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Impact of tree planting on household well-being: evidence from the central highlands of Vietnam

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Abstract

Household land use decisions in the tropics have a wide range of outcomes and impacts on economic development, environmental conservation, and social development. This study seeks to contribute to this debate by examining the effects of tree planting on poverty alleviation and welfare improvement in Vietnam. We employ a combination of multinomial endogenous treatment effect and propensity score matching, using survey data collected from 239 households in 11 communes in Vietnam's Central Highlands region. We find that households engaged in tree planting can increase their income and alleviate poverty compared to non-engaging households. Specifically, long-term cashew plantations provide early harvests and have proven to be a preferred crop for households dealing with immediate livelihood needs. However, short-term acacia timber crops contribute insignificantly to poverty reduction and may be more suitable for households with greater financial resources. The policy implication underscores the importance of interventions tailored to support impoverished households with urgent livelihood needs. Prioritizing immediate necessities is crucial before households can invest in long-term tree planting.

Keywords Impact evaluation, Tree species choice, Income, Multinomial endogenous treatment effect, Propensity score matching, Vietnam

Introduction

In the context of diminishing natural forests, global efforts to plant trees have led to a significant expansion of planted forests, covering 294 million hectares globally in 2022, which accounts for approximately 7% of the total global forested area (FAO 2023). Smallholder tree plantations in developing countries, driven by government reforestation and land-decentralization programs, have played a crucial role in this initiative. These efforts have had a profound impact on local livelihoods, environmental preservation, and the achievement of Sustainable Development Goals (Osman et al. 2023; Aggarwal et al. 2021; Razafindratsima et al. 2021; Degnet et al. 2020; Turner-Skoff and Cavender 2019; Kröger 2014).

Commercial tree plantings are primarily justified by the financial gains from timber harvesting and associated benefits. Studies show that tree plantations contribute significantly to household income, ranging from 17 to 46% globally (Vedeld et al. 2007; Abebaw et al. 2012; Gebreegziabher et al. 2020; Miller et al. 2020; Li et al. 2020). In Ethiopia, for example, Holden et al. (2003), Jagger and Pender (2003) and Asfaw et al. (2013) find that income from eucalyptus contributes 20–32.6% to the total household income, whereas private trees in Nepal contribute to merely 5.8% of household income. However, this impact is not universally positive. In various

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regions, tree-planting initiatives have yielded minimal income, increases, or, in certain cases, limited or detrimental effects on household economies (Ameha et al. 2014; Alix-Garcia et al. 2015; Andersson et al. 2015). Van der Meer Simo (2020) reviewed tree-planting initiatives in the Greater Mekong sub-region, indicating that plantations contributed to sustainable livelihoods in only a few communities. Aligning with this viewpoint, Malkamäki et al. (2018) conducted a systematic review, revealing a negative impact of 48% on local livelihoods in large-scale plantation contexts, although they acknowledged limited robust evidence.

From an environmental standpoint, planting trees, particularly in mixed species schemes, presents an attractive prospect, offering several benefits, including soil conservation, biodiversity restoration, crop disease mitigation, increased returns per unit area, and enhanced resilience to climatic hazards (Tassone et al. 2004; Montagnini and Nair 2004). A comprehensive examination across 8000 households in 24 developing countries by Angelsen et al. (2014) revealed that environmental income constituted up to 28% of total household income, with a substantial portion (77%) stemming from natural forests. Interestingly, in the context of the increasing adverse effects of climate change in many parts of the world, farmers are willing to forego additional income from crop production and instead adopt tree planting. This shift provides greater resilience and adaptability to changing climatic conditions.

The establishment of tree plantations extends beyond income generation to encompass the development of local infrastructure and services, enhancing economic activities within communities and income disparities (Malkamäki et al. 2018). In particular, sustainable forestry practices are reported to improve social security services and increase timber value by approximately 20–25% (Degnet et al. 2020).

In Vietnam, tree planting has increased significantly over the past three decades, expanding from 0.7 million hectares in 1989 to 4.66 million hectares in 2022.[1] Approximately 3.93 million hectares of this area are used for commercial purposes.[2] Smallholder households have played a crucial role in tree plantations in Vietnam, accounting for 21.6% of the national plantation area, which is equivalent to 3.20 million hectares. Their contribution has had a significant impact on the country's forest cover, effectively doubling it from 20.80% in 1990 to 42.02% in 2022. The primary factor behind this achievement is the implementation of the forestland allocation (FLA) program. This policy involves granting 50-year land use rights to households and communities to support sustainable forest management, rural development, and livelihood improvement. It aims to boost forest protection, local participation in conservation, and secure land tenure for forestry activities, aligning with the nation's sustainable development goals, particularly by enhancing household livelihoods through tree planting and related activities. Since 1994, the program has allocated 11.37 million hectares of forestland to various stakeholders, including smallholder households, while 3.42 million hectares remain under the control of local authorities. However, government officials, academics, and practitioners argue that up to 70% of the land has not been cultivated or has been allocated for alternative uses due to differing responses among land recipients to the FLA policy (Dinh et al. 2017).

Empirical studies on the impacts of tree planting on household welfare and poverty reduction in Vietnam have shown mixed results. Socioeconomic inequalities further complicate the picture, with forest-derived income benefiting both the wealthiest and poorest households to varying degrees, from 20 to 77% of household income (Castella et al. 2006; Clement and Amezaga 2009; Nguyen et al. 2010; Nguyen and Noriko 2008; Nguyen and Tran 2018; Cuong et al. 2019; Khuc et al. 2020). However, there has been limited research simultaneously examining the effects of diverse tree-planting practices on household economies and livelihoods in Vietnam. This study aims to fill this gap by evaluating the impact of planting different tree species on household income and poverty reduction in Vietnam's Lam Dong province.

This paper provides new empirical evidence to the existing knowledge by examining the impact of tree planting initiatives under Vietnam's FLA program on household income and poverty levels. Our thorough assessment of FLA's effectiveness can provide valuable insights for informing the development of similar interventions in other contexts. Unlike previous studies that focus on the aggregate impact of a single or multiple tree species, this study evaluates the income effects of two distinct plantation initiatives: a 6–7 year acacia plantation for wood chip and paper pulp, and a 35-year cashew plantation for nut production. We use a combination of the parametric approach known as multinomial endogenous treatment effect (METE) and the propensity score matching (PSM) technique to estimate the economic impacts of FLA on household income and poverty levels. This combination helps to control for selection bias from both observed and unobserved heterogeneities and ensures the robustness of the estimated results when

[1] Minister Decision No. 2357/QĐ-BNN-KL on reporting the 2022 forest status.

[2] Vietnam country report on forest status, 2022. Available at: https://www.mard.gov.vn/VanBan/VanBan/2357-QD-KL-14062023.pdf (Accessed 20th July 2023).

evaluating the influence of tree planting on household welfare (Lawin and Tamini 2018; Basnet et al. 2021).

The remainder of the paper is organized as follows. "Methods" section describes a detailed method, including a brief description of the study area, data collection, and the estimation strategy. The "Results" section presents the outcome of the model estimation and the "Discussion" section explains how planting tree species affects household income and poverty status. Finally, the findings are synthesized to derive conclusions and policy implications.

Methods

Survey area and data

This study collected data from three districts within Lam Dong province,[3] situated in the Central Highlands region of Vietnam (see Fig. 1). The survey was conducted between June and September 2012, targeting household heads or senior members. The research team consisted of six interviewers, including the first author, a lecturer, and four trained enumerators of Ho Chi Minh Agriculture and Forestry University. Focus group discussions, key informant interviews and household surveys using semi-structured questionnaires were also used to obtain data and information. We also collaborated with local authorities to obtain secondary data on land use and socioeconomic conditions within the study area.

A two-stage sampling approach was employed in selecting households for the survey. Initially, a random selection of 11 communes was made from a total of 37 communes listed among three districts, as shown in Table 1. Subsequently, a complete list of 937 households participating in FLA activities within the chosen communes was obtained from the Forest Ranger Offices. This list was then divided into two sub-lists: households engaged in tree planting and households not involved in such activities. Furthermore, we used a random selection process to determine the sampling units in proportion to the sizes of the planting and non-planting groups within each district. Since cashew and acacia are two predominant species, comprising over ninety percent of the population, we excluded households that planted other tree species to ensure uniformity of data collection and analysis. The employed sampling approach ultimately yielded a sample frame of 240 households across three districts. Among these households, 172 were identified as FLA households with plantations, while the remaining 68 households did not have any plantations. A total of 240

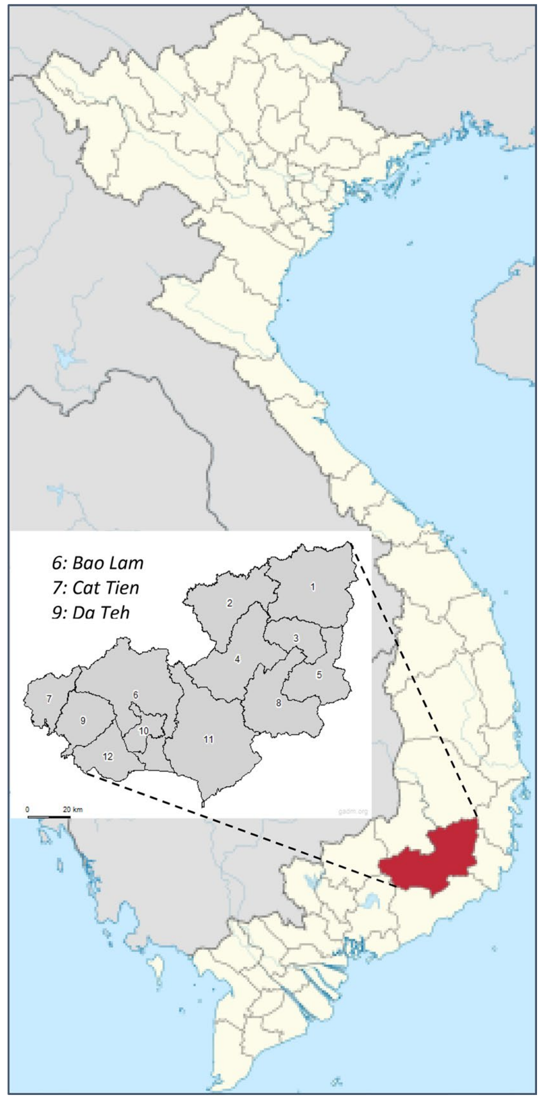

Fig. 1 Map of the study area, Lam Dong province

households were interviewed using a structured questionnaire, except for a single non-planting household that chose not to participate in the survey. Hence, the survey response rate was 99.6%.

The survey questionnaire included variables of interest, such as household characteristics, biophysical endowments, and financial attributes like household income and government subsidies. In this survey, "household income" refers to the total cash income from various sources, with monetary values based on the year 2014. Table 2 shows that the percentage of survey respondents involved in acacia plantations was the lowest, accounting for 18.41%. This proportion is significantly lower, about three times less, than the percentage of respondents engaged in cashew plantation

[3] Lam Dong province was chosen for its diverse socioeconomic and ethnic makeup, standard FLA policy implementation, its role in the government's post-Vietnam War resettlement program, and as a typical area where cash crop cultivation clashes with land encroachment and forest degradation—an ideal setting to study these interactions.

Table 1 General information of the three districts of the studied area. *Source*: Statistical Office of Lam Dong province, 2012

	Natural area (km^2)	Number of communes	Number of communes selected	Population	Number of households
Bao Lam	1463.43	14	5	110,741	22,460
Cat Tien	426.57	12	3	37,631	7633
Da Teh	524.19	11	3	44,667	9060

Table 2 Land use action and species choices by households. *Source*: Surveyed data

Land use pattern	Observation	Mean area (Ha)	Percentage
Inaction (control)	67	5.66	28.03
Acacia plantation	44	7.48	18.41
Cashew plantation	128	3.12	53.56
Total/mean	239	4.84	100

(53.56%). On average, households planted 4.84 hectares of trees. To avoid any spillover effects when assessing differential income growth, we did not survey the few households with both acacia and cashew plants.

Econometric models

Farmers' land use decisions are influenced by their ability and motivation, resulting in differences in investment. To analyze the effects of these decisions, we employed a multinomial endogenous treatment effect (METE) analysis and conducted a propensity score matching (PSM) for additional validation.

The multinomial endogenous treatment effects (METE) model

To estimate the METE model, we employed a mixed multinomial logit (MMNL) model to analyze land use decisions for tree planting. As argued by Deb and Trivedi (2006), this model considers the interdependence of planting decisions and addresses selection bias from observable and unobserved characteristics. Farmers may self-select endogenously, and their decisions are likely to be influenced by unobserved factors that may be correlated with outcome variables. Controlling for selection bias helps ensure that our results accurately reflect the intended sample, thereby strengthening the validity of the conclusions of this study. In the second stage, we utilized ordinary least squares (OLS) to evaluate the impact of tree planting on household income and poverty severity. The MMNL model maximizes the expected utility (EV) of the ith individual household, considering the jth land use decision:

$$EV^* = z_i'\alpha_{\mathrm{j}} + \delta_i l_{ij} + \eta_{ij} \tag{1}$$

where z_i is a set of exogenous covariates for the ith household, α_{j} is the vector of corresponding parameters, l_{ij} denotes the latent factor, δ_i is the vector of corresponding parameters, and η_{ij} represents the independent error terms.

In this study, we assumed that farmers would choose the forestland use alternative that offers the greatest expected utility. To incorporate this selection, we defined a multinomial variable d_i to denote the observed land use choice, where $d_i = d_{i1}, d_{i2} \ldots, d_{ij}$, and l_i is represented as a sequence $l_{i1}, l_{i2} \ldots, l_{ij}$. Subsequently, the probability of selecting a specific land use choice, given the latent variables, can be written as:

$$Pr(d_i|z_i, l_i) = f\left(z_i'\alpha_1 + \delta_1 l_{i1}, z_i'\alpha_2 + \delta_2 l_{i2}, \ldots, z_i'\alpha_J + \delta_J l_{iJ}\right) \tag{2}$$

where f is an appropriate multinomial probability distribution. Following Deb and Trivedi (2006), we assume that f has a mixed multinomial logit (MMNL) structure, defined as:

$$Pr(d_i|z_i l_i) = \frac{\exp\left(z_j'\alpha_j + \delta_j l_{ij}\right)}{1 + \sum_{k=1}^{j} \exp\left(z_j'\alpha_k + \delta_k l_{ik}\right)} \tag{3}$$

In Eq. (3), we assumed that each land use choice is affected by a single latent factor $\delta_j = 1$ for all j, in order to normalize the scale for each treatment choice equation.

In the second stage of the model, we evaluated the impact of various land use alternatives on the outcome variables. The expected outcome is derived as:

$$E\left(y_i|d_i, x_i, l_i\right) = x_i'\beta + \sum_{j=1}^{J} \gamma_j d_{ij} + \sum_{j=1}^{J} \lambda_j l_{ij} \tag{4}$$

where y_i represents the outcome variables, x_i denotes a set of exogenous factors with parameter β, γ_j represents the treatment impacts, and λ_j represent the impact of the latent factor l_{ij} on the outcome.

Outcome variables We have considered two outcome variables, household income and poverty severity. Household income measures the total income obtained from tree planting, specifically acacia or cashew plantation in Vietnamese local currency VND in million.

We measured poverty severity by using the poverty classification introduced by Foster et al. (1984), which can be written as:

$$FGT_{\alpha} = \frac{1}{N}\sum_{i=1}^{P}\left(\frac{z - K_I}{z}\right)^{\alpha} \tag{5}$$

where N represents the total sample size, P represents the number of households classified as poorer, z_i, is the poverty line, K_I represents the household's per capita income, and α denotes the poverty scale, where the value of 0, 1 and 2 indicates the levels of poverty incidence. When α = 0, $FGT_0 = \frac{P}{N}$, which is the *headcount index*, and measures the proportion of the population that is classified as poor. Similarly, the values for α = 1, denoted as FGT_1, represents the poverty gap, and α = 2, denoted as $FGT_2 = \frac{1}{N}\sum_{i=1}^{P}\left(\frac{z-K_I}{z}\right)^2$.

According to the Vietnamese government, the poverty line for the period 2012–2014, is set at VND 4.8 million per year.[4] This threshold is significantly lower than the poverty line determined by the Vietnam Statistics Office and the World Bank in 2012, which was VND 10.46 million. In this study, the poverty threshold is adjusted to VND 6.24 million per year to cover those close to poverty, resulting in 66 households (27.6% of the sample) being classified as in poverty.

Endogeneity and identification issues Previous studies have proposed using instrumental variables to address endogeneity when evaluating the economic impact of agricultural technology. Variables such as governmental subsidies, agricultural output and productivity, prior knowledge of new technology, and plot-level characteristics have been included in the analysis (Di Falco et al. 2011; Michalek et al. 2014; Manda et al. 2016).

In this study, we examined the use of government support and grey soil as instrumental variables within our empirical framework. These variables were found to influence the farmers' decisions regarding the adoption of cashew or acacia plantings, despite not directly impacting household income and poverty. We conducted a falsification test to assess their validity and found that they meet the criteria established by previous studies (Di Falco et al. 2011; Di Falco and Veronesi 2013).

[4] Governmental Decision 09/2011/QĐ-TTg stipulates that the rural poverty line is VND 4.8 million/year/head (0.77 USD/person/day), and close to poverty is VND 6.24 million/year/head (0.83 USD/person/day), which is closer to the World Bank's rate of 1.25 USD/person/day. The exchange rate in 2012 was VND 20,828/USD.

The propensity score matching (PSM)

In this study, we apply the propensity score matching (PSM) technique, which neither requires parametric distributional assumptions nor covariate exogeneity, making it easier to estimate causal effects in observational studies. This method helps reduce selection bias by balancing pre-treatment characteristics between treatment and control groups. It is especially valuable when randomized controlled trials are not possible due to practical or ethical constraints.

In a binary treatment framework, the average treatment effect on individual farm households can be written as follows:

$$\begin{aligned}\theta(x) &= E\left(Y^T - Y^C|D = 1, X = x\right)\\ &= E\left(Y^T|D = 1, X = x\right) - E\left(Y^C|D = 1, X = x\right)\end{aligned} \tag{6}$$

where Y^T and Y^C represent the outcome of the individuals who received treatment ($D = 1$) and of the individuals in the control group ($D = 0$). X represents a set of exogenous factors.

In Eq. (6), the potential outcome of the counterfactual $E\left(Y^C|D = 1, X = x\right)$ is unobservable. Hence, $\theta(x)$ can be estimated using the matching approach, provided that the possible outcomes of the control group are independent from the treatment, conditional on the exogenous covariates. This is referred to as the Conditional Independent Assumption (CIA). The CIA does not require matching based on observable characteristics, but rather focuses on the propensity score, which is the probability of being treated conditionally on the observable characteristics. Within the PSM framework, we employed binomial models, which involve households planting acacia and cashew trees, instead of those not engaged in any planting activities.

Variable consideration

The dependent variable consists of three distinct values: 0 represents the control group where no action is taken, 1 represents the group afforested with acacias, and 2 represents the groups afforested with cashews. A set of explanatory variables has been defined to determine the factors influencing the establishment of acacia and cashew plantations (Table 3).

Table 3 provides insights into the factors that influence the adoption of acacia and cashew trees, as well as the subsequent impact on household income and the poverty severity. It has been observed that there are no significant variations in household characteristics between households that engage in planting activities and those that do not. These characteristics include the age and education level of the household head, the number of household members, ethnicity, migration status,

Table 3 Variable description and descriptive statistics (N = 239)

Variable	All households (N = 239)		Non-planting households (N = 67)		Planting households (N = 172)		Statistical test
	Mean	SD	Mean	SD	Mean	SD	
Dependent variable							
Planting decision (dummy = 1 if acacia, 2 for cashew, otherwise 0)							
Outcome variables							
Household total income (VND mil.)	79.91	146.60	41.80	38.05	95.06	169.43	4.83***[b]
Poverty severity (%)	0.12	0.21	0.21	0.24	0.83	0.19	4.16***[a]
Independent variables							
Household characteristics							
Age of household head (years)	49.49	11.24	48.37	10.88	49.94	11.38	− 0.82[b]
Education of household head (year)	6.33	3.29	6.28	2.93	6.36	3.43	− 0.17[a]
Number of family member (person)	4.79	1.68	4.53	1.48	4.84	1.75	− 1.27[a]
Household with at least one member working for the government (yes = 1)	0.16	0.37	0.15	0.36	0.17	0.38	0.18[c]
Ethnic minority (yes = 1)	0.15	0.36	0.12	0.32	0.16	0.37	− 0.89[c]
Migrant status (yes = 1 if households from outside the province)	0.83	0.37	0.88	0.32	0.81	0.38	1.29[c]
Farm endowment							
Off-farm income (VND mil.)	29.59	132.78	13.67	22.49	35.93	136.02	− 1.17[b]
Agricultural land (hectare)	1.09	1.27	1.20	1.51	1.05	1.16	0.25[b]
Income from forestry (VND, mil.)	13.61	29.67	2.34	9.64	18.09	33.54	6.32***[b]
Forestry experience (years)	8.24	7.51	5.91	8.19	9.16	7.03	− 4.43***[b]
House size (m^2)	61.62	47.17	51.22	23.52	65.76	53.26	− 2.36**[b]
Value of livestock (mil. VND)	13.02	19.29	16.79	23.02	11.52	17.44	1.77*[b]
Value of production asset (VND mil.)	9.02	65.41	8.38	49.21	9.27	70.96	− 2.63**[b]
Bio-physical factors							
Forest road availability (yes = 1)	0.29	0.45	0.18	0.38	0.33	0.47	− 2.41**[c]
Average distance from home to plots (km)	5.87	7.47	9.90	8.92	4.27	6.14	5.38***[b]
Grey (yes = 1)	0.31	0.47	0.38	0.49	0.29	0.45	1.44[c]
Soil quality (= 1–4, 1 is the lowest, 4 is the highest in the region)	2.83	0.57	2.79	0.59	2.85	0.57	− 0.69[a]
Social-institutional support							
Loan from all sources (mil. VND)	9.04	30.41	2.06	14.72	11.82	34.38	− 5.21***[b]
No. of support from the government (seedlings, fertilizers, credits.)	0.47	0.79	0.01	0.12	0.65	0.87	− 9.30***[a]
Number of years since obtaining land use right certificate (years)	8.63	1.86	8.62	1.71	8.63	1.92	− 0.07[a]
District dummy (= 1 if from Cat Tien)	0.525	0.500	0.62	0.49	0.49	0.50	

*Significant at 10%

**Significant at 5%

***Significant at 1%, SD is standard deviation

[a] *t*-test

[b] Wilcoxon rank sum test

[c] χ^2 test

and affiliation with governmental institutions. From a resource endowment perspective, households engaged in planting activities have statistically significant advantages in terms of off-farm and forest incomes, larger houses and more experience in forestry. Interestingly, the two groups do not differ significantly in terms of agricultural land area and the value of production assets. However, non-planting households have a higher value of livestock. In terms of biophysical attributes, the planting group has a smaller proportion of grey soil, which is considered the province's second most favourable soil type after basaltic soil. Additionally, the planning group tends to have a shorter average distance from their residences to the plots. However, they generally reside in regions with better forestry infrastructure, including forestry roads.

Results

Multinomial endogenous treatment effect

Table 4 presents the parameter estimates for the mixed multinomial logit model of acacia and cashew impacts on household income, representing the first stage of the METE model in Eq. (3). The non-planting category is used as the base for comparison. The model fits the data well with a Wald test statistic $\chi^2 = 764.18$ and a P-value $P > \chi^2 = 0.00$, rejecting the null hypothesis that all regression coefficients are zero. The likelihood ratio test rejects the null hypothesis of treatment exogeneity at a significance level of 1%, thereby supporting the exclusion restriction that addresses endogeneity in the treatments. Falsification tests reveal that government support and grey soil variables are significant in the treatment equations but not in the outcome equation, leading to exclusion from the outcome equation.

The analysis indicates that both acacia and cashew plantations have a positive impact on household income, with significant increases of 110% for acacia and 86%[5] for cashews, compared to non-planting households. Semi-structured interviews with FLA farmers reveal that 79% of households believe tree planting contributes to future food security and income generation (Fig. 2). This finding is consistent with previous research on acacia (Nguyen et al. 2010; Nguyen and Tran 2018; Nigussie et al. 2021) and cashew (Mariwah et al. 2019), as well as tree plantations in general.

In addition, the reasons for planting trees include insufficiently fertile land for crops (83%, sum of Very important, Relatively Important and Important in Fig. 2), less labor required (83%), accessible resources (83%), potential profitability (81%), and contributing to food security (79%). The primary motivations for investing in tree planting were not the requirement to plant trees or government support, as reported by 48% and 36% of respondents, respectively.

However, up to 28% of households abandoned land. The explanations included the following (Fig. 3): households lacked money and labor resources; households were not compelled to plant trees; planting trees was not profitable; and food production was more critical, accounting for 39.4%, 37%, 33%, and 21.5%, respectively. Additionally, 23% of respondents considered government assistance insufficient to endure plantations.

The cashew latent variable (λ) has a highly significant ($P = 0.00$) and negative impact, indicating a negative selection bias for cashew farmers. This means that the unobservable characteristics associated with adopting cashew are linked to lower income levels. Conversely, the acacia variable is significant at the 10% level and has a positive coefficient, suggesting that the unobservable characteristics related to selecting acacia plantations are associated with higher income levels.

The analysis indicates that the level of education of the household head does not significantly affect household income, while age has a negative impact, consistent with the findings of Dinh et al. (2017) and Nguyen and Tran (2018). Together with off-farm income, forest income, is statistically significant at the 1% level, suggesting that tree planting under the FLA program greatly contributes to household income. The number of household members, government job affiliation, agricultural land ownership, house size, rural infrastructure, and livestock and productive asset value significantly influence household income, in line with previous research by Nguyen et al. (2010), Sikor and Baggio (2014), and Van der Meer Simo (2020). However, factors like migrant status, forest experience, and years since acquiring land may negatively impact income.

Table 5 presents the effects of acacia and cashew plantations on reducing poverty severity. The Wald test statistic $\chi^2 = 248.76$ and the corresponding P-value $P > \chi^2 = 0.00$ strongly support the rejection of the null hypothesis that all regression coefficients are equal to zero in the context of poverty severity. The likelihood ratio (LR) test for exogeneity of treatment also yields a significant result at the 5% level, indicating rejection of the null hypothesis of exogeneity. The variables of government support and grey soil pass the falsification tests, similar to the model used to assess the impact on income. The impact patterns of the latent variables of acacia and cashews exhibit are similar to those observed in the context of household income, indicating the presence of selection bias.

The results from the treatment equation in Table 5 indicate that acacia plantations do not have a significant impact on poverty alleviation. However, cashew plantations have a negative effect, suggesting that households with this crop are 11.1% less likely to experience poverty compared to non-planting households, supporting the hypothesis that early cashew harvests can help poverty alleviation (Mariwah et al. 2019).

Propensity scores matching (PSM)

The PSM estimators in Table 6 demonstrate that both cashew and acacia plantations affect household income and poverty severity. The PSM results in a 115%-point difference for acacia plantation, while the METE produces a 110%-point difference. For cashew plantation, PSM generates a 25.0%-point difference

[5] Since income is logged and tree plantation is a dummy, the percentage for acacia and cashew should be $100 * (\exp(0.744) - 1)\%$ and $100 * (\exp(0.621) - 1)\%$, respectively.

Table 4 Mixed multinomial logit model estimates of acacia and cashew plantations on household income

Variable	Acacia plantation	Cashew plantation	Impact on household income (ln)
Household characteristics			
Age of household head (year)	0.001 (0.029)	0.004 (0.027)	–0.011 (0.007)**
Education of household head (year)	–0.086 (0.096)	–0.083 (0.094)	0.014 (0.018)
Number of family member (person)	–0.105 (0.194)	–0.072 (0.139)	0.053 (0.024)***
Household with at least 1 member in government services (yes = 1)	0.349 (1.015)	–1.064 (0.911)	0.575 (0.118)***
Ethnic minority (yes = 1	2.981 (0.801)***	1.981 (0.759)***	–0.026 (0.174)
Migrant status (yes = 1 if household from outside province)	–2.323 (0.740)***	0.115 (0.826)	–0.351 (0.147)*
Farm endowment			
Off-farm income (VND mil.)	0.045 (0.009)***	0.042 (0.009)***	0.002 (0.001)***
Agricultural land (ha)	0.186 (0.282)	–0.136 (0.216)	0.180 (0.042)***
Income from forestry (VND mil.)	0.085 (0.033)***	0.076 (0.032)**	0.008 (0.001)***
Forestry experience (year)	0.105 (0.040)***	0.076 (0.033)**	–0.007 (0.008)*
House size (m^2, ln)	2.561 (0.800)***	1.496 (0.743)**	0.345 (0.179)**
Value of livestock (VND mil.)	–0.014 (0.023)	–0.026 (0.015)*	0.006 (0.002)***
Value of production asset (VND mil, ln)	0.152 (0.185)	0.300 (0.169)*	0.055 (0.027)**
Bio-physical factors			
Forestry road availability (yes = 1)	–1.325 (0.825)	–0.873 (0.825)	0.296 (0.110)***
Average distance from home to plots (km, ln)	–0.320 (0.263)	–0.634 (0.183)***	0.059 (0.031)
Grey soil (yes = 1)	–2.398 (0.836)***	–1.613 (0.681)**	
Soil quality (1 is the lowest, 4 is the highest)	0.702 (0.665)	1.617 (0.571)***	–0.041 (0.116)
Social-institutional support			
Loan total (VND mil. ln)	1.327 (0.390)***	1.495 (0.343)***	–0.008 (0.029)
Number of government support household received	2.984 (1.086)**	3.821 (1.003)***	
Year obtained FLA land (year)	0.438 (0.194)**	0.184 (0.179)	–0.030 (0.035)*
Dummy district (= 1 if from Cat Tien)	–2.478 (0.737)***	–1.051 (0.656)	0.038 (0.097)
Constant	–12.086 (3.914)***	–9.419 (3.969)**	2.327 (1.053)**
Acacia plantation			0.744 (0.157)***
Cashew plantation			0.621 (0.139)***
lnsigma		–1.247 (0.933)***	
Lamda_acacia		0.122 (0.289)*	
Lamda_cashew		–0.598 (0.189)***	

Log pseudolikelihood = –331.942; Wald chi2 (63) = 764.18; Prob > chi2 = 0.000

Likelihood ratio (LR) test (Ho: No exogeneity of treatment variable): 15.878***; *P* = 000

Observations 239

Control group consists of the households who leave the land abandoned, i.e., non-planting. The sample size is 239 households and 300 simulation draws per observation based on a Halton sequence

****P* < 0.01, ***P* < 0.05, **P* < 0.1; Robust standard errors in parentheses

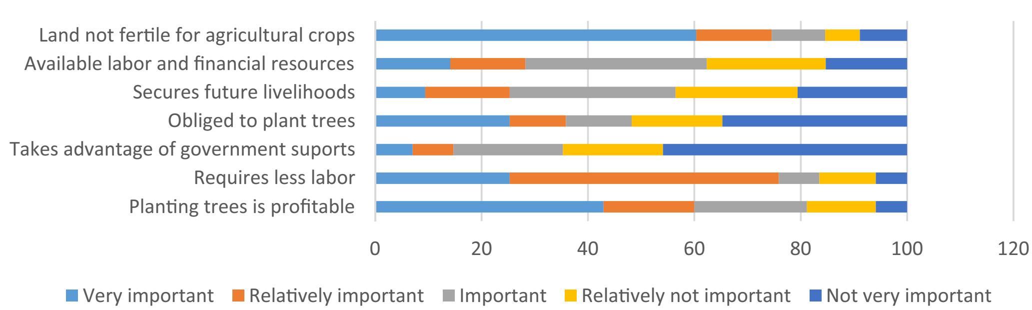

Fig. 2 Reasons FLA households plant trees (n = 172). *Source*: Survey data, Obs: 239

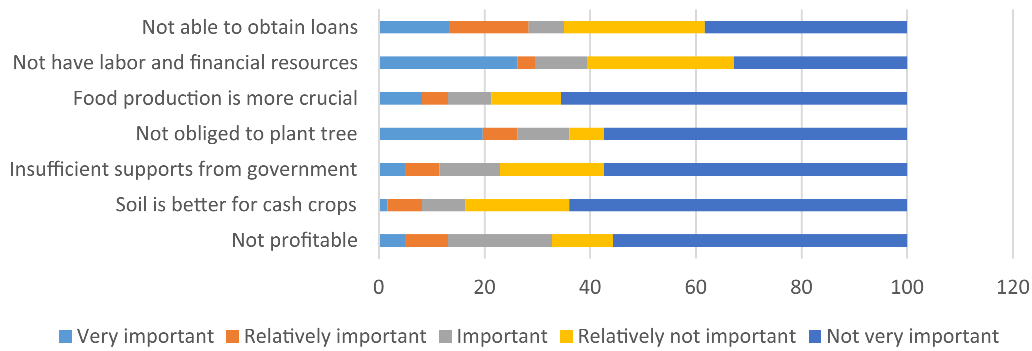

Fig. 3 Reasons FLA households do not plant trees (n = 67). *Source*: Survey data; Obs: 239

compared to METE's 86%-point difference. However, METE consistently yields larger magnitude than PSM for the effect of tree planting on poverty severity.

The differences in the magnitudes of the treatment effects in PSM and METE may be because PSM only controls for observed heterogeneity, while METE addresses both observed and unobserved heterogeneity originating from selection biases that could influence the treatment effect (Lawin and Tamini 2018). The factor-loading parameters (λ) are statistically significant in all models, justifying the use of the METE model.

The estimated impacts of cashew and acacia plantations can be sensitive to the cut-off values for in-sample classification in the selection model. The selection model calculates the proportions of correctly predicted cashew and acacia plantations based on the chosen cut-off value. To visualize this, we plotted the accuracy at different cut-off levels, resulting in a Receiver Operating Characteristic (ROC) curve. The areas under the ROC (AUROCs) for acacia and cashew plantations are estimated to be 0.6633 and 0.6229, respectively (Fig. 4). These values indicate that the estimated model fits well (Mandrekar 2010), with an accuracy or Correctly Classified Ratio (CCR) of 0.8075 and a predictive performance of 0.7993, where the "n" represents the number of observations and the propensity score cut-off point.

Discussion

Based on the analysis results, it can be seen that although both acacia and cashews have improved income and reduced poverty, the decision to choose a tree species that is suitable for household resources, livelihood conditions and other factors including governmental support is quite interesting in this case study. Accordingly, the households that decide to grow cashews are mostly poor and need to make a living, as shown by the average total income of cashew-growing households being 67.69 million VND/year. In comparison, that of acacia-growing households is 173.67 million VND/year. Our focus group discussions have revealed that cashew plantations provide a viable livelihood option for poor households, as they offer quicker harvests, typically within 3–4 years, compared to the longer 6–7 years for acacia trees. This supports the assertions that the early harvest of cashew trees can significantly reduce poverty severity by meeting immediate household livelihood needs (or providing early income) instead of dealing with the uncertainty and long-term return of acacia and other crops (Mariwah et al. 2019; Do et al. 2020).

The insignificant effect of acacia on poverty may be due to households being in the early stages of plantation. This finding is consistent with previous studies in Vietnam by Nguyen et al. (2010) and Nguyen and Tran (2018), as well as research in Mexico (Alix-Garcia et al. 2015), Malawi (Jumbe and Angelsen 2006), and Ethiopia (Ameha et al. 2014). Long-term tree plantations, such as acacia trees mandated by land allocation policies, may be more suitable for financially stable households capable of long-term investments. Acacia planting may not be ideal for socioeconomically disadvantaged households facing acute livelihood challenges.

Other interesting factors that impact tree planting and income are worth discussing further. First, we need to consider the impact of large-scale migration from the North to the Central Highlands province and its effect on socio-economic dynamics. Migrant households are less likely to cultivate acacia. At the same time, cashew is commonly grown near residences and on more fertile soil types, possibly due to the intensive cultivation practices associated with cashews. Second, the average distances between residences and cashew or acacia plantations are 3.01 km and 7.89 km, respectively, indicating a connection between choosing to grow cashews to support immediate livelihoods. Finally, acquiring FLA land at an earlier stage is unlikely to significantly increase

Table 5 Mixed multinomial logit model estimates of acacia and cashew plantations on household poverty status

Variable	Acacia plantation	Cashew plantation	Impact on poverty severity
Household characteristics			
Age of household head (year)	− 0.003 (0.030)	0.004 (0.027)	0.001 (0.001)
Education of household head (year at school)	− 0.066 (0.097)	− 0.082 (0.097)	− 0.001 (0.004)
Number of family member (person)	− 0.156 (0.204)	− 0.065 (0.146)	0.022 (0.006)***
Household with at least 1 person in the government services	0.297 (1.030)	− 0.913 (0.925)	− 0.074 (0.020)***
Ethnicity minority (yes = 1)	3.013 (0.845)***	2.291 (0.793)***	− 0.008 (0.037)
Migrant status (yes = 1 if household from outside province)	− 2.344 (0.714)***	0.162 (0.817)	0.095 (0.025)**
Farm endowment			
Off-farm income (VND mil.)	0.041 (0.011)***	0.034 (0.010)***	− 0.001 (0.000)***
Agricultural land (ha)	0.199 (0.263)	− 0.115 (0.221)	− 0.014 (0.008)*
Income from forestry (VND mil.)	0.087 (0.033)***	0.078 (0.033)**	− 0.0006 (0.000)**
Forestry experience (year)	0.089 (0.039)**	0.068 (0.033)**	0.002 (0.002)
House size (m^2, ln)	2.573 (0.806)***	1.611 (0.745)**	− 0.035 (0.022)
Value of livestock (VND mil.)	− 0.009 (0.024)	− 0.028 (0.016)*	− 0.001 (0.001)**
Value of production asset (VND mil, ln)	0.187 (0.178)	0.298 (0.167)*	− 0.008 (0.004)*
Bio-physical factors			
Forestry road (= 1 if available)	− 1.201 (0.815)	− 0.805 (0.832)	− 0.003 (0.025)
Average distance from home to plots (km, ln)	− 0.291 (0.270)	− 0.601 (0.190)***	− 0.009 (0.006)
Grey soil (= 1 if yes)	− 2.562 (0.821)***	− 1.691 (0.730)**	
Soil quality	0.817 (0.658)	1.607 (0.544)***	0.001 (0.020)
Social-institutional support			
Loan (VND mil. ln)	1.424 (0.407)***	1.554 (0.378)***	− 0.006 (0.006)
Number of government support household received	3.403 (1.189)***	4.275 (1.118)***	
Year obtained FLA land (year)	0.389 (0.198)*	0.157 (0.174)	0.063 (0.006)
Dummy district (= 1 if from Cat Tien)	− 2.485 (0.757)***	− 1.208 (0.666)*	0.022 (0.025)
Constant	11.521 (3.881)***	− 9.263 (3.791)***	0.018 (0.136)
Acacia plantation			− 0.012 (0.033)
Cashew plantation			− 0.111 (0.034)***
lnsigma		− 2.361 (0.148)***	
Lamda_acacia		− 0.094 (0.023)***	
Lamda_cashew		0.085 (0.012)***	

Log pseudolikelihood = 4.947; Wald chi2 (63) = 248.76; Prob > chi2 = 0.000;

Likelihood ratio (LR) test (Ho: No exogeneity of treatment variable): 15.350**; *P* = 0.000

Observations 239

Control group consists of the households who leave the land abandoned, i.e., non-planting. The sample size is 239 households and 300 simulation draws per observation based on a Halton sequence

****P* < 0.01, ***P* < 0.05, **P* < 0.1; Robust standard errors in parentheses

Table 6 Impact estimation by the nearest-neighbour estimators of propensity scores matching

	Impact on income			Impact on poverty		
	Coefficient (SE)	*t*-stat	Matched number	Coefficient (SE)	*t*-stat	Matched number
Acacia choice	0.766*** (0.169)	4.51	238	− 0.081*** (0.022)	− 3.56	238
Cashew choice	0.219* (0.115)	1.90	239	− 0.046** (0.021)	− 2.19	239

****P* < 0.01, ***P* < 0.05, **P* < 0.1

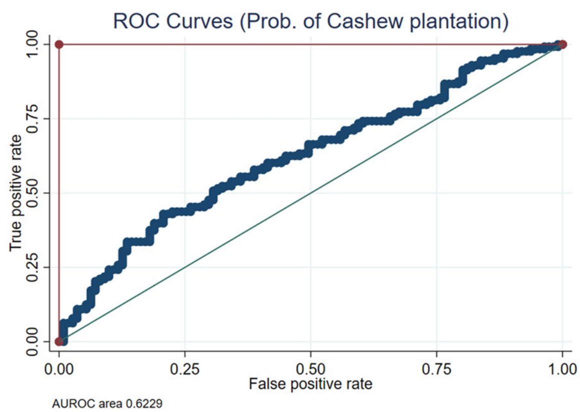

Fig. 4 ROC curves of selection models of Acacia and Cashew plantations

household income through investments in tree planting, even with rich expertise in forestry.

There are several reasons why a significant proportion of households (28.03%) could not afford afforestation. First, their mean income is 41.28 million VND/year, only half the income of planted households (95.06 million VND/year). Additionally, these households often receive remote plots of land, making investing in afforestation difficult. Survey data also shows that the average distance from home to the plot of planted households is 4.3 km, while for non-planted households, it is 9.9 km. This long-distance prevents poor households from planting intensive crops like cashews. Combining these two factors creates further difficulties that hinder households from planting trees.

The results of our case study show that the goal of generating income and contributing to income generation and poverty reduction through forestland allocation and tree planting has not been fully achieved. Tree species with long business cycles and large investments, such as acacia, are difficult for poor households and those in immediate livelihood needs to implement. As a result, these households are forced to choose tree species that align with government planting goals but also meet their immediate livelihood needs. Therefore, alternative livelihood strategies should be considered before committing to long-term tree planting with credit support (Larson et al. 2007; Meyfroidt and Lambin 2008; Dinh et al. 2023).

While our approach effectively tackles selection bias stemming from unobserved heterogeneity, an ideal model for households' intricate land use decisions should incorporate risk and uncertainty factors through a probability analysis approach (Do et al. 2020).

Conclusion and policy implication

Despite the long-standing implementation of Vietnam's Forest Land Allocation (FLA) policy, many households choose not to participate in tree planting or utilize trees for other purposes. This is particularly true in the Central Highlands region, where factors such as livelihoods, migration, and crop competition complicate the relationship between tree planting and household welfare. This study aims to analyze the impact of tree planting, specifically planting different species over different periods (7-year acacia versus 35-year cashew plantations), on household income and poverty reduction. We examine this relationship using both a multinomial endogenous treatment effect and a propensity score matching estimator. The multinomial endogenous treatment estimator will account for both observed and unobserved heterogeneity in measuring the impact of tree planting on household income and poverty levels.

Our research unveils the transformative potential of tree planting, particularly the cultivation of acacia and cashew plants, in significantly elevating household income. With acacia increasing income by up to 110% and cashew increasing income by up to 86% compared to households not engaged in tree planting, our findings demonstrate the importance of tree planting and the difference the tree species makes to household income. In terms of poverty reduction, cashew plantation shows promise with a modest reduction of 9.9% in the likelihood of experiencing poverty. This outcome, while seemingly modest, carries two potential explanations. First, larger farms may be more likely to embrace acacia planting and are not experiencing poverty. Acacia may not be the best species to target for poverty alleviation, particularly when landowners require immediate livelihoods. Second, the duration of the impact evaluation on poverty may have been too short to reveal any significant effects for acacia plantations.

We also found that acacia plantations are more suitable for households with higher socioeconomic status, while cashew farms are more practical for households with lower socioeconomic status. This suggests that many impoverished and migratory households have chosen to cultivate cashew crops to support their livelihoods instead of engaging in acacia planting, which requires a waiting period of 6–7 years before harvesting timber. It is important to consider the broader implications of tree plantations and encourage the government to provide incentives to impoverished households or those without agricultural land, encouraging them to pursue alternative livelihoods such as agroforestry or environmental income.

Increasing the sample size would improve the accuracy of the propensity score model in capturing the characteristics of the data. Additionally, using panel data would allow the model to account for variations in FLA land utilization. Despite the survey being conducted in 2012, no subsequent studies have examined the impact of the FLA land allocation program on household income and poverty levels. This study contributes to the ongoing scholarly discourse on rational decision-making in land use, considering the limitations imposed by household resource constraints. The research also has implications for future comprehensive studies that explore the social and environmental impacts of such behavior, as well as related issues like land grabbing, tenure reinforcement, and capital accumulation under risk and uncertainty within the context of households' investments in tree planting.

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Author contributions
HHD collected data, analyzed data and wrote the first draft of the manuscript. SB curated, analyzed data, wrote first draft of a manuscript. AZ contributed to model specification and edited the manuscript.

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Availability of data and materials
The data supporting the findings of this study are available upon request.

Declarations

Ethics approval and consent to participate
Not applicable.

Competing interests
The authors declare no competing interests.

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References

Abebaw D, Kassa H, Kassie GT, Lemenih M, Campbell B, Teka W (2012) Dry forest-based livelihoods in resettlement areas of Northwestern Ethiopia. For Policy Econ 20:72–77
Aggarwal S, Larson A, McDermott C, Katila P, Giessen L (2021) Tenure reform for better forestry: an unfinished policy agenda. Forest Policy Econ 123:102376. https://doi.org/10.1016/j.forpol.2020.102376
Alix-Garcia JM, Sims KRE, Yañez-Pagans P (2015) Only one tree from each seed? Environmental effectiveness and poverty alleviation in Mexico's Payments for Ecosystem Services Program. Am Econ J Econ Pol 7:1–40
Ameha A, Nielsen OJ, Larsen OH (2014) Impacts of access and benefit sharing on livelihoods and forest: case of participatory forest management in Ethiopia. Ecol Econ 97(2014):162–171
Andersson K, Lawrence D, Zavaleta J, Guariguata MR (2015) More trees, more poverty? The socioeconomic effects of tree plantations in Chile, 2001–2011. Environ Manag 57(1):123–136
Angelsen A, Jagger P, Babigumira R, Belcher B, Hogarth NJ, Bauch S, Wunder S (2014) Environmental income and rural livelihoods: a global-comparative analysis. World Dev 64:S12–S28
Asfaw A, Lemenih M, Kassa H, Ewnetu Z (2013) Importance, determinants and gender dimensions of forest income in eastern highlands of Ethiopia: the case of communities around Jelo Afromontane forest. For Policy Econ 28:1–7
Basnet SK (2021) Analysing and measuring the economic effects of zero-tillage technology: the case of the rice-wheat cropping system of the Indo-Gangetic Plains. Int J Agric Resour Gov Ecol 17(1):38–62. https://doi.org/10.1504/IJARGE.2021.119648
Castella J-C, Boissau S, Hai Thanh N, Novosad P (2006) Impact of forestland allocation on land use in a mountainous province of Vietnam. Land Use Policy 23(2):147–160. https://doi.org/10.1016/j.landusepol.2004.07
Clement F, Amezaga JM (2009) Afforestation and forestry land allocation in northern Vietnam: analyzing the gap between policy intentions and outcomes. Land Use Policy 26:458–470
Cuong T, Chinh T, Xie Y (2019) The impacts of forest plantation on household's income. Open Access Library J 6:1–17
Deb P, Trivedi PK (2006) Maximum simulated likelihood estimation of a negative binomial regression model with multinomial endogenous treatment. Stata Journal 6:246–255
Degnet MB, van der Werf E, Ingram V, Wesseler JHH (2020) Do locals have a say? Community experiences of participation in governing forest plantations in Tanzania. Forests 11(7):782
Di Falco S, Veronesi M (2013) How African agriculture can adopt to climate change? A counterfactual analysis from Ethiopia. Land Econ 89(4):743–766
Di Falco S, Veronesi M, Yesuf M (2011) Does adaptation to climate change provide food security? A micro-perspective from Ethiopia. Am J Agr Econ 93(3):829–846
Dinh HH, Nguyen TT, Hoang VN, Clevo W (2017) Economic incentive and factors affecting tree planting of rural households: evidence from the Central Highlands of Vietnam. J for Econ 29(1):14–24
Dinh HH, Basnet S, Wesseler J (2023) Impact of land tenure security perception on tree planting investment in Vietnam. Land 12(2):503. https://doi.org/10.3390/land12020503
Do H, Luedeling E, Whitney C (2020) Decision analysis of agroforestry options reveals adoption risks for resource-poor farmers. Agron Sustain Dev 40(3):20. https://doi.org/10.1007/s13593-020-00624-5
FAO (2023) The state of the world's forests 2022. Available online at: See details at: https://www.fao.org/3/cb9360en/online/src/html/deforestation-land-degradation.html
Foster J, Greer J, Thorbecke E (1984) A class of decomposable poverty measures. Econometrica 81(2):761–766
Gebreegziabher Z, Mekonnen A, Kassie M, Köhlin G (2020) Household tree planting in Tigrai, Northern Ethiopia: tree species, purposes, and tenure security. Land Use Policy 96:104635. https://doi.org/10.1016/j.landusepol.2020.104635
Holden ST, Benin S, Shiferaw B, Pender J (2003) Tree planting for poverty reduction in less-Favoured areas of the Ethiopian highlands. Small Scale for Econ Manag Policy 2(1):63–80
Jagger P, Pender J (2003) The role of trees for sustainable management of less-favored lands: the case of eucalyptus in Ethiopia. Forest Policy Econ 3(1):83–95
Jumbe C, Angelsen A (2006) Do the poor benefit from devolution policies? Evidence from Malawi's forest co-management program. Land Econ 82(4):562
Khuc VQ, Le TAT, Nguyen TH, Nong D, Tran BQ, Meyfroidt P, Paschke MW (2020) Forest cover change, households' livelihoods, trade-offs, and constraints associated with plantation forests in poor upland-rural landscapes: evidence from North Central Vietnam. Forests 11(5):548
Kröger M (2014) The political economy of global tree plantation expansion: a review. J Peasant Stud 41(2):235–261
Larson AM, Pacheco P, Toni F, Vallejo M (2007) The effects of forestry decentralization on access to livelihood assets. J Environ Develop 16(3):251–268
Lawin KG, Tamini LD (2018) Land tenure differences and adoption of agri-environmental practices: evidence from Benin. J Develop Stud. https://doi.org/10.1080/00220388.2018.144321

Li R, Zheng H, Zhang C, Keeler B, Samberg LH, Li C, Ouyang Z (2020) Rural household livelihood and tree plantation dependence in the central mountainous region of Hainan Island, China: implications for poverty alleviation. Forests 11(2):248
Malkamäki A, D'Amato D, Hogarth NJ, Kanninen M, Pirard R, Toppinen A, Zhou W (2018) A systematic review of the socio-economic impacts of large-scale tree plantations, worldwide. Glob Environ Chang 53:90–103
Manda J, Alene AD, Gardebroek C, Kassie M, Tembo G (2016) Adoption and impacts of sustainable agricultural practices on maize yields and incomes: evidence from rural Zambia. J Agric Econ 67(1):130–153
Mandrekar JN (2010) Receiver operating characteristic curve in diagnostic test assessment. J Thorac Oncol 5(9):1315–1316
Mariwah S, Evans R, Antwi KB (2019) Gendered and generational tensions in increased land commercialisation: rural livelihood diversification, changing land use, and food security in Ghana's Brong-Ahafo region. Geo Geogr Environ 6(1):e00073 (**ISSN 2054-4049**)
Meyfroidt P, Lambin EF (2008) The causes of the reforestation in Vietnam. Land Use Policy 25(2):182–197
Michalek J, Ciaia P, Kancs D (2014) Capitalization of the single payment scheme into land value: generalized propensity score evidence from the EU. Land Econ 90(2):260–289
Miller DC, Muñoz-Mora JC, Rasmussen LV, Zezza A (2020) Do trees on farms improve household well-being? Evidence from national panel data in Uganda. Front for Global Change 3:16
Montagnini F, Nair PKR (2004) Carbon sequestration: an underexploited environmental benefit of agroforestry systems. Agrofor Syst 61:281–295
Nguyen NV, Noriko S (2008) Forest allocation policy and level of forest dependency of economic household groups: a case study in northern central Vietnam. Small Scale for 7(1):49–66
Nguyen TV, Tran TQ (2018) Forestland and rural household livelihoods in the North Central Provinces, Vietnam. Land Use Policy 79:10–19
Nguyen TT, Bauer S, Uibrig H (2010) Land privatization and afforestation incentive of rural farms in the Northern Uplands of Vietnam. Forest Policy Econ 12:518–526
Nigussie Z, Tsunekawa A, Haregeweyn N, Tsubo M, Adgo E, Ayalew Z, Abele S (2021) The impacts of Acacia decurrens plantations on livelihoods in rural Ethiopia. Land Use Policy 100(2021):104928
Osman AI, Fawzy S, Lichtfouse E, Rooney DE (2023) Planting trees to combat global warming. Environ Chem Lett 21:3041–3044
Razafindratsima OH, Kamoto JFM, Sills EO, Mutta DN, Song C, Kabwe G, Sunderland T (2021) Reviewing the evidence on the roles of forests and tree-based systems in poverty dynamics. Forest Policy Econ 131:102576. https://doi.org/10.1016/j.forpol.2021.102576
Sikor T, Baggio J (2014) Can smallholders engage in tree plantations? An entitlements analysis from Vietnam. World Dev 64:101–112
Tassone VC, Wesseler J, Nesci FS (2004) Diverging incentives for afforestation from carbon sequestration: an economic analysis of the EU afforestation program in the south of Italy. For Pol Econ 6:567–578
Turner-Skoff JB, Cavender N (2019) The benefits of trees for livable and sustainable communities. Plants People Planet 1(4):323–335
Van der Meer Simo A (2020) Livelihood impacts of plantation forests on farmers in the greater mekong subregion: a systematic review of plantation forest models. Forests 11(11):1162
Vedeld P, Angelsen A, Bojö J, Sjaastad E, Kobugabe Berg G (2007) Forest environmental incomes and the rural poor. For Policy Econ 9:869–879

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