Working Paper

# Beyond carbon sequestration – local knowledge about tree functions. Case study from male and female Arabica coffee farmers in Vietnam

*Elisabeth Simelton, Rachmat Mulia, Clement Rigal, Duong Minh Tuan, Nguyen Mai Phuong, Hanna North, Le Hieu Xuan*

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**Abstract**

Estimates of carbon sequestration for timber trees is well documented, while fruit trees are understudied. The few existing estimates indicate that fruit trees and fertiliser management on them, can substantially sequester carbon in coffee monocultures, albeit unlikely to the same extent as timber trees. A carbon investor may thus favour timber. In this light, as programs for planting billions and trillion trees are launched “to save the climate”, a wide range of gender, social, justice and environmental concerns are voiced.

To challenge the mitigation perspective, we contrasted two hypothetical tree planting strategies: a mitigation (carbon finance) perspective and a livelihoods-centred (local) perspective and explored what a rapid, gender and social inclusion-oriented livelihoods perspective could bring to the process of tree selection. The survey documents indigenous knowledge of trees’ potential (dis)benefits in coffee agroforestry systems among 106 female and male arabica-growers in northwest Vietnam.

The results display many similarities between women and men in term of perceived benefits from trees. Women and men prioritized trees based on their economic benefits, impacts on coffee production and improved soil fertility. However, in determining the preferred species, women considered more factors, including consequences for pest and disease (on host tree or coffee), microclimate regulation and shade provision. These findings resemble those by others from the same region and demonstrate that consulting both women and men can result in a more diverse shortlist of potential trees for agroforestry/afforestation that reflect both genders’ economic and labour contributions to the household. Furthermore, tree planting projects would benefit from seeking collaboration for bundled ecosystem services, rather than merely from carbon finance. Conversely, carbon investors can rely on farmers’ preferences and rest assured that they also contribute to sequestering carbon.

**Keywords**

agroforestry, mitigation, local knowledge, coffee, multipurpose trees, co-benefits, gender

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## 1. Introduction

In the last decade, numerous campaigns have been launched to plant billions of trees to contribute to the remaining budget of 400-500 billion tonnes of CO2-equivalents (CO2e), required to limit the Earth's warming to 1.5°C above pre-industrial levels (e.g., UNEP, 2008; https://www.nature.org/en-us/; https://www.trilliontreecampaign.org/). This has been followed by a surge in research questioning whether such large-scale tree planting can take into consideration social inclusion and biodiversity (Warren-Thomas *et al*., 2018; Heilmayr *et al*., 2020; Martin *et al*., 2021), and whether carbon mitigation foci override governments' ambitions to achieve the Sustainable Development Goals, such as poverty reduction and food security (Gaworecki, 2021; Soergel *et al*., 2021).

For complex value-chains with many dissected steps between producer and consumer, life cycle analyses risk being simplified to carbon footprints, leading to recommendations to plant timber trees (Andrade *et al*., 2014), even though management in the production stage can reduce pressure on ecosystems (Giraldi-Díaz *et al*., 2018; Nab and Maslin, 2020). Meanwhile, research suggests that reforestation efforts may look very different if women have more voice in agricultural and environmental decision making (FAO, 2011; Fortnam *et al*., 2019) and in food systems value-chains (Lentz, 2021). Women and men have different (i) preferences for tree species selection (Sari *et al*., 2020), (ii) power over decisions (Akter *et al*., 2017; Simelton *et al*., 2021), (iii) investment priorities, and (iv) they are involved in different tasks than men; for example, women tend to be managers of various household tasks that relate to energy use and associated emissions (UNDP, 2016; Doss *et al*., 2018). Tree planting may also be implemented differently if project designers consider women's preference to adapt to environmental change in groups (Perez *et al*., 2015) and through collective action (Rao *et al*., 2019b; van Noordwijk, 2019).

The Koronivia Joint Work on Agriculture addresses the agriculture sector's roles in adapting to and mitigating climate change within the UNFCCC and considers Indigenous People's livelihoods and knowledge to be an integrated part of ecosystems (FAO, 2021). However, gender and social integration in climate policy has been slow globally, including the Nationally Determined Contributions (Huyer *et al*., 2020). In the 2016 NDCs, 64 out of 190 countries, all non-Annex I countries, refer to women or gender. However, only 12 countries mentioned gender in the context of mitigation (compared to 27 for adaptation), highlighting a gap between the prime investors in mitigation (Annex I countries) and non-Annex I countries, whose commitments are largely conditional (Siegele, 2020).

As the world's second largest coffee producer in 2020, Vietnam needs to evaluate mitigation and resilience co-benefits for coffee cultivation systems. Among 18 revised NDCs in 2020, Vietnam was among the 11 NDCs emphasizing that all proposed measures need to promote gender equality. Furthermore, agroforestry was introduced as a strategy for land conservation and carbon sequestration (The Socialist Republic of Viet Nam, 2020). The preceding technical assessment indicated that in ten years (2021-2030), Arabica and Robusta coffee agroforestry could sequester 16±2.1 and 45±4.5 million $tCO_2e$ (a total of aboveground, below ground and soil carbon) for 275,000 and 638,000 ha of land, respectively (Mulia *et al*., 2020). The same study also reported that existing Arabica and Robusta agroforestry together covers 256,000 ha, storing about 143 million $tCO_2e$. The sequestered carbon in coffee agroforestry was found to be up to 3-4 times higher than that in coffee monoculture.

In 2020, Vietnam's prime minister declared the country would plant one billion trees by 2025 (https://www.nature.org.vn/en/2021/05/drastic-forest-development-vietnam-to-plant-1-billion-trees-but-how/). Agroforestry, not limited to coffee, could be a contending method to such initiatives, with the potential to expand to an area up to 2.4 million ha across Vietnam (Mulia *et al*., 2020)--an attractive technique for sustainability or carbon certification schemes (Nab and Maslin, 2020). While Vietnam steps up its agricultural mechanization to compete on global markets, studies draw attention to potential exacerbated gender and social inequalities (Ylipaa *et al*., 2019; Mulia *et al*., 2021), including in coffee value-chains (SCA, 2018) alongside the low utilization of tree diversity found in reforestation programmes (McElwee and Tran, 2021).

To challenge the monoculture-dominated mitigation perspective, we contrasted two hypothetical tree planting strategies, a mitigation (carbon finance) perspective and a livelihoods-centered (local) perspective, and explored what a rapid gender and social inclusion-oriented livelihoods perspective could bring to the process of tree selection. This work illustrates the potential of rapid participatory tools that can facilitate gender-inclusive perspectives in local consultations prior to tree-planting projects. Here, the tool is designed to document and compare women's and men's preferences for trees in coffee-based agroforestry systems, based on the perceived benefits. Implications are discussed from the point of mitigation, and resilience benefits are discussed.

## 2. Methods

The study was conducted with coffee-farmers in northwest Vietnam in 2019 and 2020. The communities belong to the Thai ethnic minority and have been cultivating coffee for decades, as monoculture and in agroforestry systems with fruit or timber trees (for a site description, see Simelton *et al*., 2021). We conducted semi-structured interviews with 106 Arabica growers in Son La (30 women, 30 men) and Dien Bien (23 women, 23 men) provinces, selected randomly from the village leaders' residential ledger. Each respondent first selected nine preferred tree species from a longlist of 23 (12 fruit, 7 timber, and 4 other trees) that had been identified previously (Nguyen *et al*., 2020a), then ranked each species plus Arabica coffee according to each of the 13 benefits, and reported open-ended comments to the enumerator. The benefits represented 'overall preference', as well as economic and ecological characteristics (Table 1). The scores were recalculated using percentile rank from 0 (lower) to 1 (higher) indicating higher preference due to the associated benefit (Roscoe, 1975). To inform what benefits farmers considered when selecting trees, we conducted a multivariate analysis of the percentile ranks (using JASP software) with 'overall preference' as the dependent variable and the other 12 benefits as independent variables for women and men separately. Only species selected by at least 10 farmers were included in the analyses, in total 18 out of 24.

In terms of caveats, it was beyond project resources to measure the carbon potential of the respondents' fields. In contrast to timber species, the literature on carbon sequestration and allometric equations for fruit trees is sparse (Scandellari *et al*., 2016; Sharma *et al*., 2021). Reference is made to field measurements and estimates by Mulia *et al*. (2020) and Nguyen *et al*. (2020b). The latter used the Rapid Carbon Stock Appraisal (RaCSA) approach (Hairiah *et al*., 2011) on nine selected coffee-agroforestry systems in the same provinces as this study, and reported that they could store 20-306 tCO2-eq/ha (Nguyen *et al*., 2020b, Table 2).

Although excluded from the analysis, all species and their respective biomass scores are retained in Figure 1 for demonstration. Ranking of tree biomass was discarded from the analysis and instead carried out separately in 8 focus groups (4 groups each of women and men) to ensure respondents' understanding of the meaning. This experience alerted the team to concerns over possible risks for biased tree selection, if based solely on carbon sequestration potential, which will be subject to further research.

## 3. Results and Discussion

Figure 1 maps women's and men's average scores of 13 benefits from trees in coffee agroforestry systems. Overall, women and men scored similarly on tree functions. For example, reading the map horizontally, both genders agreed on all indicators for *Psidum guajava* (low average scores). Top scores were given to *Leucaena leucocephala* on most indicators, while monoculture arabica received bottom scores (except for economic benefits) followed by *Carica papaya*. Reading vertically, the benefits most agreed on were the tree's ability to function as a wind break, fertilizer input requirements, and the provision of mulch through litterfall. In contrast to Duong *et al*. (2016) and Sari *et al*. (2020) we found no general gendered preferences towards fruit or timber trees. A few exceptions were that more men selected *Pinus latteri* (15 men: 2 women) and more women opted for *Prunus mume* (12 men: 20 women). In Dien Bien, only men selected *Pinus latteri* and *Canarium nigrum*. In Son La only men selected *Senna alata* while only women selected *Leucaena leucocephala* and *Macadamia spp*.

The multivariate analysis (Table 1) shows that both women's and men's preferences for trees correlated to a tree's economic contributions (to coffee production and additional income) and soil quality. Farmers observed the soil's health status (notably texture, moisture, erosivity, fertility) and also remarked on tree morphology and (un)desirable tree-coffee interactions, such as competition for soil nutrients and moisture. Here, the leguminous species *L. leucocephala* scored high among both gender groups, while monoculture coffee and high-yielding fruit trees scored low for demanding external fertiliser (Figure 1).

In addition to the economic and soil factors, women's tree preferences correlated with a tree's contributions to pest and disease mitigation, microclimate regulation and shade provision. Surprisingly, the ability to regulate microclimate did not correlate with the overall preference. This contrasts with farmers in northwest Vietnam, who weighed in trees' roles for microclimate regulation, as frost and drought can destroy entire coffee trees [1](Rigal *et al.*, 2020). Improved microclimate is also a key adaptation strategy to maintain Arabica production in the coming decades (Gomes *et al.*, 2020).

[1] https://www.breedcafs.eu/agroforestry-a-protection-against-winter-frosts

**Figure 1.** Individual ranking of coffee monoculture and 18 tree species in coffee agroforestry systems among male (M) and female (F) farmers in northwest Vietnam. Gendered average scores are colour coded in four levels from high to low: green= 0.75-1; light yellow 0.51-75, orange 0.26-0.50, red 0-0.25, where * denotes no significant difference between gender groups. Removed from the analysis but displayed for additional information are the bottom five species and carbon sequestration as biomass. The biomass scoring was conducted separately in groups of women and men and involved fewer trees (grey indicates trees were not selected).

| Tree (when intercropped with coffee) | | | Overall preference | | Coffee production | | Soil quality | | Soil erosion | | Mulch provision | | Micro-climate regulation | | Wind control | | Frost control | | Shade provision | | Pest and disease | | Labour requirements | | Economic benefits | | Use of fertilizer | | Carbon | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *contributes to* | | *the tree-crop system* | | *coffee pro-duction* | | *improve soil fertility* | | *reduce topsoil erosion* | | *litterfall (soil carbon)* | | *reduce subcanopy temperature* | | *wind break* | | *reduce chill damage on coffee* | | *shade coffee* | | *prevent out-breaks* | | *reduce labour demand* | | | | *reduce fertilizer input* | | *biomass* | |
| | *Common name* | *n* | *M* | *F* | *M* | *F* | *M* | *F* | *M* | *F* | *M* | *F* | *M* | *F* | *M* | *F* | *M* | *F* | *M* | *F* | *M* | *F* | *M* | *F* | *M* | *F* | *M* | *F* | *M* | *F* |
| *Coffea arabica (monoculture)* | coffee | 106 | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | | | * | * | * | * | * | * | | |
| *Carica papaya* | papaya | 63 | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | | | * | * | | | | |
| *Musa acuminata* | banana | 90 | * | * | | | * | * | | | * | * | * | * | * | * | * | * | * | * | | | * | * | * | * | * | * | | |
| *Citrus sinensis* | orange | 20 | * | * | * | * | | | | | * | * | * | * | * | * | * | * | | | * | * | | | * | * | * | * | | |
| *Citrus grandis* | pomelo | 58 | * | * | * | * | * | * | | | * | * | | | * | * | | | * | * | * | * | * | * | * | * | * | * | | |
| *Citrus* | manda | 18 | | | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | | |

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| *reticulata* | rin | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Prunus mume* | apricot | 32 | * | * | * | * | * | * | * | * | * | * | * | * | * | * | | | * | * | * | * | | | * | * | * | * | | |
| *Prunus persica* | peach | 56 | | | * | * | | | | | * | * | | | * | * | * | * | * | * | | | * | * | * | * | * | * | | |
| *Psidium guajava* | guava | 67 | * | * | * | * | * | * | * | * | | | * | * | * | * | * | * | * | * | | | * | * | * | * | * | * | | |
| *Pyrus granulosa* | pear | 20 | * | * | | | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | | | * | * | * | * | | |
| *Macadamia spp.* | macadamia | 25 | * | * | * | * | * | * | | | * | * | * | * | * | * | | | | | * | * | * | * | | | * | * | | |
| *Prunus salicina* | plum | 65 | | | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | | |
| *Vernicia montana* | Mu oil tree | 25 | * | * | * | * | * | * | * | * | * | * | | | * | * | * | * | * | * | * | * | * | * | * | * | * | * | | |
| *Melia azedarach* | chinaberry | 62 | * | * | * | * | * | * | * | * | * | * | | | * | * | * | * | * | * | * | * | * | * | * | * | * | * | | |
| *Canarium nigrum engler* | Chinese black olive | 24 | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | | | * | * | * | * | * | * | | |
| *Artocarpus heterophyllus* | jackfruit | 67 | | | | | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | | |
| *Dimocarpus longan* | longan | 80 | * | * | | | * | * | * | * | * | * | | | * | * | | | * | * | * | * | * | * | * | * | * | * | | |
| *Pinus latteri* | Tenasserim pine | 16 | * | * | * | * | * | * | | | | | | | * | * | | | | | * | * | | | * | * | | | | |
| *Leucaena leucocephala* | tamarind | 43 | | | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | | | * | * | | |
| *Michelia tonkinensis* | magnolia | 11 | | | * | * | | | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | | | | | | |
| *Senna alata* | candle bush | 5 | * | * | * | * | | | * | * | * | * | | | | | * | * | * | * | | | * | * | * | * | * | * | | |

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| *Fructus gleditschiae (Gleditsia)* | honey locust | 6 | | | | | | | * | * | | | | | * | * | * | * | * | * | | | | | | | * | * | | |
| *Chukrasia tabularis* | Indian mahogany | 8 | * | * | * | * | | | * | * | * | * | | | * | * | | | | | * | * | | | * | * | * | * | | |
| *Eucalyptus spp.* | eucalyptus | 8 | * | * | * | * | | | * | * | * | * | * | * | | | * | * | * | * | * | * | * | * | * | * | * | * | | |

**Table 1.** Multivariate regression with overall preference of tree benefits in coffee agroforestry systems in northwest Vietnam (df=17 species, excluding Arabica coffee, n= 106). Descriptors in brackets: sex (M/F), age, respondent's code.

| Variable. Tree's contributions to 'Overall preference' | Women (n=53) | | Men (n=53) | | Interpretation | Selected farmer quotes for scores | |
|---|---|---|---|---|---|---|---|
| | coefficient | P-value | coefficient | P-value | | Benefit | Disbenefit |
| Improves soil quality (moisture and/or fertility) | 0.174 | < 0.001 | 0.193 | < 0.001 | Both women and men prefer tree species that can improve soil quality | "Jackfruit, peach, plum, grapefruit, and longan make the soil humid and can be intercropped with coffee." (M, 45, AC23)<br><br>"Plum roots make the soil porous" (F, 28, MC22) | "Monoculture makes the soil erode and drift away" (F, 36, MC9)<br><br>"Coffee dries the soil when there is no shade" (M, 40, MC17; F 32, CC11)<br><br>"I don't like banana and guava because they consume a lot of nutrients |

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| | | | | | | | and degrade the soil" (F, 32, CC11) |
| Provides additional economic benefits | 0.561 | < 0.001 | 0.550 | < 0.001 | Both women and men prefer tree species that can provide higher additional economic benefits | "I prefer to intercrop because it has more economic benefits" (M, 37, CC17)<br><br>"The more trees I add the more economic benefits. Plums require little management and give a lot of fruit" (F, 27, CC25)<br><br>"Plum gives the highest income, can sell pine resin and wood" (M, 40, MC17)<br><br>"Plum sells at 18,000-25,000 VND/kg, peach at 15,000 VND/kg, longan at 10,000 VND/kg. The price increases by 1,000-2,000 VND/kg/year." (F, 33, CC29)<br><br>"Longan sells at 17,000-18,000VND/kg, peach at 10,000VND/kg" (F, 31, CC14)<br><br>"Prefer macadamia to coffee because it sells at higher price and is less expensive to manage" (M, 30, AN12) | "Coffee takes a long time, and only one harvest at the end of the year" (M, 34, AN2)<br><br>"I do not like to grow apricots because there is no economic benefit, no markets (F, 45, AC9) Bananas, papayas are used for animals and the household, not sold." (F, 33, CC29)<br><br>"Guava and jackfruit are not sold, only for household consumption"(M, 48, MC23)<br><br>"Pomelo and jackfruit give negligible income, most for the household." (F, 37, CC3) |

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| Improves coffee production | 0.128 | 0.001 | 0.147 | <0.001 | Both women and men prefer tree species that can improve coffee production | "Plum and pear do not affect the coffee yield" (M, 37, CC17)<br><br>"Tamarind keeps the soil moist and give shades, so coffee plants develop well and give high, good yield" (F, 28, AC16)<br><br>"Jackfruit and tamarind shade and keep the coffee moist, which gives high yield" (M, 33, AN15) | "Coffee productivity decreases when there is competition for nutrients. Bananas make coffee grow poorly and give bad cherries" (M, 37, CC17)<br><br>"Guava, peach, papaya, pomelo, banana require nutrients for their fruits, so that coffee yields decrease. Monoculture coffee gives small, tiny cherries" (M, 33, AN15)<br><br>"Eucalyptus and tamarind reduce coffee yields because the trees are tall and with many roots that compete for nutrients" (F, 28, MC22) |
| Prevents pests and disease | 0.118 | 0.002 | -0.039 | 0.318 | Women prefer tree species that can prevent or do not generate pests and disease | "Banana and papaya do not have pest." (M, 22, MC6)<br><br>"Banana, papaya, pine have almost no pests that affect coffee" (F, 24, CC22) | "Monoculture has more pests, needs more spraying than when planted with other crops" (M, 22, MC6)<br><br>"Longan often has aphids that spread to coffee. Tall trees are difficult to spray. Pests from guava, plum, peach and apricot spread |

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| | | | | | | | to coffee" (F, 33, CC29) |
| Provides shade | -0.116 | 0.008 | -0.050 | 0.411 | Women prefer tree species that give moderate shade to coffee | "Pine gives the best shade because it is big and tall" (M, 30, MC19)<br><br>"Jackfruit is large and has a wide canopy that can shade coffee" (M, 31, CC28)<br><br>"Too much shade is not good for coffee, so after the coffee harvest, the tamarind is pruned to improve the air circulation moderate and even sunlight for the coffee" (F, 24, AN18) | "Apricot, plum and peach are usually grafted, so trees are low and do not give much shade" (M, 31, CC28)<br><br>"Plum, peach, apricot do not cover much because the leaves are small and sparse. Guava ranks last because the plant is short and straight with few leaves" (F, 36, MC9) |
| Regulates microclimate (subcanopy temperature, fresh air) | 0.114 | 0.046 | 0.082 | 0.112 | Women prefer tree species that can regulate microclimates | "Longan has many leaves that makes the air cool and fresh" (F, 21, CC7)<br><br>"Banana and longan can withstand extreme weather events. If many are planted the surrounding air is cooler" (F, 31, CC14)<br><br>"Tall trees make the coolest climate. Trees with more and larger leaves condition the air better" (F, 41, MC18) | "Monoculture makes the microclimate drier and more unpleasant" (F, 36, MC9) |

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| Reduces labour requirement | -0.116 | 0.012 | -0.058 | 0.214 | Women accept labour-intensive tree species, such as fruit trees, if they generate substantial economic benefits | “Intercropped trees have less weed and require less labour” (F, 32, CC11) | “Intercropping requires more time to prune. Pomelo, jackfruit, pine, plum require a lot of labour input to prune and spraying” (M, 37, CC17) |
| Reduces fertiliser requirements | -0.062 | 0.206 | -0.064 | 0.213 | Not an important factor; both women and men prefer tree species that can maintain or improve soil fertility | “Banana, pine, papaya and chinaberry grow without fertiliser” (M, 37, CC17)<br><br>“Apricot, papaya, banana do not need fertiliser, remaining fruit trees will not give fruit without fertiliser” (F, 31, CC14) | “Coffee is the most fertiliser demanding plant” (M, 37, CC17)<br><br>“Coffee requires fertilisers 3-4 times per year” (M, 35, CC30)<br><br>“Monoculture coffee needs fertiliser 1-2 times per year depending on availability of family labour” (M, 34, AN2)<br><br>“Monoculture requires more fertiliser than intercropping” (F, 28, MC22) |
| Prevents frost damage | 0.083 | 0.089 | 0.089 | 0.074 | Relatively important ($p<0.10$), likely depending on recent experience | “Pine trees are best because they withstand frost and have a wide canopy that covers the coffee. Plum can block hoar frost and give a lot fruit.” (F, 41, MC18)<br><br>“Longan, jackfruit, Chinese | “Banana, coffee and papaya do not tolerate frost, many die, so they are [also] not good as windbreak for coffee” (M, 22, MC6)<br><br>“Nearly all the |

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|---|---|---|---|---|---|---|---|
| | | | | | | black olive with big canopy and many thick leaves [tolerates frost]" (F, 43, MC24) | monocultured coffee died" (M, 48, MC23) |
| Provides wind control | 0.071 | 0.195 | 0.046 | 0.371 | Not directly important, but women prefer tree species that can regulate microclimates more broadly | "Tall trees with flexible, tough branches and wide canopy give good wind protection for coffee. Jackfruit branches are strong." (M, 22, MC6)<br><br>"Plum, apricot, peach have elastic stem and deep roots so do not break" (M, 37, CC2) | "If the tamarind or chinaberry are too tall, they can fall over and damage the coffee. Pomelo branches also break." (F, 57, AN24)<br><br>"Grafted longan is short and brittle. Banana and papaya have shallow roots and easily fall" (F, 36, MC9) |
| Reduces soil erosion | 0.033 | 0.491 | 0.018 | 0.699 | Some farmers considered this as an important factor for overall preference | "Jackfruit is best because it has wide canopy, large stem and spreading roots" (F, 30, CC5)<br><br>"Densely grown coffee is resistant to soil erosion" (M, 35, CC30)<br><br>"Leucaena's canopy [buffers rainfall before hitting soil surface] and many roots protect against soil erosion" | "A lot of soil erosion during heavy rain" (M, 30, AN6)<br><br>"Longan, mandarin, plum, peach and apricot are all small trees and do not retain much soil. Papaya and banana roots are very shallow and cannot hold water. Monoculture cannot retain soil and moisture so cause the |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | (F, 36, AN3) | most erosion." (F, 36, MC9) |
| Provides green mulch (litterfall) | 0.040 | 0.383 | 0.062 | 0.165 | Some farmers considered mulch important to their overall preference | "Tamarind is best, has a lot of green leaves. Longan has fewer leaves that decompose slowly" (M, 36, AN4)<br><br>"Intercropping gives more leaves which cover the soil better" (M, 30, AC12)<br><br>"*Melia azedarach* sheds many leaves that decompose make soils more fertile for coffee" (F, 57, AN24) | "Where there is no canopy, no shade, no leaves, soil is bad, red, does not give good coffee and need to add more fertiliser" (F, 24, AN18)<br><br>"Banana and papaya leaves remain dry on the tree and do not fall off" (M, 38, MC10)<br><br>"Macadamia and guava only shed old leaves" (M, 34, AN2) |

Table 2. Estimated carbon sequestration potential of Arabica coffee-agroforestry systems in northwest Vietnam, as a function of age and planting density. For reference numbers, unless specified, see Nguyen *et al*. (2020).

| **Coffee-based agroforestry system** (age, planting density) | **Ref No** | **Est ton C/ha** | **Estimated C (tCO2-eq/ha)** |
|---|---|---|---|
| Monoculture Arabica coffee, 10 yr, ~6200 trees/ha | Mulia *et al*. 2020 | | ~18 |
| Coffee 7yo, 750 trees/ha<br>Macadamia 5 yo, 100 trees/ha<br>Jackfruit 4 yo, 30 trees/ha<br>Mix: Peach, longan, plum 2 yo, 170 trees/ha | 6 | 5.5 | 20 |
| Coffee 7yo, 2000 trees/ha<br>plum 20 yo 75 trees/ha<br>mango 4yo, 50 trees/ha<br>peach 2yo, 40 trees/ha | 5<br>5 | 12.5<br>21.2 | 46<br>78 |
| Coffee 4yo, 1460 trees/ha<br>*D. indica* 9yo, 50 trees/ha<br>Mix: mango, peach, pear 3 yo, 45 trees/ha | 4<br>4 | 11.6<br>22.4 | 43<br>82 |
| Coffee 20 yo 85 trees/ha<br>*D. indica 20* yo, 20 trees/ha<br>Peach 10-20yo, 115 tree/ha<br>Mix: pomelo, mango, pear 20 yo 55 trees/ha | 8 | 14.0 | 51 |
| Coffee 13 yo, 1110 trees/ha<br>Longan 26 yo, 170 trees/ha<br>Plum 22 yo, 135 trees/ha<br>Pomelo 10 yo, 50 trees/ha<br>Mix: mango, jackfruit, guava, starfruit, 3 yo, 140 trees/ha | 7 | 67.5 | 248 |
| Coffee 10 yo, 3110 trees/ha<br>Longan 30 yo, 330 trees/ha<br>Plum 19 yo, 270 trees/ha<br>Mix: pomelo, mango, litchi, guava, peach 3 yo, 440 trees/ha | 9<br>9 | 46.3<br>83.4 | 170<br>306 |

If we take 'overall preference' to represent a question such as 'What tree species do you prefer?', the analysis suggests that women considered more variables for tree selection, which resulted in a wider repertoire of potential trees to include in agroforestry systems. Farmers' intuitive ability involves experience, technical knowledge and anticipation skills (Nuthall and Old, 2018). The fact that soil fertility and pest and disease benefits were part of women's intuitive considerations, reflects women's active engagement in agriculture management. Soil quality and crop protection is also linked to labour inputs, something women farmers in particular are short of (Simelton *et al*., 2021). Additionally, the results indicate that farmers generally considered coffee-tree interactions, providing important entry points for shifting from intensive to organic production, where the role of tree functions for optimizing shade and legumes for nitrogen-fixation is key (Schnabel *et al*., 2018). Although it was not the purpose of the study, follow-up interviews during the COVID-19 pandemic in 2020 and 2021, indicate that the households practicing coffee agroforestry had more diverse income sources and were economically more resilient than those cultivating coffee monoculture. For example, Nguyen *et al*. (2020b) reported that coffee agroforestry in Northwest Vietnam could generate a gross annual income from US$ 650-8900/ha in 2020, with production costs from US$ 74-2100/ha depending on tree diversity, density, and age. Considering these trade-offs, it is unsurprising that farmers' quotes frequently rationalized high scores for income generation, while trees for home consumption scored low and were not translated as money saving. These findings have implications for smallholder coffee-farmers' contributions to climate change mitigation. In the literature, coffee monoculture is considered a net emitter of greenhouse gases, while coffee agroforestry can reduce emissions by reducing chemical inputs and sequestering carbon (Kuit *et al*., 2020). Our study indicates that women's selection of trees can (intuitively) address both. This illustrates the inherent problem of neglecting gender in NDCs, in particular for mitigation (Siegele, 2020).

The coherent evidence for an existing diversity in existing agroforestry systems (Table 2; Nguyen *et al*., 2020b) and the similarities between genders for overall tree preferences in the northwest region (Figure 1, Table 1; Nguyen *et al*., 2020a) provide inconclusive evidence that more involvement of women in tree selection would alter agroforestry systems per se. However, we do not say this is a default situation. In fact, many scholars stress that women (presumably also men) are not one homogenous group (Doss *et al*., 2018; Rao *et al*., 2019a). Therefore, gender quotas should be the minimum start to reaching equal shares of benefits from tree conservation and development outcomes (Cook *et al*., 2019), before moving beyond numbers to unpack relations of power, decision making and cultural beliefs (Rao *et al*., 2019b; Huyer *et al*., 2020). Instead, this study cautions against exaggerating gendered differences about tree preferences. More importantly, this study stresses the importance of local and indigenous knowledge, and that ensuring women's voices in local consultations on tree selection would yield a wider range of multipurpose tree species. Using simple tools like this interactively, can facilitate engagement of local communities and help in improving transparency and communication, which in turn could address some existing shortcomings in the monitoring of tree planting programs (Martin *et al*., 2021).

## 4. Recommendations

Indigenous knowledge of trees' potential (dis)benefits in agroforestry systems and tree-planting programs is an asset.

This methodology helps pointing out what women and men perceive as (dis)benefits from trees, whether they perceive similar and different benefits, and what potential trees can meet their criteria.

In this case, women and men agreed on many benefits, while women considered more factors for their preferences which resulted in a more diverse shortlist of potential trees for agroforestry/afforestation.

Engaging women and men farmers in tree selection from the start of a tree planting process, and understanding how they interpret trees' contributions, helps negotiating short-term mitigation and development goals and a wider range of diverse bundled agroecosystem functions.

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World Agroforestry (ICRAF) is a centre of scientific and development excellence that harnesses the benefits of trees for people and the environment. Leveraging the world's largest repository of agroforestry science and information, we develop knowledge practices, from farmers' fields to the global sphere, to ensure food security and environmental sustainability.

ICRAF is the only institution that does globally significant agroforestry research in and for all of the developing tropics. Knowledge produced by ICRAF enables governments, development agencies and farmers to utilize the power of trees to make farming and livelihoods more environmentally, socially and economically sustainable at multiple scales.

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