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How contracted tree farmers engage in and benefit from inclusive value chains: Evidence from Vietnam

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ABSTRACT

In contrast to agricultural crops, long-term tree contract farming (CF) for high-quality timber production under sustainable forest practices contributes to social and economic development, as well as environmental conservation. However, there is limited understanding and insufficient literature on the motivations and benefits of tree growers participating in timber and its associated value chains. This study aims to address these gaps by examining the factors influencing tree grower participation in the tree CF model in Vietnam. We analyzed national panel data of 1272 timber plots in 12 provinces from 2008 to 2018 using penalized maximum likelihood estimation. Additionally, we conducted a local survey of 55 tree producers and stakeholders to compare the household financial performances under the contract versus non-contract and their benefits in the respective value chain. Our findings confirm that households benefit significantly from CF and gain more by delaying harvest for three additional years with forest certification, compared to harvesting timber at year five for woodchips. We recommend increased investment from international and national businesses, as well as government programs, to support tree CF. Future research should explore the roles and impacts of various stakeholders and intervention to better understand and improve tree CF and their inclusive value chains.

1. Introduction

Contract farming (CF) is a prevalent business model in many countries that contributes significantly to economic and social development and possibly environmental conservation under the Sustainable Development Goals, particularly if it involves long-term tree-planting strategies. CF is an agreement between farmers and agribusinesses in which the farmer agrees to produce a specific crop or product based on the agribusiness's requirements and standards (Eaton and Shepherd, 2001). It enables smallholder farmers in low and middle-income (LMIC) countries to access credit, markets, and technologies from high-income countries and to overcome resource constraints, risk aversion, investment reluctance, and ineffective land tenure institutions to produce and supply high-quality products (Glover, 1984; Eaton and Shepherd, 2001; Minot and Sawyer, 2016; Dinh et al., 2023). Conversely, businesses, especially multinational corporations, can access lands that have often been fully allocated and utilize their financial resources and technology to secure material supplies of a certain quality standard (Arnold and Dewees, 1997; FAO, 2013; Vamuloh et al., 2019). As a result, households experience improved productivity, trademarks, job creation, and production efficiency, which should improve livelihoods, food security, climate resilience, gender equality, and environmental conservation (Bijman, 2008; Rode et al., 2014; Minot and Ronchi, 2015; Otsuka et al., 2016; Ton et al., 2018; Ros-Tonen et al., 2019).

While CF for short-term food crops has been overwhelmingly endorsed by empirical evidence from around the world, there is a paucity of development literature analyzing tree CF, including outgrower schemes or partnership arrangements (Arnold and Dewees, 1997; Desmond and Race, 2000; Baumann, 2000; Myers, 2000; Szulecka et al., 2016; Ncube, 2020). In the context of global institutional investment in timberland (both forest and forestland) approaching USD 100 billion, there is an urgent need to dissect the CF proportion, especially to investigate the roles, responsibilities, and levels of benefits of the actors involved, as well as the social and environmental pros and cons, and potential inherent unsolvable issues for such investment and partnership (Evans and Turnbull, 2004; Zhang, 2022; Barney, 2024).

There have been relatively few cases of CF except for studies of fast-growing timber species including acacia in Indonesia (Nawir and Santoso, 2005; Szulecka et al., 2016; Permadi et al., 2018, Hardiyanto et al., 2024), eucalyptus in Laos (Barney, 2024) and Thailand (Boulay et al.,

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2012), India and Brazil (Roberts and Dubois, 1996; Rode et al., 2014; Salles et al., 2019; Richards et al., 2020; De Moraes Gonçalves et al., 2020) and perennial crops such as palm oil in many tropical countries (Gatto et al., 2017; Cahyadi and Waibel, 2012), cashew in Ghana (Dubbert, 2019), avocado in Kenya (Johnny et al., 2019), and coffee and tea in Vietnam (Saigenji and Zeller, 2009; Nguyen et al., 2019), just to name a few. Studies on timber outgrower schemes frequently focus on assessing the benefits enjoyed by contractors and contractees, as well as the social and economic implications of these schemes (Permadi et al., 2018), rather than investigating the factors that influence smallholder involvement in such outgrower schemes. These mechanisms allow firms to boost raw material production without buying land, allowing for smaller and shorter-term investments, whereas outgrowers receive guaranteed wood sales, technical support, and financial support through credits and adjustments. However, CF also involves a company that holds a monopoly as both the sole seller of its end product and the exclusive buyer of farming inputs, leading to an imbalanced power dynamic resulting in the exploitation, disguised proletarianisation, loss of independence, and subservience of farmers (Eaton and Shepherd, 2001; Clapp, 1998). Poor financial performance might result from inadequate extension services and heterogenous farmer experience (Barney, 2024). In temperate outgrower scheme, Lienhoop and Brouwer (2015) found that farmers participating in the agri-environmental scheme in Germany exhibit a notable reluctance towards large forests and long-term contracts. They indicate a willingness to accept decreased subsidies if they receive technical forest management advice and retain the choice to return to agricultural land-use after the contract period concludes. The exclusion of environmental costs from contracts also leads to long-term productivity declines and environmental degradation in the (Morvaridi, 1995).

Smallholder plantations are crucial for global afforestation efforts, making up 32 % of all planted forests worldwide, totaling 278 million hectares as of 2015. This underscores their significant social and economic impacts on a global scale (Meyfroidt and Lambin, 2008; Payn et al., 2015; Arvola et al., 2020; Nambiar, 2021; Miller et al., 2021; Oldekop et al., 2021). Preserving these plantations and avoiding premature harvests is essential for conservation. With rising market demand and timber prices, smallholder plantations and woodlots in tropical regions will play an increasingly pivotal role in timber production until 2050 (Held et al., 2021). However, there is an urgent need for intervention in CF policies to not only sustain the current planting momentum but also shift the focus from short-term and low-quality wood production to long-term and high-quality timber (Permadi et al., 2018). A thought-provoking question arises: How does CF for long-term forestry crops differ from CF for annual agricultural crops?

First, forestry crops require years to mature, resulting in longer-term contracts that involve significant financial and asset investment, irreversible sunk costs, and risks of opportunistic behavior (e.g., side selling) and market and natural conditions (Williamson, 1983; Wesseler et al., 2003; Tassone et al., 2004; Rode et al., 2014; Minot and Sawyer, 2016; Koomson et al., 2022; Zhang, 2022). This can be particularly challenging for smallholder farmers who need to balance long-term investments with immediate livelihood needs (Arnold and Dewees, 1997; Nawir and Santoso, 2005; Dinh et al., 2017). Furthermore, agricultural commodity and forestry crop markets may differ in terms of demand drivers, pricing mechanisms, and market structures, which can impact CF negotiation and implementation and the risks and benefits for both farmers and agribusinesses (Mayers, 2000; Saenger et al., 2014). Forestry crops may also involve different land tenure regimes, with many such crops planted on publicly owned land or private forest plantations, which may affect access to land and resource rights in CF agreements (Baumann, 2000; Arvola et al., 2020; Dinh et al., 2023). In a systematic review of seven outgrower schemes, Desmond and Race (2000) observe that companies benefit from a low-cost timber supply and fewer conflicts, while tree growers benefit from employment opportunities, income from shared timber revenue, and secure land tenure. In addition, forestry crop supply chains are often more complex than those for agricultural commodities, with multiple intermediaries involved in the production, processing and distribution process, leading to significant logistical, quality control, and pricing issues (Kittredge, 2005; Race et al., 2009; Donovan et al., 2015; Saenger et al., 2014; Ferreira et al., 2019). Finally, because forestry crops involve sustainable forest practices, they have a larger environmental impact than agricultural commodities, meaning that CF agreements for forestry crops may require stricter environmental criteria and monitoring systems (i.e. to pass the 10 principles and 56 criteria of Forest Stewardship Certification system-FSC) (Curtis and Race, 1998; Di Girolami et al., 2023). Thus, the conditions for agents (tree growers) to participate in afforestation CF is not solely economic but also include social and environmental policy (and related actors) considerations (Nawir and Santoso, 2005; Robert and Dubois, 1996; Szulecka et al., 2016; Pirard et al., 2016).

The absence of debate regarding the role of CF in inclusive value chain (IVC) development is one of the limitations of many empirical studies in CF. The concept of an IVC is derived from the concepts of inclusive development and inclusive business, which aim to foster fair and transparent relationships between all stakeholders. The IVC emphasizes social inclusion, gender equity, and the empowerment of the poor (Hickey et al., 2015; Gupta et al., 2015; Gupta and Pouw, 2017). Based on Prahalad's theory of the commercial and development potential of "Serving the Poor" at the bottom of the pyramid (Prahalad, 2004), the IVC approach targets smallholder farmers, who often face limited access to resources, markets, and technology, and seeks to align profit and growth with equity, sustainable development, and poverty alleviation. In positioning CF in IVC, recent empirical literature suggests that CF can be an effective strategy for tackling market failures and integrating smallholders into IVC development (Devaux et al., 2018; Ros-Tonen et al., 2019; Tham et al., 2021). Race et al. (2009) suggest that small-scale growers can boost profits by engaging more directly in the forestry value chain, including harvesting, transporting, and selling logs at alternative locations, as well as forming cooperatives or hiring brokers directly. To achieve these goals, IVC emphasizes the participation of public actors and NGOs, and the use of frugal innovation that makes use of local knowledge and technologies (Knorringa et al., 2016; Mark-Herbert and Prejer, 2018; Lashitew et al., 2018).

This paper aims to fill this gap by investigating the motivations of tree growers to participate in tree CF and by examining the benefits that smallholder tree growers in Central Vietnam gain from the inclusive value chain of furniture through their involvement in a tripartite acacia timber production and processing linkage model with the world's largest home-furnishing retailer (IKEA) and a domestic wood processor, Scansia Pacific Ltd. (SP Ltd.).

Vietnam presents a compelling case for addressing afforestation CF due to the government's forestland decentralization program in 1994, which allocated 14.3 mil. Hectares of land to various recipients, including 1.2 mil. Households[1] (Dinh and Wesseler, 2024). The ideology of egalitarian land distribution, pressured by a decade-long exhausted economy under centrally planned policies, clashes with the constraints on household investment. As a result, over 20 years after its launch, 70 % of the allotted land remained abandoned or misused (ibid). Despite significant progress in reducing poverty, many independent tree growers are compelled to harvest their trees prematurely, typically at 3–5 years of age, in order to sell the woodchips at a low price to meet their immediate livelihood requirements. Approximately 80 % of the total 4.5 mil. Hectares of planted forests in the country, 70 % of which

[1] As of 2023, the Vietnamese government is continuing plans to allocate 3.3 million hectares of forest land—currently managed inefficiently by local communal authorities or lacking a clear owner—to households and other entities. Available online at: Accelerate the handover of 3,3 million hectares of forest land that have no real owner to the people - Vietnam.vn (Accessed Feb 30, 2024)

are owned by smallholders, are harvested at these ages for woodchips and paper pulp (Nguyen et al., 2018). Despite having a large plantation area, Vietnam lacks quality timber materials and the wood processing industry had to import raw timbers worth $2 billion in 2022. This has led to a social and policy campaign to promote large timber plantations with tangible economic and environmental benefits. In addition, among 6039 wood processing and trading enterprises, approximately two-thirds are located in the Southeast processing triangle hub (Ho Chi Minh-Binh Duong-Dong Nai) while 77.1 % plantations area stretches from the Southcentral coast up to thousands of kilometers away in the northeastern provinces (Dinh et al., 2023). This is also the material zone for only 34.7 % of national enterprises of which 88.2 % are primary processed and woodchip ones (ibid). This necessitates the need for southern landless wood processors to contract with remote tree growers, in the Central and Northern regions, to secure their material supply. Meanwhile, there exist afforestation CF models across the country, either between national wood processors (NWP) and tree growers or a three-party timber production and processing model led by IKEA (Nguyen et al., 2018). These models reflect a paradigm shift in the market, hierarchy and global environmental changes, emphasizing the need to improve technology, sourcing efficiency, and market accessibility while minimizing costs (Zhang, 2022; Shin et al., 2022). However, there has been no study that address why some tree growers participate in and benefit from this contract mechanism while the majority of others do not. Thus, research on understanding and promoting global IVC by involving smallholder tree growers in afforestation CF is a critical contribution to both theory and practice[2] and assists smallholders, entrepreneurs, and the Vietnamese government (as well as those in other countries) in moving beyond their current unsustainable timber industries.

Despite little evidence of the overall socioeconomic and environmental benefits of the timber production linkage model, previous analyses did not take into account a comprehensive investigation, including the CF influencing factors, financial performance, and value chain analysis. This paper attempts to fill this gap in three ways: first, using the panel data of the Vietnam Access to Household Survey (VARHS) from 2008 to 2018 to examine and have an overview of the determinant factors of smallholder engagement in tree CF. This estimation allows us to test the hypothesis that the household's immediate livelihood needs, proxied through household income, and the available and accessible credit market are major drivers of tree growers' engagements in CF. Second, we analyze the financial performance of the CF of 8-year certified acacia timber production and compare it with the same investment horizon of 8 years but invested independently by households without forest certification. We also analyze and compare the household's 5-year non-certified woodchip production to examine the trivial financial return for households if tree producers opt for this investment choice as opposed to delaying the harvest for 3 more years and engaging in the contract with forest certification. Finally, building on the studies by Maraseni et al. (2017), Backburn et al. (2020), and Tham et al. (2021), we aim to conduct a rapid analysis of the three corresponding inclusive timber value chains to understand how much smallholder tree growers benefit from those value chains.

We will introduce the details of the tripartite IKEA-led production model in Section 2. Section 3 will elaborate on the method, conceptualizing framework underpinning CF adoption. Section 4 describes the study area, data collection, and method of analysis, followed by Section 5, where we present and discuss the results. Following the econometric regression results, financial performance, and value chain analyses, the paper concludes with some policy implications presented in Section 5.

[2] The Prime Minister's decision 523/2021/QĐ-TTg has outlined a strategy to achieve 1 million hectares of large timber by 2030.

2. The IKEA-lead timber production model

The timber production and processing model implemented by IKEA Vietnam involves three key entities.[3] IKEA Vietnam establishes a Strategic Partnership Agreement with the National Wood Processor (NWP) and procures certified acacia furniture from them, such as Scansia Pacific Ltd. IKEA provides low-interest credit to NWP to support the establishment of Chain of Custody (CoC) sawmills and an upfront payment of 25–50 % of the ordered amount. NWP processes the certified acacia furniture for IKEA, operates CoC sawmills, and engages in Community Forestry (CF) with tree growers. Tree growers supply certified timber to NWP through their sawmills. Local authorities facilitate CF and resolve disputes, while NGOs provide technical expertise and financial resources for sustainable forest management and certification initiatives.

IKEA selects NWPs based on criteria such as annual wood processing turnover, financial and technical capabilities, commitment to collaboration, and exclusive production for IKEA. NWPs, like Scansia Pacific Ltd., supply processed products, specify volume, type, and price, provide evidence of timber origin and sustainable certification, and undergo regular inspections by IKEA to ensure compliance with standards.[4]

IKEA has agreements with multiple NWPs nationwide, with orders totaling around 200 million USD in 2020 (Nguyen et al., 2018; Do, 2020). Scansia Pacific works with over 1000 households in Quang Tri and Thua Thien Hue for certified acacia timber production. Scansia Pacific and WWF provide financial assistance for forest certification. Scansia Pacific operates CF with smallholder tree growers, offering lower interest rates than commercial banks and providing loans for timber sales. The model benefits NWPs, tree growers, and IKEA by ensuring a stable supply of legal and sustainable wood materials, access to investment capital, technical support, higher timber premium prices (10–18 %), and a secure market for timber output.

Furthermore, SP is located thousands of kilometers away from the material zone and is concerned about the risks of investing in afforestation without cooperating with farmers, especially in remote areas. There are concerns about risks such as fire, destruction, theft, and so on (Szulecka et al., 2016). Companies believe that without farmer cooperation, the forest will be at risk of being destroyed. Therefore, it is essential for companies to integrate household responsibilities into this business to safeguard the interests of both parties. The production linkage model with IKEA provides stability and sustainability in the timber industry, benefiting all parties involved.

3. Materials and method

3.1. Methods

In this study, we used 1272 timber plot observations from the national panel data collected in 12 provinces (Fig. 1) from 2008 to 2018 to investigate the determinant factors that affect tree growers' decisions to enter CF. Then, we conducted a survey in 2022 specifically in Quang Tri province to evaluate the financial performance of acacia CF. We compared this performance with that of non-contract plantation models and conducted value chain analyses to assess the benefits that tree growers derive from acacia timber value chains, regardless of their involvement in CF.

[3] Currently, IKEA has established strategic partnerships with three companies across the country (Scansia Pacific, NAFOCO, Woodlands) to connect with tree growers in two central provinces (Quang Tri and Thua Thien Hue) and four northern provinces (Phu Tho, Tuyen Quang, and Yen Bai).

[4] IKEA's conditions are extremely stringent, ranging from certified wood supplies to factory production conditions, and are subject to regular inspection. The contract will be cancelled if NWP violates it.

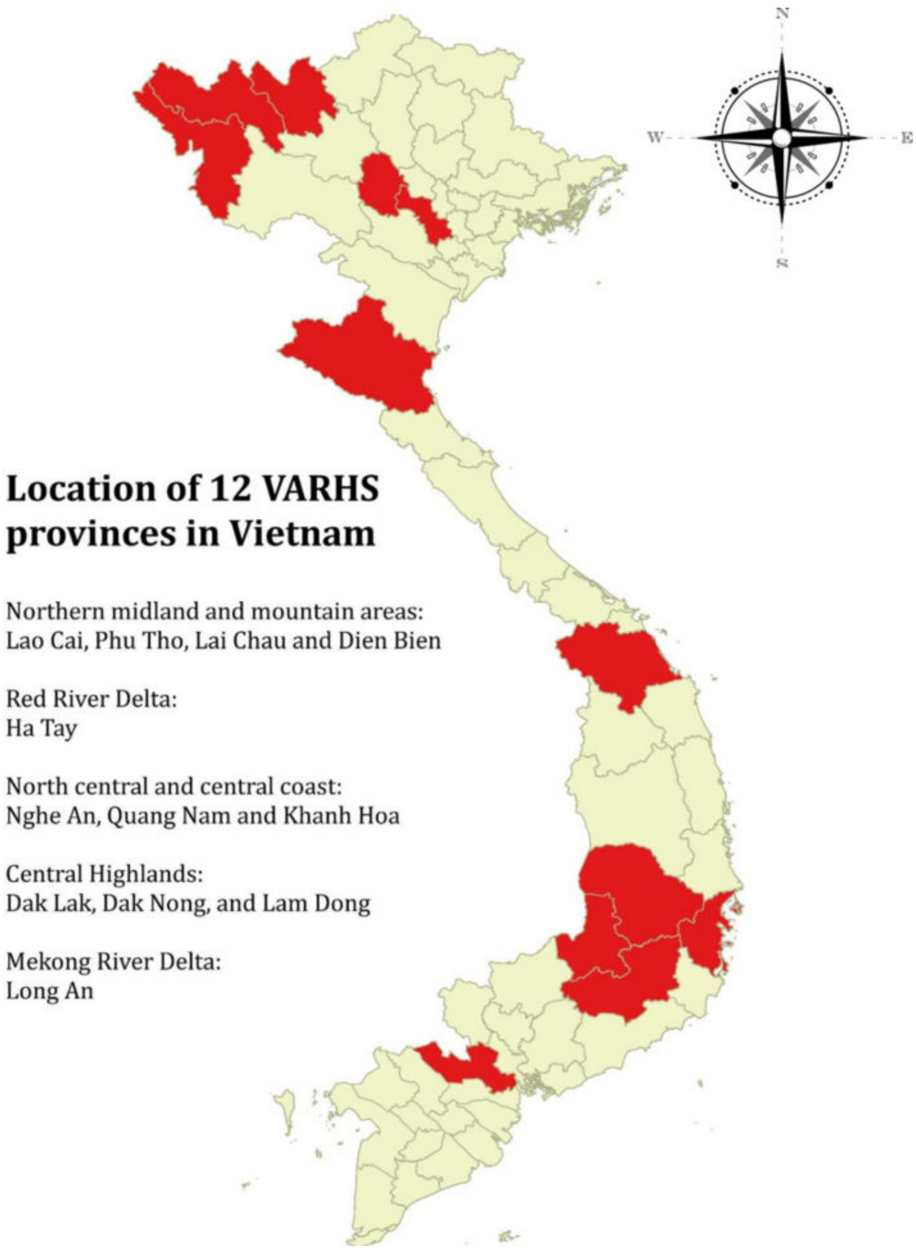

Fig. 1. Map of surveyed provinces of VARHS.

3.1.1. *Model specification and estimation for determinant factors of tree CF*

Under the utility maximization framework, binary logit estimation has been widely used in previous CF studies, for example, Baumann (2000), Gatto et al. (2017) and Akyoo et al. (2019) and Liu et al. (2019), to model determinant factors influencing participation in CF. Endogenous switching regression and the Heckman two-step procedure are two of the most popular methods for modeling participation in CF (Ton et al., 2018). However, due to the small number of households participating in CF in our case, we chose to use a penalized maximum likelihood and two-stage conditional maximum likelihood (2SCML), as described below.

Let Y_{it} denote the binary dependent variable indicating whether farmer i participates in CF at time t. The participation in CF for farmer *i* can be modeled using the following logistic regression equation:

$$Logit\ (\mathrm{P}(Y_{it}=1)) = \beta_1 X_{1it} + \beta_2 X_{2it} + \beta_k X_{kit} + \alpha_i + \varepsilon_{it} \tag{1}$$

where:

$\mathrm{P}(Y_{it}=1)$ is the probability that farmer *i (1…N)* participates in CF at time *t (=1…T)*.

$X_{1it}, X_{2it}, X_{kit}$ are the *k* independent variables that may influence the farmer *i*'s decision to participate in CF at time *t;* $\beta_1, \beta_2, \beta_k$ are the corresponding coefficients of the independent variables, α_i is the individual-specific random effect or unobserved heterogeneity for farmer *i,* ε_{it} is the error term.

In standard maximum likelihood estimation, the model (1) is fitted by maximizing the log likelihood function, which is denoted here by $l(\boldsymbol{\beta})$. However, due to the limited number of observations that participate/not participate in CF in our national data (Contracted/Non-contracted: 169/1103), we used a penalized maximum likelihood estimation (PMLE) to account for the small-sample bias (Firth, 1993; Cook et al., 2018). To account for unobserved heterogeneity and to improve the model's prediction accuracy by overcoming the small sample size, Firth (1993) proposed a binary penalized maximum likelihood estimation (PMLE) by adding a penalty term $\frac{1}{2} trace \left[I(\beta)^{-1} \frac{\partial I(\beta)}{\partial \beta_j} \right]$ in the maximum likelihood-based score Eq. (2):

$$U(\beta_j) = \frac{\partial l(\boldsymbol{\beta})}{\partial \beta_j} = 0 \quad (2)$$

Then, the modified score equations are:

$$\mathrm{U}\left(\beta_j\right)^* = \mathrm{U}\left(\beta_j\right) + \frac{1}{2}\mathrm{trace}\left[\mathrm{I}(\boldsymbol{\beta})^{-1}\ \frac{\partial \mathrm{I}(\boldsymbol{\beta})}{\partial \beta_j}\right] = 0\ (\mathrm{j} = 1,\ \ldots,\ \mathrm{k}).$$

Where $I(\boldsymbol{\beta})^{-1}$ is the inverse of information matrix evaluated at $\boldsymbol{\beta}$.

The corresponding penalized log-likelihood function for the above modified score function is:

$$l(\boldsymbol{\beta}) + \frac{1}{2}log|I(\boldsymbol{\beta})\,|$$

The penalty term used above is known as Jeffreys invariant prior and its influence is asymptotically negligible. The Firth type penalized maximum likelihood estimation $\boldsymbol{\beta}$ is thus:

$$\widehat{\beta} = argmax\left\{l(\boldsymbol{\beta}) + \frac{1}{2}log|I(\boldsymbol{\beta})\,|\right\}$$

The estimated coefficients β can be used to determine the factors that significantly influence farmers' participation in CF, while the estimated individual-specific random effects αi can capture the unobserved heterogeneity that may affect farmers' participation decisions.

The PMLE has several advantages over traditional maximum likelihood estimation (MLE) in the context of generalized linear models. Firstly, PMLE is asymptotically consistent and can eliminate the small-sample bias that is often present in MLE. Secondly, PMLE can handle situations where standard likelihood-based estimates are not feasible, for instance, when dealing with binary-response models that exhibit complete separation. Thirdly, PMLE can control for unobserved heterogeneity that is not captured by observed variables, leading to more accurate estimates of the coefficients of interest. Additionally, PMLE is a flexible and robust estimation method that can accommodate multiple variables and their interactions, while addressing issues of overfitting and multicollinearity. Finally, PMLE is also suitable for analyzing panel data, as it can account for dynamic factors resulting from time-varying variables (Zorn, 2005; Cook et al., 2018).

3.2. Estimation strategy

A likelihood ratio test was performed to obtain the best model specification. A Hausman test confirmed that the fixed effects estimator is not preferred. For a robustness check, we compared the PMLE results with the multi-level mixed-effect logit and probit model. It can also be used to fit different model outcomes. The panel data were estimated using the *firthlogit*, *melogit* and *meprobit* commands in Stata 17.

To deal with endogeneity, we follow the approach of Brandão and Schoneveld (2021) and treat household income as exogenous to the decision to participate in CF. This is because, during the data collection period, only a small number of households received income from timber.[5] We used Dubin-Wu-Hausman test to confirm this exogeneity (and other endogenous variables). To ensure a save approach, we used the share of off-farm income and share of agricultural income in the model instead of household total income. For parsimony, we also excluded the share of agricultural income since it was not significant.

The second endogenous variable in modeling CF determinants is the total farmland area (Bidzakin et al., 2019). Larger farms may be more likely to participate in CF due to economies of scale and better negotiation power, leading to increased farm size through improved access to resources and markets. Progressive or risk-taking farmers with larger farms may also be more inclined to enter into contracts (ibid). To address this endogeneity, we employed a two-stage conditional maximum likelihood (2SCML), which is more flexible than the standard instrumental variable model and can be used for non-linear models (Wooldridge, 2014; Navarro-Castañeda et al., 2021). In the first stage, we regress farm size on the instruments and other explanatory variables to obtain the residuals. In the second stage, we include both the residuals and farm size in the CF equation. To instrument for farm size, proxies such as population density, historical land allocation, and land inheritance status are recommended (Ton et al., 2018). Due to data availability, we used a dummy variable for governmental land allocation and a dummy variable for households with inherited land plots. (The significance of the residuals from these instruments in the main model later justifies their appropriate selection and the Kleibergen-Paap rk Wald F statistic = 9.9). In the second stage, we inserted both the residuals and the total farmland variable itself into the CF equation. The Sagan statistic indicated that the model is identified.

3.2.1. Financial performance of tree CF and its inclusive value chain

Because acacia plantations require long-term investments, we used Net Present Value (NPV) to compare the economic performance of three timber production models over the entire rotation periods (Boulay et al., 2012; Rode et al., 2014; Tham et al., 2021), the NPV is identified as follows:

$$\mathrm{NPV} = \sum\nolimits_{t=1}^{n}\frac{\mathrm{B}^t - \mathrm{C}^t}{(1+\mathrm{r})^t} \quad (1)$$

where B_t, C_t are the benefits and costs at time t, respectively, r is the discount rate, and n is the time horizon. We used a discount rate of 7 % for the business-as-usual (BAU) scenario, in line with Maraseni et al. (2017), Frey et al. (2018), Tham et al. (2020) and Blackburn et al. (2020). This rate represents the average interest rate in Vietnam from 2014 to 2021 (International Monetary Fund (IMF), 2024; Asian Development Bank ADB, 2024). Additionally, we applied discount rates of 5 % and 9 % for a comprehensive and robust sensitivity analysis. We then divided the benefit of each production model's entire commercial cycle to equalize their benefits over time (Equivalent Annual Benefit-EAB), allowing the annual benefits of three models to be compared. We also assessed the Internal Rate of Return (IRR) and Cost-Benefit Ratio (CBR) to evaluate various plantation models, in order to determine their financial viability and profitability.

To calculate the expenditure of forest certification, we used the annual rate of 27 USD/ha/yr,[6] which is the highest cost for household group certification.[7] This rate is three times higher than the rate of 8.5 USD/ha/yr, which was claimed by Maraseni et al. (2017) as the threshold for cost-effective FSC-certified timber production in the case of the largest area of 3000 ha eligible for group certification. Additionally, the cost of land rental was not factored into our analysis as the majority of households in the study area have secure and long-term land use rights, and transfer of forestland is infrequent. Moreover, according to the current policy, farmers who do not process the planted timber are exempt from paying any tax on it, and as such, this cost was also not included in our study.

3.2.2. Inclusive value chain analysis

In this study, we utilized the value chain analysis framework developed by Kaplinsky and Morris (2001) to analyze the acacia timber value chain. Value chain analysis is a systematic approach used to

[5] At the time of the survey, 1257/1272 observations had zero forest income.

[6] The cost of forest certification was consulted with Quang Tri's Forest Certification Association, which is around 5 mil.VND/ha/yr for an 8-year cycle. We rounded it to 27 USD/ha/yr.

[7] There is a great concern that unless international support and national wood processors step into cover the cost of forest certification in the future, smallholders may lose interest in contract farming (CF) with certification. Our calculations include the certification cost in order to demonstrate that even with this additional expense, farmers can still achieve much higher returns by investing in large timber with forest certification through CF.

Table 1

Descriptive statistics of variables influence participation in CF.

Variable	Population (1272) Mean	Std. Dev.	Contracted (169) Mean	Std. Dev.	Non-contracted (1103) Mean	Std. Dev.
Dependent variable (=1 if participated in CF)	0.13	0.34	0	1	0	0
Sex (male = 1)	0.84	0.36	0.85	0.36	0.84	0.36
Education of the head (# years)	7.92	3.10	7.40	3.58	8	3.01
Age of household head (years)	51.69	12.95	51.86	12.99	51.67	12.95
Ethnicity minority household (yes = 1)	0.642	0.48	0.76	0.43	0.62	0.49
Distance to the main road (km)	3.57	6.29	5.71	8.47	3.24	5.83
Distance from home to the plot (km)	1.11	2.10	0.93	2.85	1.13	1.96
Household perception of compensation if land is confiscated (= 1 if with compensation, either following market price or arbitrary by government)	0.43	0.49	0.21	0.41	0.46	0.50
Number of family members (# person)	4.45	1.80	4.69	1.81	4.41	1.80
Dependent ratio (%)	0.267	0.277	0.304	0.233	0.261	0.282
Dummy poor (=1 if household is poor or average)	0.458	0.498	0.178	0.383	0.5	0.5
Total land area (ha)	2.13	2.84	2.06	2.57	2.14	2.89
Labor cost (mil. VND)	10.98	163.26	6.06	21.17	11.73	175.13
Value of output (mil. VND)	13.89	46.92	30.26	44.12	11.38	46.85
Maximum collateral value from all assets (mil. VND)	98.05	288.73	427.21	486.18	47.62	202.36
Interest rate (%)	62.01	45.10	80.02	60.30	59.25	41.65
Agriculture extensions visit (# visit)	5.35	4.45	5.54	4.11	5.32	4.50
Trust in agricultural extension service (1÷4, 4 is not trustworthy)	2.19	0.47	2.44	0.23	2.15	0.48
Share off-farm income (%)	0.44	0.32	0.29	0.29	0.46	0.32
Local market trust (1÷4, 4 is least trustworthy)	2.55	0.56	2.60	0.36	2.55	0.58
Lao Cai (yes = 1)	0.15	0.35	0.18	0.39	0.14	0.35
Nghe An (yes = 1)	0.12	0.33	0.12	0.11	0.14	0.35
Quang Nam (yes = 1)	0.15	0.35	0.11	0.32	0.15	0.36
Long An (yes = 1)	0.17	0.37	0.32	0.47	0.14	0.35

Source: VARHS, 2008–2018.

While including a lagged dependent variable could potentially capture the persistence in CF participation, the rare event nature of our dependent variable and the use of Firth's logistic regression provide a justifiable rationale for its exclusion. Our approach ensures the stability and reliability of the estimates, focusing on the critical exogenous determinants that drive participation decisions.

identify and map out the actors involved in the production, distribution, and marketing of a specific commodity. Although this mapping provides valuable information, it is largely descriptive in nature and serves primarily as a heuristic tool.

In order to conduct the value chain analysis, we quantified the timber in tons at every conceivable stage, starting from standing trees in a household's plantation area and ending at the sawmill or woodchip mill, as relevant to our survey. Ton was the standard unit of measurement and pricing for timber prior to being processed into cubic meters at sawmills. Nevertheless, the cubic meter of timber sold by sawmills was the units utilized to determine the benefits received by each stakeholder in the VC (Maraseni et al., 2017). The converting ratio was 2.2 tons of debarked timber to one tone of dry woodchip ready for export. One cubic meter of certified and non-certified sawtimber required 2.45 and 2.48 tons of certified and non-certified round wood respectively.

Combining NPV with inclusive value chain analysis enables landowners to make informed investment decisions in tree CF by evaluating both the financial returns over time and the distribution of value across the production process. This approach ensures a holistic assessment of economic viability and long-term sustainability (Zhang and Pearse, 2011; Devaux et al., 2018).

3.3. Study area and data collection

3.3.1. Panel data

The regression analysis in this study utilized data from the Vietnam Access to Resources Household Survey (VARHS), which is a longitudinal panel survey consisting of six waves conducted biennially from 2008 to 2018 in 12 provinces across North, Central, and South Vietnam (Fig. 1). The sampling strategy employs a multi-stage stratified sampling to ensure representative and comprehensive data collection across various rural areas in Vietnam. Initially, the sampling frame consists of a list of communes, which are stratified by region and economic characteristics. Within selected communes, households are randomly sampled to capture diverse agricultural and socio-economic profiles. This approach allows for the collection of detailed information on the socio-economic status of households and their access to resources including land use, labor, credit, and specific investment decisions related to tree planting.[8] To ensure data quality, a cleaning process was applied to retain only timber plots, removing missing observations and outliers. As a result, the dataset was transformed into an unbalanced panel dataset comprising 1272 observations. The attrition rate was higher in 2012, 2014, and 2016 but decreased in 2018, likely due to factors such as household dropouts or changes in land use (see Appendix Table A-4).

The dependent variable in this study was binary, taking a value of 1 if the tree grower engages in CF and 0 otherwise. The selection of independent variables was based on empirical studies related to CF, including the latest systematic review by Minot and Sawyer (2016), Devaux et al. (2018), Vamuloh et al. (2019), Ncube (2020), and case studies on tree planting, such as acacia, eucalyptus, and perennial crops mentioned earlier (Boulay and Tacconi, 2015, De Moraes Gonçalves et al., 2020; Vermeulen et al., 2008). The independent variables covered a range of factors, including demographic characteristics (age, sex, education, ethnicity, family size, dependent ratio), biophysical factors (soil fertility, plot area, distance, location dummies), endowment (income, cropland, labor, collateral asset value), market uncertainty (interest rates, output price represented by output values, labor cost), and institutional support (perception of land tenure, training assistance). Descriptive statistics for these variables are provided in Table 1.

While this dataset lacks specific variables such as output price, certification support, contract duration, etc., that could potentially

[8] The VARHS was designed to complement the Vietnam Household Living Standards Survey (VHLSS), conducted by the General Statistics Office (GSO). The population census and VARHS/VHLSS household similarities. Thus, VARHS findings can be generalized to the whole country.

influence CF participation, it does include a comprehensive set of important variables from the specified groups mentioned above. Furthermore, with its 10-year longitudinal nature, this dataset enables addressing time-invariant unobserved heterogeneity, dynamic relationships over time, improves the identification of causal relationships, and provides enhanced statistical power.

The descriptive statistics from the panel data suggest that there are minimal differences in the values of the explanatory variables, except for a few. Notably, the distance from the plot to the main road, dependent ratio, output value, and interest rate of CF households are higher than those of non-CF households. Conversely, non-contracted households seem to be wealthier and have incurred higher costs for hiring labor compared to contracted households.

3.3.2. Cross-sectional data

To conduct a financial performance and value chain analysis, we carried out a survey in Cam Lo district, Quang Tri province, in the central region of Vietnam (Fig. 2). Quang Tri province was selected for the following reasons: (i) it is a pioneering region for the IKEA-led production linkage model, which has been in operation since 2006. Under this collaboration, Scansia Pacific Ltd., a "strategic partner" of IKEA headquartered in Ho Chi Minh City, has signed contracts with smallholder tree growers; (ii) the province has 246,000 ha of forest land, of which nearly 48.5 % is plantation forests, with more than half owned by households and cooperatives.[9] This allows for the inclusion of various timber production models in the analysis and comparison in this study; (iii) the natural conditions in the region are relatively homogeneous, which enables the assumption of constant natural conditions to be applied when analyzing variances in socioeconomic and investment decisions for each model.

In order to analyze and compare the financial performance of Acacia sp. plantations, three single-rotation models were examined: (i) an 8-year certified timber model under the IKEA-led CF scheme (Model 3); (ii) an 8-year non-certified non-CF timber production model by smallholders (Model 2); and (iii) a 5-year non-certified household independent pulp/woodchip production model (Model 1). The benchmark model used was a household independent 8-year acacia plantation (Model 2), while the desired model was an IKEA-led 8-year certified timber production CF. In this model, domestic wood processors enter into contracts with smallholder farmers, utilizing their land and labor, while investors contribute capital, technology, and marketing support. This represents the common collaborative approach in outgrower schemes, particularly the model 2 + 3 in Laos[10] (Arnord et al., 2022). Smallholders following the Business-As-Usual (BAU) model had independently invested in their forestlands and had not participated in a CF. These smallholders were determined and varied in their investment resources. The focus of this study was to collect data and information for analyzing and comparing the financial performance and benefits along the respective value chains.

In November 2022, the first author, accompanied by two trained undergraduate students from the Economic University of Ho Chi Minh (UEH) and two trained enumerators from Keo Son Forestry Cooperatives in Cam Lo district, conducted a field trip to carry out the survey. Both qualitative and quantitative data collection methods were used to gather primary and secondary data (Bryman, 2006). A total of 55 key informants were interviewed, including 30 households (10 households per model, purposively selected, just harvested over the last 12 months), 2 cooperatives, 4 local collectors, 4 Chain-of-Custody (CoC) sawmills, 2 woodchip processors, 4 furniture processors, and 4 exporters and distributors (Table 2). In contrast to what is stated in the grey literature about the credit support provided in the IKEA-led CF scheme for acacia plantations, which is a maximum of VND 4 million/ha/yr^{-1} at a 2 % lower interest rate than the market (Nguyet et al., 2018), our survey found that only 4 out of 30 tree growers received such credit support. As a result, we chose not to incorporate the advantage of low-interest loans in our financial analysis.

To conduct a Net Present Value (NPV) analysis, household heads were interviewed to collect information on why they participated in CF, its advantages and disadvantages, potential risks and conflicts, as well as detailed quantities and prices for costs and benefits associated with different stages from plantation to harvesting. Three group discussions were organized, one for each model, to investigate the role, responsibility, rights, and benefits of each stakeholder involved in the CF and along each value chain. The discussions also covered reasons and conditions for participating in the CF, cross-checking costs and benefits, limitations associated with participating/non-participating, and future challenges and opportunities.

We sought input from local authorities and NGOs operating in the region, including organizations like the World-Wide Fund (WWF), Quang Tri Forest Certification Association, and local authorities. These consultations aimed to gather information about the roles and responsibilities of relevant parties involved in CF and along the Acacia timber value chain. Additionally, we consulted with representatives from IKEA and Scansia Pacific Ltd. to obtain information about the requirements for participating in this collaboration and the benefits experienced by each party.

To conduct value chain analyses, we engaged with various stakeholders from the three timber value chains to gather information on their overall costs and benefits. We did not ask to provide a detailed breakdown of every cost incurred in the production stage. We opted for this data collection method due to the unregistered nature of local collectors' businesses, which results in non-payment of taxes and lack of transparency in their business information. Whereas sawmills are required to issue sales invoices and are subject to a 10 % value added tax (VAT) when selling lumber to the NWP. This disparity in tax compliance makes it challenging to conduct a cost-benefit analysis across actors in the value chain. Furthermore, some stakeholders are hesitant to discuss their costs and benefits or to do so in an honest manner. As a result, we simply asked for a rough estimation of their costs and revenue before taxes. To determine the ultimate benefit of each stakeholder in each value chain, we calculated the average of the costs and benefits experienced by all stakeholders at a similar stage in that chain. We obtained the prices of the final products used in our value chain analysis directly from the final in-country processors.

Obtaining accurate information from local collectors who handle the logging and transportation of timber for delivery to the woodchip factory was extremely challenging, e.g., the depreciation of assets such as trucks and saws. In the majority of cases, local collectors do not possess business registration, and there is a lack of clarity regarding tax information. Consequently, we have chosen to inquire about the overall costs and profits of all stakeholders involved in the value chains (VCs). Certified timber is typically sold directly to sawmills, meaning that in many cases, the responsibility for harvesting falls on the sawmills themselves, bypassing the involvement of local collectors. As a result, we consider harvesting and transportation costs as renting fees on the household side. Unlike Tham et al. (2021), who utilized a standard chair (98 chairs/1 m^3 sawn timber) to assess the value chain, we used the average overall output value from processing 1 m^3 of sawn timber, which can be chairs or a set of outdoor table furniture.[11]

[9] Decision 2860/QĐ-BNN-TCLN on Vietnam Forest status, Ministry of Agricultural and Rural Development, December 2022.

[10] In the 2 + 3 model, the smallholder provides labor and land (the '2') and the commercial investor/grower provides capital, technology and marketing (the '3') (Arnold et al., 2022).

[11] In our survey, 1m^3 acacia can produce from 83 to 85 standard chairs or 6 sets of tables for outdoor furniture.

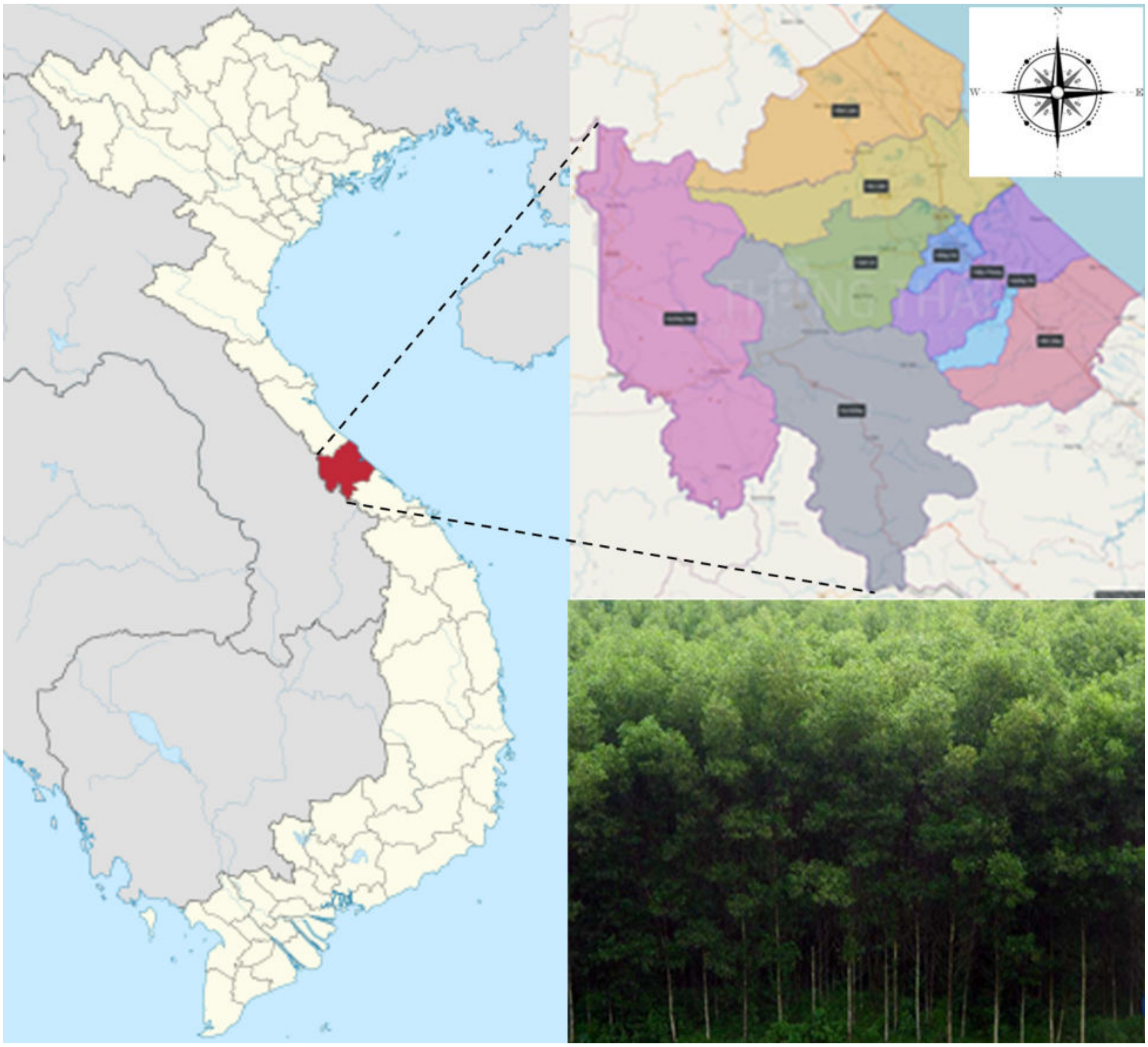

Fig. 2. Map of Quang Tri province.

4. Results and discussion

4.1. Determinant factors of participation in tree CF

The results of the penalized maximum likelihood estimation (PMLE) of influencing factors determining tree-grower participation in timber CF using national panel data are shown in Table 3. The results of the multilevel mixed effects logit model (MMEL) and multilevel mixed effects probit model (robust standard error) are also presented in this table for robustness checks. In general, the three models produce similar results in terms of impact magnitudes[12] and directions. All models are statistically significant as revealed by the chi-squared ($p = 0.000$) which suggests that our variables jointly and significantly explain tree growers' participation in CF. Both the residuals and the endogenous variable of total farmland are significant, indicating that farm size is endogenous, and the selection of two instrumental variables (land distribution by the government and land inheritance) is appropriate.

The PMLE model tends to produce larger coefficients compared to its counterparts, but the significance levels and directions are mostly similar to the other two models. The smaller standard deviation and narrower confidence intervals in the PMLE model indicate that it accounts for small sample bias better and fits the data more effectively than the other two models.

According to the PMLE results, the total fam size of household is positive corelated with participation in CF as expected, as larger landholdings can support more extensive and diverse farming activities. This finding supports quite many studies including Amatayakul and Azar (2008), Bolwig et al. (2009); Boulay et al. (2012) but contradict to that of Bidzakin et al. (2019). Unlike age (e.g. Bidzakin et al., 2019) and education, being male household head is less likely to participate in tree CF. This is unexpected, but it could be the case that male-headed households might have better access to alternative income sources such as hiring out labor, or prefer traditional farming methods over CF.

Minority households may have limited access to resources and markets, making CF an attractive option for securing stable income and support from contracting firms. This is logical given that ethnic

[12] The coefficients in the probit model are smaller than those in the logit models due to the difference in the variance of the underlying latent variables, with the logistic distribution having a larger variance compared to the standard normal distribution.

Table 2
Number of interviewers.

	5-yr woodchip plantation	8-year non-certified timber	8-year certified CF timber
Tree growers	*10*	*10*	*10*
Cooperative	*1*	*1*	*0*
Local collectors	*2*	*2*	*0*
Local sawmill	*0*	*2*	*2*
Woodchip processors	*2*	*0*	*0*
Furniture processor	*0*	*2*	*2*
Exporter/ distributor	*1*	*1*	*2*
Local authorities/ NGOs	*← 5 →*		
Total	***16***	***23***	***16***

Source: survey data, 2022.

households are often regarded as less educated, isolated, facing language barriers, and having fewer financial resources compared to the majority Kinh population, who make up more than 80 % of the Vietnamese population. This finding aligns with the case of coffee perennial crop CF in the Central Highlands of Vietnam (Nguyen et al., 2019). However, recent instances of land grabbing from ethnic households by outsiders under the guise of agricultural production "collaboration" also raise concerns, indicating the need for the government to enforce policies to protect indigenous land, especially in the Central Highlands of Vietnam.

In all models, the distance from home to plots and from plots to the main road is negatively correlated with CF participation. This likely occurs because CF requires a significant labor investment over the 8-year term, including tasks such as weeding (by hand or machine, unlike the burning often used in independent plantations), pruning, and thinning. These activities can lead to substantial travel costs, time commitments, and other intensive investments over the long-term horizon of CF. At this point, it is also important to note that for 4–5 years, acacia plantations for woodchips are common among farmers. Especially in Quang Tri province, farmers pay little or no cost for thinning and weeding (as can be seen from the cost structure in Fig. VI-2). They simply plant the trees and wait for harvest after 5 years. Our result partly corroborates the impact of distance of land plot that Vermeulen et al. (2008) and Baumann (2000) highlighted in the case of other commercial tree crops like tea, coffee, cacao, and rubber.

The fact that tree growers are unlikely to participate in CF, even though they know that there might be compensation in the future if land is confiscated, is because the compensation is not enough or arbitrarily paid by the government (Mayers and Vermeulen, 2002). With respect to human resources, the results indicate that households with a higher number of family members are less likely to participate in CF. This could be due to larger households allocating labor to work in other agricultural crops, as evidenced by the negative output value of the dominant agricultural production. However, households with a higher dependent ratio are more likely to participate in CF.

The unexpected negative correlation of extension visits with tree CF participation may be due to the fact that households engaged in tree CF also participate in other agricultural activities, leading extension visits to focus on wetland rice or annual crops rather than tree planting. Additionally, households participating in contract farming are required

Table 3
Determinant factors influence tree grower participation in CF in Vietnam.

VARIABLES	Penalized maximum likelihood		Multilevel mixed-effects logit		Multilevel mixed effects probit	
	Coeff.	*R. E*	*Coeff.*	*Robust S. E*	*Coeff.*	*Robust S. E*
Total land area (ha) (ln)	*13.73****	*(4.443)*	*14.24****	*(4.458)*	*7.779****	*(2.350)*
Residuals of total land area	*−14.6****	*(4.457)*	*−15.16****	*(4.472)*	*−8.255****	*(2.350)*
Sex of household head (male = 1)	*−1.288***	*(0.523)*	*−1.329****	*(0.519)*	*−0.770****	*(0.282)*
Education of head (# years)	*0.003*	*(0.035)*	*0.002*	*(0.034)*	*−0.05*	*(0.018)*
Age of household head (years)	*−0.013*	*(0.010)*	*−0.014*	*(0.010)*	*−0.008*	*(0.005)*
Ethnicity minority household (yes = 1)	*4.712****	*(1.131)*	*4.911****	*(1.141)*	*2.623****	*(0.594)*
Distance to the main road (km) (ln)	*−1.837****	*(0.586)*	*−1.906****	*(0.593)*	*−2.244****	*(0.667)*
Distance from home to plot (km) (ln)	*−3.949****	*(0.261)*	*−4.110****	*(0.256)*	*−1.039****	*(0.311)*
Perception if land is confiscated (= 1 if with compensation)	*−2.901****	*(0.487)*	*−3.022****	*(0.451)*	*−1.609****	*(0.214)*
Number of family member (# person)	*−0.636***	*(0.266)*	*−0.660***	*(0.256)*	*−0.370****	*(0.138)*
Dependent ratio (%)	*0.7675**	*(0.429)*	*0.794***	*(0.400)*	*0.377**	*(0.214)*
Dummy poor (=1 if household is poor or average)	*1.792**	*(0.944)*	*1.859***	*(0.947)*	*1.084***	*(0.498)*
Share off-farm income (%)	*3.471***	*(1.617)*	*3.595***	*(1.600)*	*2.062***	*(0.842)*
Labor cost (mil. VND)	*−0.0004*	*−0.000*	*−0.0008*	*(0.0005)*	*−0.0005***	*(0.0002)*
Value of output (mil. VND)	*−0.012***	*(0.006)*	*−0.012***	*(0.006)*	*−0.007*	*(0.003)*
Maximum collateral value (mil. VND)	*0.004****	*(0.000)*	*0.004****	*(0.0005)*	*0.002****	*(0.0002)*
Interest rate (%)	*0.019****	*(0.005)*	*0.020****	*(0.005)*	*0.011****	*(0.002)*
Agriculture extensions visit (# visit)	*−0.067***	*(0.028)*	*−0.070***	*(0.030)*	*−0.031***	*(0.016)*
Trust in agricultural extension service (1÷4, 4 is not trustworthy)	*−0.157*	*(0.524)*	*−0.141*	*(0.523)*	*−0.136*	*(0.266)*
Trust local market (1÷4, 4 is least trustworthy)	*0.440**	*(0.247)*	*0.450**	*(0.232)*	*0.264***	*(0.115)*
Lao Cai	*3.554****	*(0.830)*	*3.693****	*(0.792)*	*1.993****	*(0.442)*
Nghe An	*−2.862****	*(0.781)*	*−3.161****	*(1.030)*	*−1.479****	*(0.473)*
Quang Nam	*2.086****	*(0.594)*	*2.160****	*(0.630)*	*1.114****	*(0.321)*
Long An	*−2.4843***	*(1.013)*	*−2.583****	*(0.974)*	*−1.442****	*(0.520)*
Constant	*−13.75****	*(2.69)*	*−14.30****	*(2.643)*	*−7.678****	*(1.373)*
Observations	*1272*		*1272*		*1272*	*1272*
			Log likelihood = − 288.487		*Log likelihood = − 291.893*	
	Penalized loglikelihood = −226.646 *Wald chi2 (24) = 203.08* *Prob > chi2 = 0 0.0000* *AIC: 503.3 BIC: 632.0*		*Wald chi2 (24) = 193.59* *Prob > chi2 = 0 0.0000* *AIC: 626.9 BIC: 755.9*		*Wald chi2 (24) = 214.03* *Prob > chi2 = 0.000* *AIC: 633.8 BIC: 762.5*	
VIF			*1.30*			

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

to follow technical guidance from contractors rather than relying on extension services.

Another factor that highlights the intricate relationship between labor, income, and CF participation is that households with a higher share of off-farm income are more inclined to participate in CF. This aligns with the notion that male household heads with potential off-farm income sources are more likely to pursue these opportunities rather than engage in CF as discussed above.

Households with high collateral asset values are more likely to participate in CF, as these assets can secure loans even with high interest rates (variable interest rate). This is plausible because they might need to apply for a small loans to cover family expenses while waiting for the long-term contract to be paid off after 7–8 years (Glover, 1990). Baumann (2000) further supports this by observing that disadvantaged households relying on tree crops as their primary income source often face severe cash flow challenges between harvests. This indicates an expectation of income gain from high timber value, as 8-year certified timber yields triple the income compared to 5-year woodchip, as shown in the financial analysis below. The positive correlation between CF participation and interest rates also supports the expectation that participants anticipate securing lower interest rate loans offered through the contract. Additionally, if households do not trust the local market, they are more likely to enter CF as expected. This is because CF offers stable demand for timber output with a 15–20 % higher premium price due to sustainable forest certification (FSC).

Although significant at the 10 % level, the poor and close to being poor households are likely to engage in CF as expected. This finding supports several other studies including Rode et al. (2014) that indicate outgrower schemes yield substantial returns for small and medium-sized farms. In addition. However, this should be interpreted with caution, as companies often contract entire forest areas in a locality for easier certification assessment.

In terms of geographic distribution, it is evident that Nghe An and Long An have a lower level of tree grower participation in CF than other provinces, while the impact is not significant in four other provinces. The limited engagement of tree growers in Nghe An and Long An provinces in CF may be attributed to their northern positioning within the Central region and Mekong Delta, respectively, which makes them either geographically distant from both southern and northern wood processors or unsuitable in the dominated wetland rice region.

However, one limitation of using this national data is the unclear type of CF and related terms and conditions that households are involved in, the absence of variables such as government support, specific product prices at different times, and the type of timber species, which could improve the specification of the CF participation equation. Thus, this analysis only provides a general view of how and why tree growers participate in tree CF in the country. Nevertheless, acacia and eucalyptus are the two main species cultivated in the province covered by VARHS, accounting for 90.6 % of the total plantation area in Vietnam.[13]

4.2. Financial performance of tree CF and benefit in the acacia timber value chains

4.2.1. Reasons for participating/not participating in collaborative model

Our study findings from Fig. 3 indicated that a significant majority of respondents, up to 86.6 %, believed that participating in CF with SP would generate greater profits from selling certified timber after an 8-year plantation, as shown in Table 5. The second and third reasons for participation were the low-interest credit offered by SP and technical assistance, such as sustainable forest management training and forest certification,[14] which were cited by 76.7 % and 70 % of respondents, respectively. This is different from the case in Thailand where contractors offer no credit or financial aid (Boulay and Tacconi, 2012). However, contrary to expectations based on prior information, few households took advantage of low-interest loans from SP. This was because SP offered interest rates similar to or only slightly lower than those of commercial banks on the market, at around 8 % per year (according to group discussions). Despite not receiving low-interest loans from SP, households chose to sign a contract with SP while borrowing from a bank, as they did not want to be obligated to sell timber to SP if the market price was higher. Therefore, the contract did not include a provision for selling timber to SP.

According to the results, delaying harvest following the CF can also result in reduced costs of replanting and tending if tree owners pursue the 5-year woodchip production model or the 7- or 8-year model to provide non-certified timber for furniture processing. In addition, securing timber sales in the context of fluctuating timber prices (e.g., woodchips) (Baumann, 2000), a lack of financial resources, and reducing the risk of forest fires are three other reasons that motivate tree growers to participate in CF.

However, the group discussions have revealed concern that there may be greater risks of forest fires and storms if trees are kept too long (8 years) to produce large timber under the CF scheme. The risk of forest fires and trees being broken by storms are two clear threats that exist in the land of Quang Tri, which is characterized by hot, dry Lao winds in the summer and tropical storms in the rainy season. Currently, there is no provision to address this issue, and it is likely that these kinds of risks will be delegated to the farmers, as is the case with eucalyptus CF in Thailand (Boulay et al., 2012). During group discussions, it was also raised as a concern that households participating in the CF model may face difficulties in exploiting and selling their timber when they urgently need cash, especially when they or their family members fall ill. CF participants must acknowledge that NWP only purchases qualified timber and they are responsible for selling the remaining timber to anyone they choose, which is also the case with Thailand eucalyptus. This can be challenging as it is difficult to sell only small trees and branches to local collectors for woodchips, which can discourage households from participating in tree CF. Additionally, it should be noted that by participating in CF, tree growers are not permitted to interplant with food crops during the early stages of forest canopy cover.

With respect to nationally supported policies, Decree No. 98/2018/ND-CP issued in 2018 promotes the development of timber production linkages. Under this decree, participants in agricultural product linkages receive 100 % cost support for consulting services (up to USD 13,000). The state also provides support by covering 30 % of capital investment in machinery, equipment, and infrastructure for the production, preservation, processing, and marketing of agricultural products (with a maximum support limit of USD 435,000). Additionally, beneficiaries may receive support in the areas of extension services, training, breeding, and supply provisions. Quang Tri province did not implement this policy until October 2022, when the provincial People Committee issued Decision 2784/QĐ-UBND to concretize Decree 98. This decision did not mention a specific level of support per project, as Decree 98 does. At the time of our survey, no timber production linkage projects had been initiated under these regulations. The actors within the value chains were unaware of this policy, which mandates local financial resources from the province for its implementation, whereas NWPs such as

[13] As December 2022, Vietnam had 2.096 million ha of acacia and 0.226 million ha of eucalyptus of all species, accounting for 90.6 % of the production forest, except for 1.02 million ha of rubber and others. (Decision 2860/QĐ-BNN-TCLN, 2022).

[14] To participate in CF, all tree farmers must adhere to FSC certification and receive training on various silviculture techniques, including cultivar selection, planting, tending, pruning, harvesting, and habitat conservation under the canopy. These practices are aimed at meeting FSC criteria for sustainable forest management and eliminating traditional practices such as burning, exploiting young, and soil disturbances.

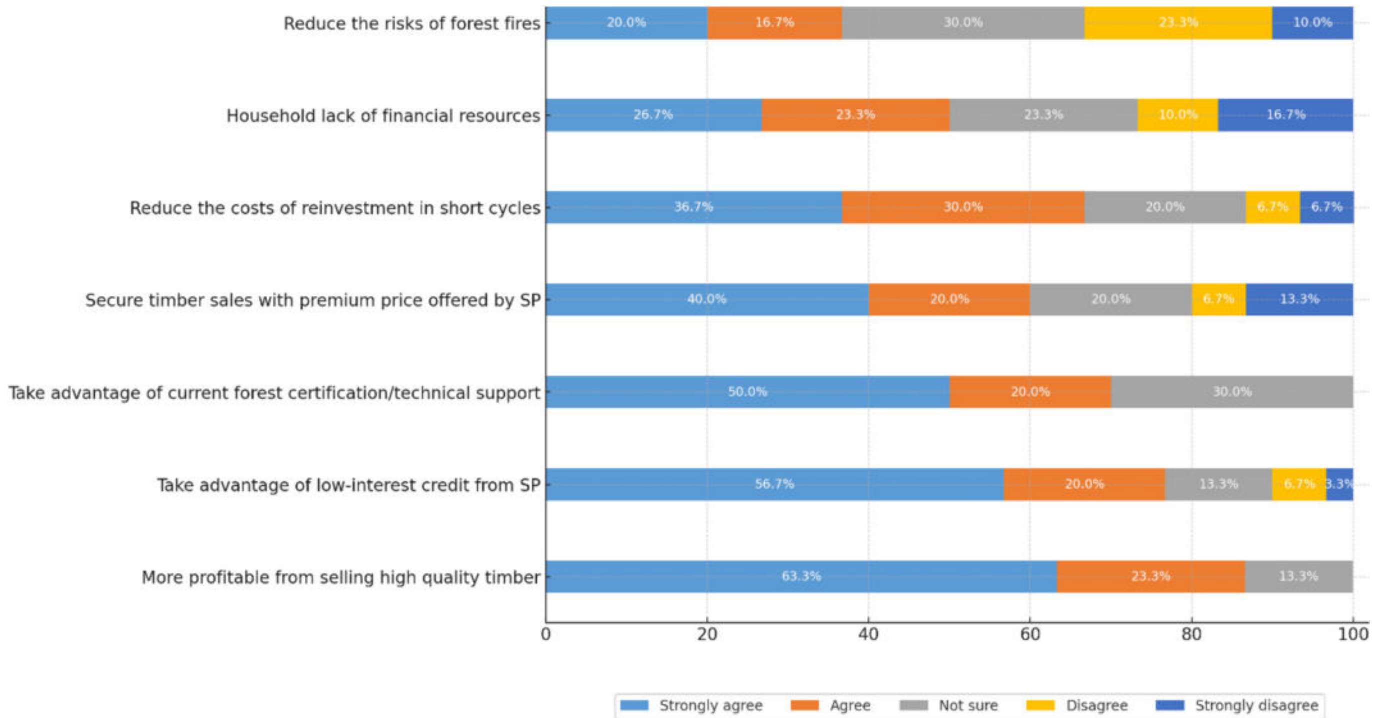

Fig. 3. Reasons for participating in acacia timber CF in Vietnam (*Source: surveyed results, 2022*).

Scansia Pacific Ltd. do not believe in easy access this funding.[15] This indicates that while the national policy may provide appealing support, its implementation on the ground has been slow and distorted.

4.2.2. Production costs of non-CF and CF model

Table 4 details the costs, benefit items, and parameters used in the analysis, while Fig. 4 illustrates the cost structure of the three plantation models. Model 1, with a higher seedling density of 3000 seedlings per hectare, has higher seedling costs but benefits from lower fertilizer costs compared to Models 2 and 3. Model 1 entails a 5-year planting period with trees harvested at smaller sizes compared to the other models, leading farmers to plant densely to maximize space utilization. Model 3, the certified model, requires seedlings from verified nurseries, resulting in higher unit prices and unique costs for fire prevention and certification services, thus imposing a financial burden to maintain certification standards.

Model 1 requires fewer labor days for site clearance and weeding compared to Model 3, which has higher labor input due to its intensive management requirements. In the 8-year models, thinning and pruning costs are included in the fourth year, unlike the 5-year model. Thinning and harvesting operations are more labor-intensive in the 8-year models, especially in the certified model (Fig. 3). Additionally, machinery costs for pruning and harvesting are higher in the 8-year models. Total labor days are presented without distinguishing between family and hired labor, although many households rely solely on family labor, either full-time or part-time, which provides greater benefits.

In terms of turnover, Model 1 growers harvest woodchips in the fifth year, while Models 2 and 3 involve pruning and woodchip harvesting in the fourth year and lumber production in the eighth year. Despite higher costs, Model 3 yields the highest sawn timber and lumber prices, illustrating the trade-off between higher initial investments and long-term financial benefits. These differences highlight the varying cost structures and economic outcomes of each plantation model, offering valuable insights for acacia plantation management decisions. Further details on the costs and benefits can be found in Tables A1, A2, and A3 in the Appendix.

Both cases involve 8-year timber plantations, but when companies purchase certified timber, they can buy logs with a 12 cm diameter. In contrast, local traders require non-certified logs to be at least 13–15 cm in diameter. This leads to a higher percentage of certified timber logs being purchased (60–65 %), while non-certified logs are often rejected, with only about 35–40 % being bought for woodchip processing. The remaining small-diameter wood is sold to woodchip companies at the same price as uncertified wood. Although Nguyen et al. (2018) reported that certified timber commands a premium price 10–18 % higher than non-certified logs, our survey found the premium to be only +7.4 %. Among the three models surveyed, Model 3 produces the highest added value.

4.2.3. Financial performance of three models

Tables A1, A2, and A3 in the Appendix provide detailed financial analysis using a 7 % discount rate. Tables 5 and 6 present comprehensive results, including sensitivity analyses for discount rates between 5 % and 9 % and woodchip price fluctuations of −10 % to +10 %. Among the models, Model 3 has the highest NPV, being 122 % higher than Model 2 and 309 % higher than Model 1, strongly supporting the findings of previous studies (Rode et al., 2014; Nguyen et al., 2018; Maraseni et al., 2017; Blackburn et al., 2020; Tham et al., 2021). The EAB analysis also shows Model 3 with the highest value and Model 1 with the lowest.

However, relative indicators like BCR and IRR differ slightly from absolute indicators like NPV and EAB. The BCR favors the 8-year models, particularly the non-certified one. The difference in NPV and BCR between Projects 2 and 3, despite both having 8-year cycles, stems from variations in cash flow and cost structures. Although Model 3 has a higher NPV, indicating greater absolute value creation, Model 2's higher BCR (2.56 vs. 2.47) suggests better cost-efficiency. The higher costs associated with certification in Model 3 lead to slightly lower investment efficiency compared to Model 2.

The 5-year woodchip model has the highest IRR at 46.40 % (at a 7 % discount rate), followed by the 8-year non-certified model at 43.19 %, and the 8-year certified model at 39.60 %. The higher IRR for the 5-year

[15] Personal interview with the Vice-General Manager of SP Ltd.

Table 4
Parameters for cost-benefit analysis of three acacia plantation models (1000 VND).

Cost items	Unit	Model 1	Model 2	Model 3
Materials				
- Density	seedling ha^{-1}	3000	2200	2000
- Price of seedlings	1000 VND seedling^{-1}	0.85	0.80	0.90
- Fertilizer	1000 VND ha^{-1}	2400	2800	3000
Services				
- Fire prevention	1000 VND ha^{-1}	Not applicable	Not applicable	800.00
- Annual certification fee[1]	USD ha^{-1}	Not applicable	Not applicable	27
Labor				
- Planting	1000 VND seedling^{-1}	1200	1000	1000
- Labor day for				
• Site clearance	day ha^{-1}	2	7	16
• Annual weeding cost	day ha^{-1}	1	1	3
• Thinning	day ha^{-1}		30	35
• Harvesting	day ha^{-1}	50	80	90
Machinery				
- Tools	1000 VND ha^{-1}	150	200	200
- Renting pruning machine	Day		5	5
- Renting harvesting machine	Day	7	10	12
- Harvesting track	1000 VND ha^{-1}	1600	2000	2000
Transportation				
- By-product[2]	1000 VND ton^{-1}		130	130
- Main product	1000 VND ton^{-1}	120	150	150
Turnover				
- Volume of by product	ton ha^{-1}		40	45
- Sawn timber	ton ha^{-1}		62	120
- Woodchip	ton ha^{-1}	105	115	84
- Price of by product	1000 VND ton^{-1}		800	800
- Price of lumber[3]	1000 VND ton^{-1}	1350	1350	1450
- Price of woodchip	1000 VND ton^{-1}	1050	1050	1050

Note: [1]: The average exchange rate in 2021 was 23.000 VND USD^{-1}; [2]: By products include either woodchip or firewood;
In contrast to Tham et al. (2020), we used a price calculation of 1000 VND ton^{-1} for all products, since ton is the only unit of measurement for timber volume when growers sell it, regardless timber is certified or not, as revealed by our survey.
Source: surveyed data 2022.

model is due to faster capital recovery, higher initial returns, and lower risk exposure. For the 8-year models, the IRR, like the BCR, is more favorable to Model 2, highlighting its efficiency despite Model 3's higher absolute value creation. These differences emphasize the need to evaluate multiple financial metrics for a comprehensive understanding of each project's performance. Poor households might prefer the 5-year woodchip model for quicker income, despite knowing that delaying harvest for 3 years with certification could quadruple their income (Minot and Sawyer, 2016). This preference aligns with findings by Arnold et al. (2020) and Nambiar (2021) that farmers may opt for early income to reduce risk.

The sensitivity analysis shows consistent patterns across the models with changes in discount rates and woodchip prices. As shown in Table 6, price volatility affects all models similarly, though a 10 % price decrease has a more significant adverse impact on Model 1's IRR compared to Model 2. This is because Model 1 relies solely on woodchips, while Models 2 and 3 benefit from diversified revenue streams from both woodchips and timber, highlighting the value of product diversification.

4.2.4. Value chain analysis and comparison

The purpose of the analysis of the three value chains under these three tree plantation models (Table 7) is to provide recommendations based on the benefit level of tree growers in each model and the corresponding value chains.

Model 3: The farmer must invest 1.7315 mil. VND (1) and make a profit of 1.821 mil. VND (2) to produce 1 m^3 of sawn timber. In order to saw out 1 m^3 of sawn timber, the sawmill had to purchase 2.45 tons of logs at a cost of 1.45 mil. VND per ton (1.45 mil. VND x 2.45 = [(1) + (2)]. This results in a cost to the sawmill of 1487.6 mil. VND (3) and a profit to the sawmill of 0.433 mil. VND (4). The price of this cost includes the cost of shipping lumber to the Scansia Pacific Ltd. warehouse in the south (Dong Nai province), where it will be sold for 5.473 mil. VND/m3 [(1) + (2) + (3) + (4)]. The transportation cost of sawn timber traveling a distance of 1096 km from Dong Ha City, Quang Tri province to Dong Nai would pose a significant challenge for local sawmills, as also found in the case of Ferreira et al. (2019). Before selling the entire products/m^3 of furniture to IKEA for 26.393 mil. VND, which is the equivalent of six sets of outdoor tables and chairs, Scansia Pacific Ltd. paid a total cost of 18.263 mil. VND (5) and earned a profit of 2.657 mil. VND (6). Tree growers benefited 6.9 % in the domestic value chain of certified timber coming out from the CF.[16] If a globally inclusive value chain was taken into account when a standard chair was sold on IKEA's website for 59.99 Euro to end users, CF tree growers received only 1.5 % of the whole value chain.

Model 2: The timber flow mechanism for the 8-year non-certified value chain is identical to that of the 8-year certified CF model. However, due to a higher recovery rate from log to m^2 of lumber (2.48), more logs are required compared to the 8-year certified CF model, which is different from applying the same recovery rate for chair production in Backburn et al. (2020). This is somewhat paradoxical as sawmills only purchased timber for semi-processing into lumber with a minimum diameter of 13 cm for the 8-year non-certified timber, whereas the minimum diameter for 8-year certified timber from CF was 12 cm. In this value chain, tree growers benefit 6.74 % of the non-certified acacia timber value chain. Also, for this chain, Scansia Pacific Ltd. bought plumbers at a price of 5.063 mil. VND/m^3 instead of 5.473 mil. VND/m^3 for certified plumbers from CF.

Model 1: In comparison to 8-year timber, 5-year woodchip timber has a shorter timber flow. A woodchip mill must purchase 2.2 tons of wood logs at the price of 2.31 mil. VND [(1) + (2)] to process 1 ton of dry wood chips that are export-ready. Additionally, the woodchip mill spends 0.408 mil. VND in costs (3) while making 0.22 mil. VND in profit per ton of dried woodchip (4). Woodchip processors sell the dried woodchips at a price of 2.938 mil. VND/ton [(1) + (2) + (3) + (4)] (125 USD/ton, 23,000 VND = 1 USD). Prior to that, tree farmers paid 1063 mil. VND (1) and received 1247 mil. VND for each ton of dried woodchip (2). However, tree growers in this value chain benefited from up to 42.44 % of the chain's overall value.[17]

Therefore, with the exception of tree growing for woodchip, it can be concluded that tree growers participating in the 8-year CF of certified timber and 8-year independent acacia plantation receive minimal benefits from the inclusive value chain. To increase the value of the forest growers, preliminary processing (sawing) should be carried out, and the

[16] If a globally inclusive value chain is considered when a standard chair is sold on IKEA's website for 55 USD, tree growers receive only 1.5 % of the whole value chain.

[17] In the assessment of financial performance, we consider the expenses incurred in hiring labour and obtaining forest certification. In practice, several households utilize family labour, and all households obtain financial assistance for forest certification. As a result, their actual benefit from the value chain is greater.

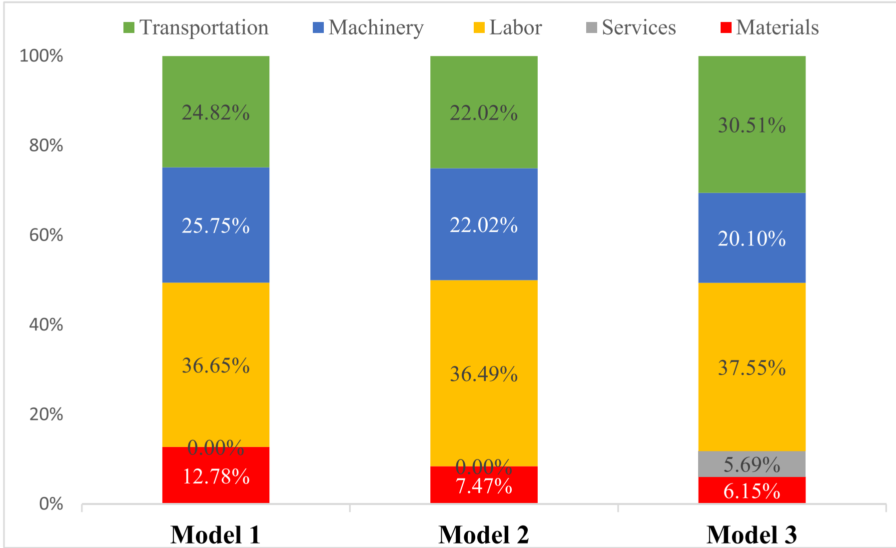

Fig. 4. Cost structure of three investment models (*Source: surveyed data 2022*)

Table 5
Financial analysis of three timber plantation models with different discount rate scenarios.

	5 %			*7 %*			*9 %*		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
NPV	60,764.31	151,319.84	186,061.68	59,498.91	150,313.92	183,980.83	58,166.55	149,111.46	181,608.15
EAB	14,819.85	25,341.20	31,159.33	14,511.23	25,172.74	30,810.86	14,186.28	24,971.36	30,413.51
BCR	2.23	2.64	2.55	2.17	2.56	2.47	2.12	2.48	2.38
IRR	49.18 %	45.91 %	42.25 %	46.40 %	43.19 %	39.60 %	43.71 %	40.56 %	37.03 %

Source: surveyed data 2022.

lumber should be sold directly to processors (bypassing the sale of logs to intermediate traders). Furthermore, if domestic enterprises continue to perform additional stages of the value chain to gain access to the market, such as establishing overseas showrooms or selling products on e-commerce platforms, there is even greater potential for value creation for the enterprises.

The final buyers are those who decide the price change on the market. If the FOB price goes down, local processors would push the price down to the traders and then to tree growers. The formation of the Association of Quang Tri Smallholder Forest Certification Groups, whose farmers participate in CF under this association, contributes to the improved functioning of the timber market (Arvola et al., 2020). This association also aids farmers in negotiating better prices for their timber.

Based on the financial and inclusive value chain analysis, the 8-year certified timber model demonstrates the highest economic feasibility for households, despite the certification cost being three times higher than the suggested cost-effective alternative and minimal direct value chain benefits. While CF tree growers currently derive minimal benefits from the value chain, this aspect holds little significance when the primary objective remains the profitability of afforestation. The disparity in net present value (NPV) and benefit levels along the respective value chains is negligible between the implementation of certified or uncertified approaches for the large timber plantation model (8 years). Although independent tree growers of the 5-year cheap woodchip model reap the greatest advantages from its inclusive value chain, its NPV performance is unsatisfactory. From the management standpoint, investment policies and guidelines should concentrate on directing individuals to invest in 8-year large timber forests (preferably with FSC certification CF), rather than pursuing the 5-year woodchip model, which has proven to be highly successful.

The CF timber production and tree planting in general also shows significant social and environmental impacts but there is limited understanding of these effects on local socioeconomic development (Rode et al., 2014; Miller et al., 2021; Oldekop et al., 2021). The CF model promotes a value chain in which each party can capitalize on their strengths, resolve or mitigate weaknesses, increase competitiveness, and invest more effectively, resulting in stable and sustainable business relationships and more sustainable economic development for society as a whole (Nguyen et al., 2018; de Moraes Gonçalves et al., 2020). In terms of carbon sequestration, the average rate for acacia sp. is reported to be 7–10 tons/ha/yr^{-1}, which is equivalent to 26–36 CO_2/ha/ yr^{-1} (Vu and Nguyen, 2008) for acacia sp. aged 2–6 years. Therefore, extending the harvest period from 5 years to 8 years, while practicing sustainable forestry with FSC certification, would make a significant contribution

Table 6
Price change scenario for woodchips in comparison to the price in 2021.

	−10 %			*0 %*			*10 %*		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
NPV	48,473.91	138,238.92	175,160.83	59,498.91	150,313.92	183,980.83	70,523.91	162,388.92	192,800.83
EAB	11,822.33	23,150.56	29,333.79	14,511.23	25,172.74	30,810.86	17,200.12	27,194.91	32,287.92
BCR	1.96	2.44	2.40	2.17	2.56	2.47	2.39	2.69	2.54
IRR	40.64 %	41.77 %	38.75 %	46.40 %	43.19 %	39.60 %	51.57 %	44.51 %	40.41 %

Source: surveyed data 2022.

Table 7
Value chain analysis and comparison of the three models (1000 VND).

	Tree Grower			Added value by sawmill/woodchip mills		Added value by wood processors		Total product value
	Cost	Added Value	Recover rate`	Cost	Added Value	Cost	Added Value	
	(1)	(2)		(3)	(4)	(5)	(6)	(7)
Model 3	1731.5 **(6.6 %)**	1821.0 **(6.9 %)**	2.45	1487.6 **(5.6 %)**	432.9 **(1.6 %)**	18,262.7 **(69.2 %)**	2656.8 **(10.1 %)**	26,392.5 **100 %**
Model 2	1619.9 **(6.7 %)**	1728.1 **(7.02 %)**	2.48	1269.0 **(5.3 %)**	445.5 **(1.9 %)**	15,661.3 **(61.1 %)**	4163.1 **(16.3 %)**	23,988.8 **100 %**
Model 1	1063.4 **(36.2 %)**	1246.6 **(42.4 %)**	2.2	407.9 **(13.9 %)**	219.6 **(7.5 %)**			**100.00 %**

towards achieving zero net carbon emissions by 2050, a commitment made by the Vietnamese government under COP26. The CF also requires compliance with environmental standards like IKEA's Way of Purchasing Products, Materials, and Services (IWAY) and FSC's Forest Management/Chain of Custody (FM/CoC) regulations, which conserve the forest, water, and biodiversity, as well as other environmental and social compliances in the timber processing phase.

However, based on the econometric analysis conducted across 11 provinces in Vietnam, as well as the financial and value chain analysis, it is regrettable to observe that poor households are still practicing short and inefficient timber production. Therefore, we strongly urge the government to implement relevant policies that can facilitate the shift from less profitable timber production for woodchips to longer high value timber production with certification under CF. The main challenge in promoting the widespread adoption of region-specific best practices for forestry lies in ensuring active participation and tailored solutions for forest owners with limited resources, aiming to increase productivity and wood value on a larger scale (Nambiar, 2021; Shyamsundar et al., 2022).

5. Conclusions and policy implications

The objective of this study was to analyze the determinants of household participation in acacia tree CF in Vietnam and compare the financial performance of CF with non-CF at different cycles and respective value chains. Our findings indicate that various factors such as farm size, ethnicity, distances, family size, dependent ratio, land tenure perception, collateral ability, interest rate, output value, and agricultural extension influence smallholder tree growers' participation in CF. Poor or vulnerable households are likely to engage in CF. However, this low significance may be misleading, as domestic companies might contract entire localities, including poorer households, to create continuous areas for forest certification.

Of the three models analyzed, the 8-year CF-certified timber model exhibited the highest net present value (NPV), which was 122.4 % higher than the 8-year non-certified timber model and 309.2 % higher than the 5-year woodchip model. Additionally, the 8-year CF-certified timber model had an EAB value that was 212.3 % higher than the 5-year woodchip model. While all three models were economically feasible as their benefit-cost ratios (BCRs) were greater than 1, the 8-year non-certified timber model had the highest BCR at all discount rates. In terms of internal rate of return (IRR), the 5-year woodchip model had the highest IRR at all discount rates in the analysis, followed by the 8-year non-certified timber model and the 8-year CF-certified timber model.

Thus, by participating in an 8-year CF to produce certified timber within the IKEA collaboration scheme, tree growers have the potential to increase their income compared to pursuing their 8-year independent household timber production, and almost double their annual income if they opt for 5-year woodchip production. Furthermore, by delaying harvest for 3 years more with forest certification within the IKEA scheme, tree growers not only have a double annual income, but also secure a raw material supply for wood processors and distributors and create significant social and environmental value for society.

Based on these study results, we recommend greater involvement of global and national wood processors and distributors to scale up long-term and CF with tree growers, and to involve tree growers in the inclusive value chain. To achieve this, policies that support impoverished families with financial assistance to cover their immediate livelihood needs are crucial. Additionally, a global initiative that puts the concept of inclusive global value chains via CF for tree planting on the agenda of sustainable and inclusive development is essential. However, to respond to these opportunities, it is necessary to invest significantly in enhancing productive capacities, business skills, and infrastructure and to have national and institutional intervention and innovation.

To better understand the complex dynamics and outcomes of tree contract farming schemes and their inclusive value chains, future research should explore the diverse roles, effects, and impacts of various stakeholders, including government authorities at different administrative levels, to identify areas for improvement. Additionally, with the current amount of 612 million tons of carbon sequestered nationally,[18] future studies could explore the potential environmental and social benefits that could accrue from long-term CF practices. Such research may employ a variety of spatial and temporal perspectives to uncover the contextual factors that shape the outcomes of CF initiatives and the distribution of benefits among participants and wider society.

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Hoang Huu Dinh: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft. **Loan Thanh Le:** Data curation, Formal analysis, Investigation, Methodology. **Justus Wesseler:** Conceptualization, Investigation, Methodology, Supervision, Validation, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence

[18] Available online at: https://www.cifor-icraf.org/publications/pdf_files/OccPapers/OP-237.pdf (accessed August 10th, 2024)

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Appendix A. Appendix

Table A1
Cost-benefit analysis of the 5-year woodchip model Unit: 1000 VND ha^{-1}

Year	2017	2018	2019	2020	2021
	1	**2**	**3**	**4**	**5**
Cash out-flow	**10,940**	**2030**	**2030**	**–**	**31,600**
Material cost					
Seedling	2550	–	–	–	–
Fertilizer	2400	–	–	–	–
Labor cost					
Site clearance	420	–	–	–	–
Planting	3600	–	–	–	–
Weeding	1600	1800	1800	–	–
Pruning and thinning	220	230	230	–	–
Harvesting					12,500
Machinery					
Tools	150				
Harversting track					1600
Rent for harvesting machines					4900
Transporting					12,600
Cash in-flow	**–**	**–**	**–**	**–**	**110,250**
Woodchip	–	–	–	–	110,250
Net cash flow	(10,940)	(2030)	(2030)	–	78,650
Discounted net cash flow	(14,340.11)	(2486.84)	(2324.15)	–	78,650
NPV (1000 VND)					59,499
IRR (%)					46.40
EAB (1000 VND)					14,511
BCR (times)					2.17

Table A2
Cost-benefit analysis of the 8-year non-certified model *Unit: 1000 VND ha^{-1}*

Year	2014	2015	2016	2017	2018	2019	2020	2021
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Cash out-flow	**10,140**	**1710**	**1820**	**16,120**	**–**	**–**	**–**	**53,550**
Material cost								
Seedling	1760	–	–	–	–	–	–	–
Fertilizer	2800	–	–	–	–	–	–	–
Labor cost								
Site clearance	1470	–	–	–	–	–	–	–
Planting	2200	–	–	–	–	–	–	–
Weeding	1500	1500	1600	1600	–	–	–	–
Thinning	210	210	220	220	–	–	–	–
Pruning				6600				
Harvesting								20,000
Machinery								
Tools	200							
Pruning				2500				
Rent for harvesting machines								7000
Transporting								
By-product				5200				

(*continued on next page*)

Table A2 (*continued*)

Year	2014	2015	2016	2017	2018	2019	2020	2021
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Harvesting track								2000
Main product								26,550
Cash in-flow	**–**	**–**	**–**	**32,000**	**–**	**–**	**–**	**204,450**
Woodchip	–	–	–	32,000	–	–	–	120,750
Timber								83,700
Net cash flow	(10,140)	(1710)	(1820)	15,880	–	–	–	150,900
Discounted net cash flow	(16,283)	(2566)	(2553)	20,815	–	–	–	150,900
NPV (1000 VND)								150,314
IRR (%)								43.19
EAB (1000 VND)								25,173
BCR (times)								2.56

Note: Labor costs for thinning and weeding have incurred in 7 years for certified model and 4 years for non-certified one.

Table A3
Cost-benefit analysis of the 8-year certified CF model *Unit: 1000 VND ha*$^{-1}$

Year	2014	2015	2016	2017	2018	2019	2020	2021
	1	2	3	4	5	6	7	8
Cash Out-flow	**12,930**	**2130**	**4135**	**18,310**	**3740**	**690**	**2595**	**63,500**
Material cost								
Seedling	1800	–	–	–	–	–	–	–
Fertilizer	3000	–	–	–	–	–	–	–
Service cost								
Fire prevention	600	–	–	–	–	–	–	–
Certification	–		1875		1250		1875	
Labor cost								
Site clearance	3200	–	–	–	–	–	–	–
Planting	2000	–	–	–	–	–	–	–
Weeding	1500	1500	1600	1600	1800	–	–	–
Thinning	630	630	660	660	690	690	720	–
Pruning				7700				
Harvesting								22,500
Machinery								
Tools	200							
Pruning				2500				
Rent for harvesting machines								8400
Transporting								
By-product				5850				
Harvesting track								2000
Main product								30,600
Cash in-flow	**–**	**–**	**–**	**36,000**	**–**	**–**	**–**	**262,200**
Woodchip	–	–	–	36,000	–	–	–	88,200
Timber	–	–	–	–	–	–	–	174,000
Net cash flow	(12,930)	(2130)	(4135)	17,690	(3740)	(690)	(2595)	198,700
Discounted net cash flow	(20,763)	(3197)	(5800)	23,188	(4582)	(790)	(2777	198,700
NPV (1000 VND)								183,981
IRR (%)								39.60
EAB (1000 VND)								30,811
BCR (times)								2.47

Note: Labor cost for weeding has incurred in 7 years for certified model and 4 years for non-certified one.

Table A4
Attrition rates of plots over the surveyed period.

Year	2008	2010	2012	2014	2016	2018	Total
Number of households	2278	3202	3704	3648	2669	3807	19,308
Total number plots	11,053	10,467	10,256	9350	8930	8456	58,512
Number of timber plots	313	308	210	178	149	204	362
Analytical	244	259	203	162	138	266	1272

Data availability

Data will be made available on request.

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