2002). This provides an opportunity for capital inflows into impoverished rural communities in developing countries (Asquith *et al.*, 2002). These projects have the dual mandate of mitigating greenhouse gas emissions and contributing to livelihood improvement (Montagnini & Nair, 2004; Landell mills & Porras, 2002).

In Uganda, government and international donors have funded on-farm plantation forestry projects as one of the tools for addressing the problem of high rural poverty and food insecurity (Kaboggoza, 2011; Sawlog Production Grant Scheme [SPGS], 2005; MWLE, 2001; MWLE, 2002; SPGS, 2005). However, there is distinct lack of empirical evidence of the impact of farm forestry enterprises on household poverty and food security.

Studies evaluating the impact of forest plantations on household welfare have largely focused on commercial plantation forests. These studies indicated that the role of commercial forest plantations in poverty alleviation is ambiguous. On the one hand, plantation forest investments have been associated with potential benefits from increasing farm income, diversification of income sources, creating jobs and gaining access to credit services (Barlow & Cocklin, 2003; Higman *et al.*, 1999; Curtis & Race, 1998; FAO, 2011; Oksanen et al., 2003). On the other hand, a number of studies indicated that poverty levels were higher than average in areas where commercial plantation forests had expanded (FAO, 2006; Naburs et al., 2014; Szuleka et al., 2014; Phuc, 2003; Sunderlin, 2005; McElwee, 2008).

Few studies have assessed the contribution of farm based forest plantations to rural livelihoods. According to Nsiah (2010), forest produce from farm based plantation forestry contributed 17.6% of the total household income in one agricultural season. Other studies indicated that on-farm plantation forests can benefit smallholder farmers but not the poorest (Angelsen & Wunder, 2003; Sandewall et al., 2010). These studies reveal the benefits and threats associated with farm forestry enterprises. However, they don't reveal whether there are any changes in well-being among farmers who adopt farm based plantation forestry and whether the changes in well-being are indeed due to this intervention. To our knowledge, this study is the first rigorous quantitative study assessing the impact of on-farm plantation forestry on household poverty and food security in Africa. Specifically, the study compared the impact of eucalyptus and carbon forestry (planvivo) woodlots on household poverty and food security. The study also analyzed the benefit incidence of farm forestry projects in Uganda.

Given the importance of alleviating poverty among rural households and the large amount of public funds that have been invested in promoting on-farm plantation forestry, it is important that its effectiveness in improving the welfare of small-scale farmers is understood. This will provide policy makers with the necessary feedback for policy adjustment and thus help in informing the design of future forestry or agricultural projects which target small-scale farmers. Eradication of poverty is a key development challenge for Uganda. According to the Uganda poverty status report 2014, approximately 19.7% of the Ugandan population suffered from absolute poverty by 2012/13 (Ministry of Finance Planning and Economic Development [MFPED], 2014).

2. Methods

2.1 On-farm Plantation Forestry in Study Area

On-farm plantation forestry has been adopted by farmers throughout Uganda. However, the south western districts of Bushenyi, Rubirizi and Mitooma have a relatively larger number of farmers practicing farm forestry. Eucalyptus is the most widely planted species by small-scale farmers in the study area. Small-scale farmers have established small-medium size woodlots of mainly *Eucalyptus grandis* while the large scale farmers have planted both *Eucalyptus* and *Pinus caribaea. Eucalptus* has been widely adopted because it is silviculturally robust, and adaptable within a range of sites (Alder et al., 2003). It is also highly adopted due to its fast growth, which allows it to provide a variety of wood products after short rotations of 3-7 years. *Eucalyptus grandis* is planted for production of a variety of wood products ranging from firewood, small size building poles, transmission poles and timber. Government has supported on-farm plantation forestry in the study area through interventions such as Farm Income Enhancement and Forest Conservation (FIEFOC) project and SPGS. Typically farmers are given tree seedlings and technical advice on tree planting.

On-farm plantation forestry has also been promoted by projects trading carbon credits under the voluntary carbon market. The trees for global benefits (TGB) is the main carbon trading project in the study area. The TGB project is a tree carbon trading scheme linking small-scale landholder farmers to the voluntary carbon market (Schreckenberg *et al.*, 2013). The project which started in 2002 contracts farmers to plant a variety of indigenous tree species in order to sell verified emissions reductions on the voluntary carbon market. The farmers can either establish woodlots or plant trees under an agroforestry system. Farmers are paid in installments over 10 years for the voluntary emission reductions. The project has explicit objectives of poverty reduction and environmental protection (Schreckenberg *et al.*, 2013). The project has more than 1500 registered participants under the Plan Vivo land use system, which is now operational in four other projects worldwide.

2.2 Survey Design and Data Collection

The study was conducted in the districts of Rubirizi and Mitooma in south western Uganda. The districts were purposively sampled because they have a higher adoption rate of on-farm plantation forestry compared to other districts. The criterion for selecting carbon forestry farmers was that the respondent must have been a participant in the plan vivo carbon forestry scheme for atleast 6 years. This is because at 6 years the participating farmer is expected to have received at least 90% of carbon payments in the contract. Secondly, there were very few farmers who had participated in this scheme for more than 6 years. Similarly, the criterion for selecting eucalyptus woodlot farmers was that the respondent must have been practicing woodlot farming for atleast 10 years and has harvested before. The idea behind including only farmers who have participated for a specified minimum period and have harvested before was to include sufficient time frame to allow for program impacts (Baker, 2000). Tree growing is a long term investment hence the need to allow for sufficient time for impact.

Stratified cluster random sampling was used to select respondents from carbon forestry, eucalyptus and control group farmers. A list of farmers in each treatment group (eucalyptus woodlots and carbon forestry) who fitted the criteria was compiled from three randomly selected sub-counties in each district with the assistance of the respective district forest officers, local leaders and NGO representatives. Respondents were randomly selected from each list according to their population proportions by sub-county.

A control group of farmers who are not practicing on-farm plantation forestry (non-participants) but have land was randomly selected from villages with low incidence of tree farming within each district. The idea behind including eligible non-participants (farmers with land) was to increase the precision of propensity score matching. Four villages were then randomly selected from a list of villages with low incidence of tree farming in each district. The sampling frame for the non-adopters in the village was provided by the village local councils. The non-adopters were also sampled proportionally by district.

To evaluate impact, a cross-sectional household questionnaire survey was used to collect data on socio-demographic characteristics, consumption expenditure and food acquisition, durable assets, subsidies received from projects, farm and non-farm income. Questionnaire survey data was supplemented by qualitative data collected through key informant interviews and focus group discussions. The household questionnaire data was collected from 960 households including; 242 carbon forestry famers in the plan vivo scheme, 322 eucalyptus woodlot farmers and 396 respondents in the control group.

2.3 Theoretical and Empirical Framework

The adoption decision in this study is modeled in the random utility framework. To model the impact of participation in farm forestry on household poverty and food security, the study followed Becerril and Abdulai (2010), Bokosi (2008), and Kassie et al., (2011). The model assumes that households decide whether or not to participate in farm forestry in order to maximize utility. Let U_{jh} be the utility associated with the participation decision, j for household, h. Where j = 1 for participants and 0, otherwise. Since these utilities are unobservable, they can be expressed as a function of observable elements in a latent variable model. We assume that total utility is a function of an outcome variable of interest associated with each participation alternative such that total utility is represented as.

$$U_{jh} = \beta y_{jh} + \delta z_h + e_{jh} \tag{1}$$

where y_{jh} represents the outcome variable of interest, z_h represents all other background factors that relate observed factors to total utility. e_{jh} is a random component which captures other unobserved factors that affect total utility, β and δ are unknown parameters. We assume that a utility-maximizing farm household, h, will choose to adopt farm forestry if the utility gained from adopting is greater than the utility of not adopting. Let the difference between the utility from adoption (U_{1h}) and non-adoption (U_{0h}) of farm forestry be denoted as S_h^*. The utility model can be expressed as:

$$S_h^* = U_{1h} - U_{0h} = \beta(y_{1h} - y_{0h}) - \delta_j z_h - e_{jh} \tag{2}$$

Where $e_{jh} = e_{1h} - e_{oh}$ and $\delta = \delta_1 - \delta_0$. The link between the binary decision variable and the latent S_h^* will be expressed as.

$$J = \begin{cases} 1 \ if \ S_h^* > 0 \\ 0 \ if \ S_h^* \le 0 \end{cases} \tag{3}$$

The above equation implies that households will only participate in farm forestry if the utility from participation is greater than non-participation. This also implies that the difference between the outcome variable of participants and non-participants is key in influencing household participation decisions. Assuming that the outcome variable varies among households depending on whether or not they participate and differences in observable characteristics, $x_h = x_h \in z_h$, equations associated with each alternative can be written as:

$$y_{1h} = \beta_1 x_h + \sigma_1 \varepsilon_{1h} \quad if \ j = 1 \tag{4}$$

$$y_{0h} = \beta_0 x_h + \sigma_0 \varepsilon_{0h} \quad if \ j = 0 \tag{5}$$

Where y_{1h} and y_{0h} denote the outcome variable associated with participation and non-participation, respectively. $\beta_1 \ and \ \beta_0$ are unknown parameters, σ_1 and σ_0 are standard deviations. ε_{1h} and ε_{0h} are the error terms with $E(\varepsilon_{jh}|x_h) = 0$.

The impact of farm forestry could be estimated by:

$$Impact = y_{1h} - y_{0h} \tag{6}$$

However, household participation in farm forestry is voluntary and it may lead to self-selection. It could be that the observed and unobserved characteristics which determine the decision to participate in farm forestry also determine the outcome variable of interest. Farmers that adopt farm forestry may be systematically different from the farmers that did not adopt. In other words, the outcomes of participants and non-participants would differ even in the absence of treatment leading to selection bias. In addition, farmers may also have decided to adopt based on expected benefits. This means that adoption of farm forestry is potentially endogenous and therefore this approach might lead to biased estimates (Kassie et al, 2011; Gilligan & Hoddinott, 2007). The standard approaches for dealing with the problem of self-selection including PSM and endogenous switching regression were used.

Two proxies were used to measure household welfare in this study. Household consumption expenditure per adult equivalent was used as a proxy for present household poverty status and daily calorie acquisition per adult equivalent as a proxy for food security. A poverty line of US$365 per year was adopted for this study, in line with comparable studies and the Uganda poverty status report (Kassie et al., 2011; MFPED, 2014).

2.3.1 Propensity Score Matching

In this study, cross-sectional PSM was used to estimate the impact of farm forestry on poverty and food security. Using PSM, the impact of participation is the average treatment effect on the treated (Rosenbaum & Rubin, 1983; Khandker et al., 2010). This is the difference between the outcome in the participants and the counterfactual. Average Treatment effect on the treated (ATT) can be represented as:

$$ATT = E(Y_1 - Y_0|J = 1, X) = E(Y_1 \,|J = 1, X) - E(Y_0 \,|J = 1, X) \tag{7}$$

Where participation is denoted by J, and J = 1 for participation and J = 0 for non-participation. X is a set of observable household characteristics that explain participation in farm forestry. Y_1 represents outcomes for participants and Y_0 outcomes for non-participants. Since the counterfactual, $E(Y_0|J = 1,X)$, is not observable in the data, the average outcome in the control group, $E(Y_0|J = 0, X)$, will be used to estimate it.

PSM is used to identify households in the control group that have similar observable characteristics with the participants. In practice, it may be difficult to ensure that the matched control for each participant has exactly the same covariates X. Instead, Rosenbaum and Rubin (1983) suggested matching along the propensity score P(X),

$$P(X) = pr(J = 1)|X \quad (8)$$

Therefore equation (1), ATT, can be expressed as

$$TT(X) = E(Y_1\text{-}Y_0|J = 1,P(X)) = E(Y_1|J = 1, P(X)) – E(Y_0|J = 1,P(X)) \quad (9)$$

This is the difference between the outcome of the participants and the counterfactual. Given the fact that propensity score is a continuous variable, exact matches will rarely be achieved. Therefore, matching estimators will accept a certain distance between treated and untreated households (Rosenbaum & Rubin, 1985). In this study, nearest neighbor, radius and kernel matching estimators were used. A vector of observed household and farm characteristics determining adoption of eucalyptus and carbon forestry woodlots was used to estimate propensity scores. It was possible to compare groups because similar observed covariates were used to derive propensity scores. Literature provides limited guidance on the selection of variables. The specification used in this paper satisfied the common support condition and balancing tests.

2.3.2 Switching Regression

PSM is a useful approach for impact evaluation when only observed characteristics are believed to affect program participation. If unobserved characteristics determine both program participation and the welfare outcome, conditional independence assumption will be violated and PSM will not be an appropriate method (Rosenbaum, 2002). We checked the sensitivity of the (ATT) estimates from PSM to hidden bias, using the Rosenbaum bounds test (Rosenbaum, 2002). This test shows the effect unobservables should have in order to reverse the findings based on matching on observables. Therefore, to check the robustness of our results under different assumptions, we also used an endogenous switching regression. Endogenous switching regression can be used to correct for selection bias due to unobservable characteristics. Following Maddala and Nelson (1975), Lokshin and Sajaia (2004), the switching regression can be defined by the following equations

$$S_i^* = Z_i\gamma + u_i \; with \, J_i = \begin{Bmatrix} 1 \; if \; S_i^* > 1 \\ 0 \;\; otherwise \end{Bmatrix} \quad (10)$$

$$Y_{1i} = X_{1i}\beta_1 + \varepsilon_{1i} \;\; if \, J_i = 1 \quad (11)$$

$$Y_{0i} = X_{0i}\beta_0 + \varepsilon_{0i} \;\; if \, J_i = 0 \quad (12)$$

Where:

Y_{1i} is household outcome measure (calorie acquisition per adult equivalent, consumption expenditure per adult equivalent) for participant in farm forestry and Y_{0i} for non-participant, X_{1i} and X_{0i} are vectors of exogenous explanatory variables relevant to each group. β_1, β_0 and γ are parameter vectors. Let S_i^* be a latent variable determining which group applies, z_i is a vector of explanatory variables assumed to explain the probability of participation in farm forestry. Equations, (10) is a selection equation determining which regime applies while Equations (11) and (12) describe the conditional expectation of the outcome variables in each of two regimes. Based on the assumption that the error terms u_i, ε_{1i} and ε_{0i} have a trivariate normal distribution, with zero mean and $\sigma_u^2 = 1$, the conditional expectation of the outcome variables equations (11 & 12) are defined as

$$E(Y_{1i}|x_i, J_i = 1) = x_i\beta_1 + \vartheta_1\lambda_1\,(Z_i\gamma) \quad (13)$$

$$E(Y_{0i}|x_i, J_i = 0) = x_i\beta_0 + \vartheta_0\lambda_0\,(Z_i\gamma) \quad (14)$$

where λ(.), is the inverse mill's ratio defined as $\lambda_1 = \frac{\phi(Z_i\gamma)}{\Phi(Z_i\gamma)}$ for positive observations (J_i = 1) and $\lambda_0 = -\frac{\phi(Z_i\gamma)}{1-\Phi(Z_i\gamma)}$ for the zero observations (J_i = 0) where ϕ and Φ are the probability density function (pdf) and cumulative distribution functions(cdf) of the standard normal variable, respectively. The difference between participants and non-participants can be estimated as:

$$E(Y_{1i}|x_i, J_i = 1) - E(Y_{0i}|x_i, J_i = 1) = x_i(\beta_1 - \beta_0) + \vartheta_1\lambda_1 - \vartheta_0\lambda_0 \quad (15)$$

If the estimated covariances $\sigma_{\varepsilon 1u}$ and $\sigma_{\varepsilon 0u}$ are statistically significant, then the adoption decision and the outcome variables are correlated. This indicates the validity of switching regression model with endogenous switching and rejects the null hypothesis of absence of sample selectivity bias (Maddala & Nelson, 1975).

Following Lokshin and Sajaia, (2004) endogenous switching regression models can be efficiently estimated by full information maximum likelihood (FIML) method. The FIML method simultaneously estimates the selection equation and the outcome equations to yield consistent standard errors. Conditional on the trivariate normal distribution assumption for the error terms, the logarithmic likelihood function for the system of equations (10) and (11 &12) can be given as

$$lnL = \sum_{i=1}^{N} J_i \left[ln\emptyset \langle \frac{\varepsilon_{1i}}{\sigma_{\varepsilon 1}} \rangle - ln\sigma_{\varepsilon i} + ln\Phi(\varphi_{1i}) \right] + (1 - J_i) \left[ln\emptyset \langle \frac{\varepsilon_{0i}}{\sigma_{\varepsilon 0}} \rangle - ln\sigma_{\varepsilon 0} + ln(1 - \Phi(\varphi_{0i})) \right] \quad (16)$$

Where $\varphi_{ji} = \frac{(\gamma z_i + \rho_j \varepsilon_{ij}/\sigma_j)}{\sqrt{1-\rho_j^2}}$, $j_i = 1,0$ with ρ_j denoting the correlation coefficient between the error term u_i in the selection equation (10) and the error terms ε_{ij} of equations (11) and (12) respectively (Lokshin & Sajaia, 2004).

2.3.3 Estimation of Benefit Incidence

The study assessed the distribution of farm forestry subsidies conditional on the pre-intervention income categories. Following Jalan and Ravallion (2003), pre-intervention income is the difference between the observed post-intervention consumption expenditure per adult equivalent and the average gain in consumption expenditure per adult equivalent estimated by PSM for participants in farm forestry intervention. Using the pre-intervention incomes, the households are assigned to quantiles using the same bounds calibrated from the Uganda National Household Survey (MFPED, 2012). Households are assigned on the basis of the consumption expenditure per adult equivalent to which they belong. Following Demery (2000), the value of the subsidy going to income/gender group j is estimated as.

$$X_j = \sum_{i=1}^{N} N_{ij}(S_i * P_i) \quad (17)$$

Where: X_j is the value of subsidy imputed to group j, S_i is the quantity of the subsidy of type i received by household, P_i is the unit price of the subsidy of type i, and N_{ij} is the number of households in group j receiving subsidy type i, N is the number of subsidy types received in group j.

3. Results

3.1 Descriptive statistics

Descriptive statistics including the means, Pearson's chi-square test of association (X^2) and ANOVA F-test of differences in means (F-value) for selected variables are presented by adoption status (Table 1) for households included in the survey. Pearson's chi-square test of association (X^2) is used for comparison of means of categorical variables while ANOVA F-test of differences in means (F-value) is used for comparison of means of continuous variables. Some of these variables are used in the estimated models we present further on.

Table 1. Descriptive summary of variables used in estimations

Variable	Eucalyptus woodlots	Carbon forests	Non-adopters of farm forestry	All sample	Pearson's chi-square (X^2) or ANOVA (F-value)
Outcome Variables					
Consumption expenditure per adult equivalent (U S $)	848_a (844)	738 (670)	612_b (522)	729 (697)	9.9***
Daily calorie intake per adult equivalent (KCal)	2768_a (3925)	2329 (2657)	2090_b (2046)	2396 (3009)	4.4**
Household characteristics					
Age of household head(years)	41.8_a (14.2)	45.5_b (13.8)	40.4_{ac} (14.0)	42 (14.1)	8.4***
Family size (number)	5.5_a (2.4)	6.1_b (2.6)	5.2_{ac} (2.3)	5.5 (2.5)	9.8***
Adults in household (number)	2.7_a	3.1_b	2.6_{ac}	2.8	5.8***

	(1.8)	(1.8)	(1.6)	(1.7)	
Household members employed (number)	2.1 (2.1)	1.9 (1.1)	2.0 (1.6)	2 (1.7)	0.87
Landsize (hectares)	4.3_a (5.7)	5.4_b (7.9)	2.7_c (1.9)	3.9 (5.4)	18.1***
Distance to market (Kilometers)	4.7_a (5.1)	3.2_b (2.9)	3.4_{bc} (3.2)	3.8 (4.0)	12.1***
Non-farm income (U Sh)	115140.2 (347582)	124985 (767499)	119827 (414114)	119346 (501443)	0.03
Marital status					
Married	35.4%	24.8%	39.7%	84.4%	4.5
Not married	42.9%	17.6%	39.4%	15.5%	
Education of household head					
None or primary	35.9%	22.0%	42.0%	77.7%	11.9*
Secondary	39.0%	27.4%	33.5%	16.6%	
Tertiary	42.0%	36.0%	22.0%	5.5%	
Forestry training					
Received training	47.1%	41.7%	11.1%	49.3%	340***
No training	26.6%	5.0%	68.2%	50.6%	
Extension visits					
None in last month	30.4%	6.3%	63.2%	41.1%	209.4***
Once in last month	47.7%	23.5%	28.6%	30.2%	
Twice in last month	33.2%	47.4%	19.3%	28.6%	
Land tenure					
Freehold	34.0%	20.6%	45.2%	30.6%	15.9*
Leasehold	58.8%	11.7%	29.4%	1.9%	
Mailo	50%	28.5%	21.4%	1.5%	
Customary	36%	25%	37.7%	65.5%	
Other	100%	0%	0%	0.3%	
Security of land tenure					
Feel secure	34.9%	24.4%	40.5%	96.1%	22.8***
Insecure	74.2%	5.7%	20.0%	3.8%	
Gender of household head					
Male	37.8%	26.0%	36.3%	69.1%	10.8***
Female	34.7%	18.2%	46.9%	30.8%	

Note. Pearson's chi-square test of association (X^2) for categorical variables and ANOVA F-test of differences in means (F-value) for continuous variables. Astericks represent level of significances, * = $p < .05$, *** = $p < .001$. Standard deviations appear in parentheses below means. Means with differing subscripts within rows are significantly different at the $p < .05$ based on a Tukey post hoc test.

The results (Table 1) show that there were statistically significant differences in socio-economic characteristics between the adopters of eucalyptus woodlots, plan vivo carbon forestry and non-adopters. Variables such as age of household head, family size, number of adults in household, land size and distance to market were significantly different by adoption status. There was also a significant association between adoption status and variables such as education of household head, forestry training, number of extension visits received, land tenure, security of land tenure and gender of household head. However, non-farm income and number of household members employed were not significantly different between the three groups. There was also no association between marital status and adoption status.

The average age of sampled household heads was about 42 years. The age of household heads was 45.5, 41.8 and 40.4 for adopters of carbon forestry, eucalyptus woodlots and non-adopters respectively and the difference was significant. The adopters of carbon forestry, eucalyptus woodlots and non-adopters had a mean landholding of 5.4, 4.3 and 2.7 hectares respectively and the difference was significant. The adopters of farm forestry had higher percentage of male headed households, household heads who achieved tertiary education, and households that received forestry training.

Table 2. Poverty status in study area

Poverty measures	Eucalyptus woodlots	Carbon forestry	Non-adopters
Poverty measures			
Head count index	0.23	0.21	0.39
Poverty gap index	0.09	0.06	0.14
Poverty severity gap index	0.05	0.03	0.06

The headcount index, the poverty gap index, and the poverty severity index of adopters and non-adopters of farm forestry are computed using the Foster–Greer– Thorbecke (FGT) poverty measures (Table 2). The head count index indicates that the poverty level in the study area is within range of the national average for rural areas. The higher poverty levels in the rural areas area have been a target of various poverty alleviation initiatives.

3.2 Empirical Results

3.2.1 Propensity Score Matching

The ATT was estimated using PSM with probit. Probit models were used to estimate the propensity to adopt the different types of on-farm plantation forestry. To assess the quality of the matching process, the common support condition and covariate balancing with a standardized bias measure and t-test were checked. A visual inspection of the density distributions of the estimated propensity scores in the four matches indicates that there is considerable overlap in common support ranging between 0.05 and 0.86 (Appendix A). This indicates that the common support condition is satisfied. Similarly, the standardized bias of all covariates was less than 20% and the p-values of t-tests indicated that the covariates were not statistically different after matching. The low mean standardized bias after matching and the insignificant p-values of the t-test indicates that both groups have the same distribution in covariates after matching. Therefore, all results presented in the following pages are based on specifications that passed the balancing tests and the common support condition. Bootstrapped standard errors based on 50 replications are reported.

The study assessed the impact of eucalyptus and carbon forestry (planvivo) woodlots on poverty and food security using consumption expenditure per adult equivalent and daily calorie acquisition per adult equivalent (Kcal) as the outcome variables. Results (Table 3) indicate the ATT using the nearest neighbor, radius and Kernel matching estimators. The three matching estimators were used to check the robustness of the PSM results. However, interpretation of ATT results will be based on the kernel matching estimator.

Table 3. ATT for farm forestry participants using PSM

Treatment	Nearest neighbor	Kernel	Radius
Consumption expenditure per adult equivalent (US$)			
Carbon forestry (n=217)	72.5(106)	69(64.9)	84(78)
ALL Eucalyptus woodlots (n= 336)	236(79.8)***	201(51.8)***	238(57)***
Long rotation eucalyptus woodlots (n=219)	317(97)***	247(66)***	248(68)***
Short rotation eucalyptus woodlots (n=117)	132(103)	148(66)**	166(62.5)***

Daily calorie acquisition per adult equivalent (Kcal)			
Carbon forestry (n=217)	469(236)**	421(183)**	390(174)**
ALL Eucalyptus woodlots (n=336)	837(247)***	744(266)***	750(257)***
Long rotation eucalyptus woodlots (n=219)	1052(379)***	1030(361)***	991(357)***
Short rotation eucalyptus woodlots (n=117)	50.6(297)	139(256)	155(191)

Asterisks represent level of significance at the 99% (***), 95% (**) and 90% (*) confidence levels. The number in brackets shows bootstrapped standard errors with 50 replication samples.

The results (Table 3) indicate that adoption of eucalyptus woodlots increases consumption expenditure per adult equivalent by US$ 201. This represents an average increase of 32% compared to non-adopters. On the other hand, adoption of carbon forestry (planvivo) had no significant impact on consumption expenditure. Further differential impact analysis of eucalyptus woodlot farming indicated that adoption of long rotation eucalyptus woodlots leads to higher increases in consumption expenditure per adult equivalent (US$ 201) than short rotation eucalyptus (US$ 148). This represents an average increase of 40% and 22% compared to non-adopters, for long rotation eucalyptus and short rotation eucalyptus farmers respectively.

The results (Table 3) indicate that adoption of eucalyptus woodlot farming provides a bigger increase in daily calorie acquisition per adult equivalent (744 Kcal) than carbon forestry (421 Kcal). This represents an average increase of 22% and 36% compared to non-adopters, for carbon forestry and eucalyptus woodlot farmers respectively. Differential impact assessment indicated that adoption of long rotation eucalyptus woodlots increases daily calorie acquisition per adult equivalent by 1030 (Kcal) as opposed to short rotation eucalyptus woodlot farming that had positive but insignificant ATT on calorie acquisition.

Table 4 presents results of the Rosenbaum bounds sensitivity analysis for the PSM results. The Rosenbaum sensitivity analysis is used to assess if our estimates based on matching are robust to the possible presence of hidden bias. The sensitivity of ATT estimates to hidden bias for the three matching estimators was different. ATT estimates from Kernel matching and Radius caliper matching were not robust to hidden bias. The critical values of gamma were 1.1, which implies that the results are insensitive to a bias that would make individuals with the same covariates differ in their odds of adoption by a factor of 10%. This suggests that even a small unobserved difference in a covariate would change our inference. This does not mean that hidden bias exists and that there is no effect of treatment on the outcome variable. This simply means that our estimates based on these matching estimators are not robust to the possible presence of hidden bias. Therefore, we cannot state whether the conditional independence assumption holds.

Table 4. Rosenbaum sensitivity analysis

Matching estimator	outcome	Critical level of hidden bias (Γ)			
		Carbon forestry	All Eucalyptus woodlots	Short rotation woodlots	Long rotation woodlots
NNM	A	1.1	1.6	1.4	1.6
	B	1.5	1.3	1.2	1.1
KBM	A	1.1	1.1	1.1	1.1
	B	1.1	1.1	1.1	1.1
Radius	A	1.1	1.1	1.1	1.1
	B	1.1	1.1	1.1	1.1

Note: A is the consumption expenditure per adult equivalent, B is the calorie acquisition per adult equivalent.

Given that the results from kernel based matching (which is the focus for interpreting our results) are sensitive to hidden bias, we check the robustness of our results by estimating the ATTS using an endogenous switching regression.

3.2.2 Endogenous Switching Regression Results

Estimating the endogenous switching regression model requires that an exclusion restriction be imposed for the model to be identified. This was done by including in the participation equation two variables that influence participation decision but have no effect on the outcome variable (Wooldridge, 2010). Tests of the validity of these instrumental variables indicated that the variables are significant in the participation equation but are insignificant in the outcome equation for non-participants (Di Falco et al. 2013).Results from the endogenous switching regression model showed that the correlation coefficient (ρ) between the respective outcome equations and the selection equations were significantly different from zero thus indicating presence of selection bias.

Results from full information maximum likelihood endogenous switching regressions (Table 5) indicate that plan vivo carbon forestry and eucalyptus woodlot farming have a significant and positive impact on consumption expenditure per adult equivalent and calorie acquisition per adult equivalent. The average treatment effect of the treated (ATT) on consumption expenditure per adult equivalent for adopters of carbon forestry and eucalyptus woodlots was 24.1% and 28.3% respectively. Similarly, the average treatment effect of the treated (ATT) on calorie acquisition per adult equivalent for adopters of carbon forestry and eucalyptus was 26.9% and 13.1% respectively. Differential impact analysis of short and long rotation woodlots indicated that both categories have a significant and positive impact on consumption expenditure per adult equivalent and calorie acquisition per adult equivalent.

Table 5. Summary of ATT from switching regression

Variable	Carbon forestry	Long rotation eucalyptus	short rotation eucalyptus	All eucalyptus
ATT, Log consumption expenditure per adult equivalent	0.241(0.032)***	0.245(0.033)***	0.349(0.043)***	0.283(0.021)***
σ_0	0.65(0.028)	0.632(0.04)	0.644(0.04)	0.635(0.041)
σ_1	0.607(0.05)	0.813(0.053)	0.468(0.04)	0.712(0.038)
ρ_0	-0.512(0.156)**	-0.524(0.179)**	-0.633(0.168)**	-0.507(0.17)**
ρ_1	-0.219(0.139)	0.19(0.214)	0.17(0.409)	0.143(0.208)
ATT, Log calorie acquisition per adult equivalent	0.269(0.022)***	0.079(0.029)***	0.228(0.031)***	0.131(0.028)***
σ_0	0.891(0.12)	0.715(0.048)	0.732(0.046)	0.718(0.052)
σ_1	0.473(0.063)	1.24(0.19)	0.362(0.087)	0.999(0.081)
ρ_0	-0.171(0.087)	-0.308(0.295)	-0.49(0.205)**	-0.319(0.296)
ρ_1	-0.233(0.126)	0.60(0.115)**	0.028(0.307)	0.49(0.10)**

Statistical significance at the 99% (***), 95% (**) and 90% (*) confidence levels. Figures in parentheses are standard errors. The significance of ρ_i values (Table 5) provides evidence of endogenous switching regression where there is correlation between the selection and the outcome equation.

In conclusion, PSM and switching regression results consistently indicated that adoption of eucalyptus woodlot farming in general (all eucalyptus) increases consumption expenditure and calorie acquisition per adult equivalent. Differential impact assessment of long and short rotations woodlots indicated that both increase consumption expenditure per adult equivalent for the adopters. The results also consistently indicated that adoption of long rotation eucalyptus woodlots had a positive and significant impact on calorie acquisition per adult equivalent while the impact of short rotations was mixed. Further investigation indicated that adoption of carbon forestry increases calorie acquisition per adult equivalent although the impact on consumption expenditure per adult equivalent is mixed.

3.2.3 Benefit Incidence Analysis of the Projects

Benefit incidence analysis results (Table 6) indicated that the poor households were well represented in the

FIEFOC and TGB projects in terms of numbers. About 39% of the project participants were poor (Table 6), which is above the national average of 24.5%, at the time of subsidy distribution (MFPED, 2012). Inspite of the good representation by the poor in terms of numbers, the results (Table 6) indicate that the poor gained just 13.7% and 18.1% of the total subsidy in the FIEFOC and TGB projects respectively. This is in contrast to 53% and 36.3% for the richest quantile in the FIEFOC and TGB projects respectively. This implies that the farm forestry subsidies in both projects were not well targeted to the poor in the population. In both cases, the poor gained significantly less than their share in the population. In the case of the FIEFOC project, the richest quantile (middle class) gained a bigger share of the total subsidy due to the much higher average subsidy received per household (Table 6). In other words, the richer households got bigger subsidies. In the TGB project, this was due to the low participation of the poorest households in the project.

The distribution of the subsidy in the TGB project was progressive in relation to expenditure. The subsidy received as a share of household expenditure was 23.8% and 8.9% for the poor and middle class respectively. In contrast, the subsidy distribution in the FIEFOC project was regressive. The middle class gained more than the poor in relation to their expenditure.

Although the subsidy per household for female headed households was approximately similar with the male headed households, the male headed households received 65% and 76% of the total subsidy from FIEFOC and TGB projects respectively. However, there was no gender imbalance in the distribution of the subsidies since the share of total subsidies is closely similar to the share of male and female headed households in the population (MFPED, 2012).

Table 6. Benefit incidence of farm forestry projects in south western Uganda

		FIEFOC PROJECT			TGB PROJECT		
	National income distribution	Per household subsidy(US$)	Share of total subsidy,%	Share of household expenditure,%	Per household subsidy,(US$)	Share of total subsidy,%	Share of household expenditure,%
Population quantile							
Poor	24.5	181	13.7	8.5	410	18.1	23.8
Insecure	42.9	546	33.2	14.4	402	45.4	11.8
Middle class	32.6	928	53	13.1	409	36.3	8.9
Gender							
Male		483	65		404	76.1	
Female		592	34		413	23.8	

4. Discussion

The results suggest that overall, adoption of eucalyptus woodlots has potential for poverty alleviation and reducing food insecurity. However, adoption of long rotation eucalyptus woodlots showed more consistency in alleviating food insecurity compared to short rotation woodlots. The study also indicated that adoption of carbon forestry under the plan vivo system increases food security. On the other hand, the study did not provide strong evidence that payments for carbon sequestration through the plan vivo system can alleviate poverty.

These findings are consistent with recent studies on the impact of farm-based plantation forestry on household welfare. A study by Sandelwall et al. (2010) in Vietnam showed that the adoption of farm-based plantation forestry improved household income and alleviated poverty. Sandelwall et al. (2010) also indicated that the wealthier farmers tend to invest in long rotation plantation forestry, whilst the poorer farmers tend to invest in short rotation plantation forestry because they require a more continuous cash flow. This may in turn lead to differential impacts since long rotation plantation forestry was reported to have greater poverty alleviation potential compared short rotation forestry.

Focus group discussions and farm visits indicated that most farmers who participated in the carbon forestry project under the planvivo system, interplant indigenous trees with food crops in an agroforestry system. This may explain the improvement in food security. The important elements of agroforestry systems that have been reported to contribute to food security include changes in the microclimate, protection through provision of permanent cover, reduced soil erosion, improving water use efficiency and contribution to soil fertility improvement (Mulugeta, 2014; Sanchez, 2002; Kwesiga & Chisumpa, 1992).

The ability of carbon forestry woodlots under the planvivo system to contribute to poverty alleviation may be constrained by the low carbon credits raised by the farmers. The carbon credits are low because the projects are planting only slow-growing native species. In addition, the price of carbon credits paid to tree farmers is still low.

However, it should be noted that our sample included farmers who had participated in the planvivo carbon forestry scheme for atleast 6 years. After 6 years of participation, carbon farmers are expected to have received 90% of the carbon payments. Therefore, our results only provide evidence of the impact of payments for carbon sequestration through the plan vivo system on poverty. Understanding the full potential of carbon forestry woodlots under the plan vivo system will require conducting the impact analysis after 25 years when the farmer have harvested timber, the main benefit from carbon forestry woodlots. Understanding the full potential of adopting the on-farm plantation forestry enterprises will also require measurement and quantifying other effects on soil condition, crop productivity and environmental effects.

The study indicated that farm forestry subsidies in two projects in the study area were not well targeted to the poor in the population. Therefore, project managers and policy makers need to put in place strategies to ensure that a larger proportion of the total subsidy in poverty alleviation projects is actually received by the poor households.

5. Conclusions

The findings of this paper provide empirical evidence that adoption of on-farm eucalyptus woodlots is an important pathway for smallholder farmers to escape poverty and improve food security. The findings suggest that adoption of long rotation eucalyptus woodlot farming is more consistent in improving food security than short rotation woodlots. Findings of the paper indicated that adoption of carbon forestry woodlots under the planvivo system had a positive impact on food security but the impact of carbon payments on poverty was mixed. Given the above evidence, policy makers should place more emphasis on promoting long rotation eucalyptus woodlots as one of the measures for poverty alleviation and reducing food security in rural areas.

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