SCALING LAND-BASED MITIGATION SOLUTIONS IN VIETNAM

LAND-BASED MITIGATION NARRATIVE CO-DESIGN

THAO PHAM, TUAN HA, ERIC RAHN

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2. Introduction

This report includes a description of a generic nation-wide transition scenario for the implementation of land-based mitigation technologies and practices for the AFOLU sector (agriculture, forestry, and other land use sectors) in Vietnam. The report shows the outcomes of a series of research steps that have been conducted in this country since the start of the project in June 2020 until the end of 2022:

First, we performed an initial scoping of key LMTs in the case study country. The scoping assessment resulted in a long list of broad portfolios of different LMTs that could be viable within Vietnam.

Second, following this long list, we developed a short-list LMT portfolio containing key LMTs that would be the most relevant for the Vietnamese context. The LMT portfolio were validated through complementary (policy) literature review and with the help of stakeholder interviews (i.e., external validation by relevant experts and stakeholders in Vietnam). Ex-ante no specific guidance of criteria for LMT portfolio short-listing was provided to allow for a free and open co-design process with stakeholders. The scoping process and results are presented in section 3 of this report (step 1 & 2).

Third, after the short-listed LMT portfolios were validated, national scaling narratives or storylines for each LMT included in their portfolio were developed. The assessments focus on climate risks, vulnerabilities as well as socio-economic co-benefits and trade-offs associated with upscaling LMTs in Vietnam. The analysis is based on a broad range of information/literature sources, and stakeholder consultations conducted. This process is supported through a risk and impact assessment (i.e. an online survey and workshops/seminar/webinars) conducted through the LANDMARC tasks 4.1, 4.2 and 5.2. The results of this analysis are a set of LMT narratives which are presented in section 4 of this report.

The research steps are designed to enable both an **analysis of the risks and (climate) impacts of scaling up land-based mitigation and negative emission solutions**. As such this report mainly contributes to objectives 2, 3 and 4 of the six LANDMARC key objectives (see Table 1).

Table 1: LANDMARC project objectives.

	Project key objectives
1	Determine the potential and effectiveness of LMTs in GHGs mitigation using Earth Observation (EO)
2	Improve climate resilience of LMT solutions at the local level for large-scale implementation
3	Assess the risks, co-benefits, and trade-offs of scaling up local LMTs nationally
4	Scaling up LMT solutions to the continental and global level to assess effectiveness
5	Improve current methodologies to estimate emissions and removals for LMTs
6	LMT capacity building and develop new tools and services for decision making

While the results shown in this report represent a mostly qualitative storyline describing the context and impact of scaling up LMTs in the Vietnamese context, they also enable project partners to proceed with the translation of the outcomes in a manner so that they can serve as direct model input.

Furthermore, this national level assessment provides a testing ground and empirical basis for the continental, and global assessment of the realistic scaling potential of land-based mitigation and negative emission solutions implemented in Work Packages 6 and 7 of the LANDMARC project (***Objective 4***).

3. Scoping of land based mitigation and negative emission solutions

3.1 Overview of potential of LMTs in Vietnam

3.1.1 Introduction

In order to inform the process of revising the Nationally Determined Contributions (NDCS) under the UNFCCC's Paris Agreement, Escobar et al. (2019) reviewed the mitigation pledges of Vietnam in the AFOLU sector using a marginal abatement cost approach. This study provides a good overview of different LMTs and their importance at national scale. In September 2020, Vietnam submitted the revised NDC now including agroforestry and added additional land management practices. Mulia et al. (2020) estimated the technical and economic mitigation potential of different agroforestry systems, which will inform agroforestry-related activities and targets for the NDC action plan. The table adapted by Escobar provides a good overview of the main LMTs in Vietnam. In the following sections, we will expand on the set of available Vietnamese LMTs in the context of LANDMARC in order to conclude with a long-list of options. As a consecutive step, we discuss which LMTs seem promising for the Vietnamese scenario development. This set of LMTs is referred to as 'short list' (see Table).

Table 2 LMT potential in Vietnam

LMT Category	LMT	Mitigation potential	Total costs	Cost effectiveness
		Mt CO_2eq	M USD	USD/tCO_2eq
LMTs-LAND MANAGEMENT	**Coffee & avocado**	0.22	-118.51	-529.4
	Coffee & durian	0.13	-30.78	-234.7
	Rubber in bare land	5.27	-135.53	-25.7
	Compost from pigs	7.31	-14.41	-2.0
	Acacia in bare land	8.81	-8.12	-0.9
	Rainforest protection	59.41	9.75	0.2
	Biogas from pigs	22.32	7.11	0.3
	Rainforest restoration	8.03	11.63	1.4
	Forest restoration	6.57	11.63	1.8
	Low tillage	1.52	2.87	1.9
	Bamboo restoration	5.22	26.83	5.1
	Coffee & cassia	5.9	88.94	15.1
	Mangrove protection	47.75	1102.63	23.1

	Bamboo protection	6.37	333.20	52.3
	Maize compost	1.69	219.13	129.8
	Sugarcane compost	0.52	97.99	187.1
	Biochar	0.17	124.23	749.7
Total		**187.21**	**1728.59**	-

Note that each LMT was considered for a defined scenario in relation to Vietnam's NDC representing a fraction of total commitments. Negative marginal cost is when a proposed option costs less than the current business as usual practice. See Escobar et al. (2019) for details. Source: Adapted from Escobar et al. (2019).

3.1.2 Technologies dependent on biomass / photosynthesis

BECCS

BECCS are currently not an option in Vietnam and are therefore not discussed.

Biochar

Biochar is already part of local knowledge and produced artisanal on small scale. Biochar is also produced on a larger scale using modern machinery. The main feedstock is rice, maize and coffee husks; however, it is unclear to what degree biochar is applied to soil and there is a lack of research on the benefits for agricultural production and soil carbon sequestration. Within the coffee sector, coffee husks have been used as feedstock with pyrolysis technology at the farmer cooperative level (Flammini et al. 2020), using the produced heat for drying coffee cherries. This is done as an alternative to currently used burners for coffee drying which are not only inefficient but also cause heavy smoke emissions with negative effects both on the health of the local population and the quality of the coffee beans. One of the key challenges of scaling biochar use is related to the application rate (i.e., amount per ha) required to improve the soil to the level of interest (e.g. pH level). A study by Scheifele & Gattinger 2017, suggested that a rate of 20 t/ha is required to raise the soil pH to an ideal range. Due to the problem of soil acidification, this is a primary concern for soil health in Robusta coffee growing areas. However, this study was conducted in laboratory only and field designs are currently under way to assess whether lower rates might be sufficient. If the required rate is too high, this could make the technology either too costly or logistically unfeasible. Depending on the carbon price on the carbon market, using biochar as soil amendment could potentially be at least partially subsidized. Given that coffee in Vietnam is planted on 650,000 ha with globally the highest yields, there is a lot of biomass (i.e., coffee husks) that is not properly returned to soils.

3.1.3 Land management practices

Afforestation

In the late 1980s, the government of Vietnam initiated major policy reforms and ambitious forest and replanting programs. By 2017, total forest cover reached again 14.4 million ha, covering 42 percent of the country, supporting economic growth, job creation, and poverty alleviation. While the overall forest area has been increasing, the quality of the forest continues to deteriorate. Today two-thirds of

Vietnam's natural forests are considered in poor condition or regenerating, while rich and closed-canopy forests constitute only 5 percent. As a result of competing land uses, pockets of deforestation are still found in the country. Agriculture continues to be the main direct cause of forest loss in Vietnam, its expansion being facilitated by the extension of rural infrastructure, particularly roads. Several initiatives are dedicated to reach zero deforestation commitments (e.g. Initiative for Sustainable Landscape Approach – jurisdictional approach).

Agroforestry

Mulia et al. (2020) have identified eight key agroforestry systems in Vietnam with a total area covering 820,000 hectares, which is 92% of the total area with agroforestry systems. These eight systems are i) Melaleuca (*Melaleuca cajuputi*)-based (245.5 x 10^3 ha), ii) Robusta coffee (*Coffea canephora*)-based (245.3 x 10^3 ha), iii) Rhizophora (*Rhizophora* spp.)-based (149 x 10^3 ha), iv) Acacia-based (129.5 x 10^3 ha), v) Rubber (Hevea-brasiliensis)-based (20.5 x 10^3 ha), vi) Arabica coffee (*Coffea arabica*)-based (10.5 x 10^3 ha), vii) Cashew (*Anacardium occidentale*)-based (10.4 x 10^3 ha), viii) Tea (*Camellia sinensis*)-based (9.5 x 10^3 ha).

Existing areas with these eight agroforestry systems in Vietnam sequester a total of 1346 $\pm$ 92 mil tCO_2eq. both above-ground, below-ground and soil organic carbon. The two systems in wetlands, namely Rhizophora- (617 $\pm$ 22 mil tCO_2e) and Melaleuca-based (482 $\pm$ 19 mil tCO_2e), contribute about 82%, thanks to their high carbon storage per hectare. Robusta coffee contributes (137 $\pm$ 30 mil tCO_2e). Soil organic carbon accounts for about 52%. Most of the coffee is currently monocropped, although intercropping systems in agroforestry with fruit trees (avocado, durian), black pepper and nitrogen-fixing *Cassia siamea* and *Leucaena* sp. (often used as living poles for pepper vines) is on the rise. Current assumption regarding the area with coffee monocropping systems range between 66% to 80%, hence there is high potential for expanding agroforestry within the existing coffee growing area. A monocropping coffee system has around 5.4 t ha^{-1} aboveground carbon (AGC) while current coffee agroforestry systems in Vietnam have around 13 t ha^{-1} AGC. Given that there are 650,000 ha of coffee, the potential increase in AGC by converting monocropping systems to agroforestry is considerable. Further increases in soil organic carbon are expected with improved agricultural management that improve soil health.

Agricultural management practices

Organic fertilizers, integrated soil fertility management, low-tillage, mulch, cover crops, intercropping, etc. can have positive co-benefits on soil carbon sequestration, particularly when several of these practices are combined. However, there is little evidence under what conditions these practices reduce soil carbon loss or increase soil carbon. Due to the long reaction time of soil carbon sequestration, modelling is often required to assess the potential benefit. Only few studies have been identified in the context of Vietnam.

Organic fertilizers derived from biogas production using animal manure (mainly piggery) has a high potential as a by-product to replace the current unsustainable energy source of wood for cooking and lightning purposes of the rural population. The Vietnam Biogas Programme led by Dutch NGO SNV started to push biogas using pig manure back in 2003 to replace wood burning stoves in rural areas. Smallholder farmers account for 80% of pig production and the use of small-scale biogas plants is one of the options to treat the manure through anaerobic digestion (AD) to provide a clean, efficient, and low-cost renewable source of energy, while the digested matter is a high quality fertilizer for crops. Roubík et al. (2018) found that the biogas potential is two times higher than current biogas generation.

3.2 Determining the LMT scope for national level simulation modelling

Priority should be given to LMTs that also contribute to improving farmers livelihoods and climate change adaptation. The Ministry of Agriculture and Rural Development (MARD) clearly emphasized that profitability and food security are prioritized before GHG reduction and carbon sequestration.

Table 3: Summary of relevant land based LMTs

LMT	Specification	Included in national LANDMARC LMT portfolio
Biochar	**Feedstock from coffee, rice or maize**	Yes
Wetlands	Mangrove protection and restoration	No
Cropland	Reduced tillage	No
	Harvest residues, crop rotation	No
	AD residue based on organic fertilizers / digestates	No
	Composting based on agricultural residues	No
	Integrated crop management in upland crop cultivation and rice cultivation	Yes
	Agroforestry	Yes
Forest land	Avoided deforestation	Yes
	Afforestation / reforestation	Yes
	Agroforestry	Yes

- **Biochar**

  Biochar at small and large scale has been identified as a priority technology by the Ministry of Natural Resources and Environment of Vietnam recommending early deployment based on 17 indicators (MONRE 2018). For the coffee sector with 650,000 ha of land and a total of more than 10 million tonnes of coffee produced in 2018, significant waste is currently either lost or inefficiently used and biochar could provide heating for coffee drying, improve soil health and sequester carbon in soils. Ongoing projects with Sofies and Unido are exploring the scaling potential of early pilots and align nicely with LANDMARC's objective.

- **Agroforestry**

  Agroforestry has been included in the updated NDC of September 2020 as part of the measures for the LULUCF sector. Agroforestry-related activities and targets will likely be elaborated in the NDC action plan that is still under development by the government (Mulia et a. 2020). Vietnam has also committed to the UNFCCC's Koronivia Joint Work on Agriculture (KJWA) to promote and enhance investment in climate-smart agriculture such as agroforestry. Enhancing terrestrial and soil carbon is among the priorities of the KJWA, along with improved nutrient and water management for food security and resilience to climate change, for which agroforestry can also generate relevant benefits.

- **Soil health improving agricultural practices**

  Investments in soil health improving agricultural practices, with co-benefits of increasing soil carbon sequestration are of high priority. Soil degradation due to erosion (75% of agricultural soils are sloping) and soil acidification is a major issue which requires high investments in order to sustain crop production. Changing demands from international markets regarding product quality and environmental costs of production have been putting pressure on the agricultural export capacity of Vietnam. Big investments from government, World Bank and private sector are changing the mode of production to comply with these new market demands.

- **Afforestation/ reforestation and avoided deforestation**

  In the last 5 years, REDD+ programs and projects have been focusing on improving institutional frameworks and policies, capacity building, developing technical guidelines and investing in the implementation of REDD+ activities. A policy on carbon payments for forest ecosystem services has been institutionalized in 2010 to generate funds for avoided deforestation and afforestation. However, afforestation is mostly based on non-native species such as *Acacia mangium* Willd, *Eucalyptus*, and *Manglietia conifer* Dandy with an average rotation of about six to seven years, therefore not contributing to biodiversity conservation and related ecosystem services. Avoided deforestation of primary forest is therefore most critical. Jurisdictional landscape approaches to sustainable sourcing of agricultural products have been set up to enable zero-deforestation pledges from public and private sector.

Not all MTs can be selected given the resource constraints of the project. Therefore, we prioritized four MTs based on their cost effectiveness and potential to align with already ongoing initiatives where Landmarc can best complement.

3.3 Discussion on short-listing LMTs

3.3.1 Land use change dynamics

Vietnam defines forest as an area with perennial timber trees, bamboos and palms of all kinds of a minimum height of 5 m, minimum tree cover of 10%, and a minimum plot area of 0.5 hectares or forest tree strips of at least 20 m in width and of at least three tree lines (MARD 2016). Forests are classified into three types according to management purposes: i) production forests that are designated for timber supply, ii) protection forests that are designated for protection functions, such as watershed and coastal areas, and iii) special use forests which are for biodiversity conservation such as national parks, protected area, biosphere etc. As can be seen in table 4, the total forest area has increased since 2005, however, the increase is mainly due to the expansion of production forest and a decrease of protection forest. Localized deforestation is still an issue, especially in the Central Highlands (World Bank 2019).

Table 4 Forest area dynamics

Year	National forest area (ha)	Types of forest (% of total)		
		Special use forest	Protection forest	Production forest
2005	12,616,700	15.52%	48.92%	35.56%
2012	13,862,043	14.59%	33.73%	50.24%
2018	14,491,295	14.87%	31.66%	53.47%

Source: http://www.kiemlam.org.vn/Desktop.aspx/List/So-lieu-dien-bien-rung-hang-nam/.

Competing land use

Vietnam is one of the world's largest exporters of rice, rubber, coffee, pepper, cashew nuts, wood products, and shrimps which compete to some extent with forests. Large-scale conversion of natural forests have occurred over the past 30 years due to commodity booms in the 1990s and early 2000s, most notably in the coffee and shrimp sectors. Between 1990 and 2017, the area of coffee plantations increased from 50,000 ha to 645,400 ha, by 2011, sea and brackish water aquaculture had expanded to cover an area of 730,000 ha, causing a major loss of mangroves. While the production of these and other commodities continues to rise, the expansion into natural forest areas has diminished since the 1990/2000s peak (World Bank 2019). Coffee expansion is expected to pose the highest risk to continued direct and indirect deforestation, as long as international demand for coffee remains strong. However, various private and public partnership projects have been set up to minimize this risk. Timber plantations are also expected to grow due to increasing demand of paper and pulp and other wood-based products (World Bank 2019).

3.3.2 Land management dynamics

Changes in land management practices are a crucial part of sustaining future agricultural production, rural livelihoods and climate change mitigation. Vietnam's agriculture is highly intensive with overuse of mineral fertilizers and irrigation, which has led to degrading soils and high pollution. Due to decreasing productivity and high demand of international markets for cleaner production, a large investment by public and private sector is being made to identify and scale management practices that restore soils and decrease pollution. There is limited research evidence on soil organic carbon dynamics of different agricultural land use systems in Vietnam, but taking into account that current management is highly intensive and unbalanced, the trajectory of soil organic carbon is expected to be negative. Given that 40% of the total area is dedicated to agricultural production and yields of several crops are above average globally (e.g. rice, coffee), there is considerable plant residue produced which is still underutilized. Livestock manure, particularly pig manure, is widely available and provide substantial organic matter input to soils, but again it is too often not managed properly and returned to soils.

Table 5 Agricultural land use in Vietnam in 2018 (in 1000 ha)

Land use category	2018
Agricultural area, total	11,498
Annual crop land	6952.1
- Rice paddy	4120.5
- Other annual crop land	2831.6
Perennial crop land	4546.4

Source: General Statistics Office of Vietnam.

4. Co-design of LMT narratives

4.1.1 Introduction

The main LMTs identified as having high potential are i) agroforestry, ii) reforestation, afforestation and avoided deforestation and iii) biochar. Agroforestry seems to have the highest potential as it is highly cost-efficient, does not necessarily lead to land use competition and can contribute to climate change adaptation and farmer livelihood diversification. Vietnam has achieved an impressive scale of reforestation and afforestation, however, this was primarily done using low quality monocropping Acacia and Eucalyptus plantations. There is high potential to improve the quality of these plantations through more sustainable mixed species management, while expansion of forested areas will be more challenging due to land use competition. Finally, biochar could potentially become a promising LMT at national level, however, there are still knowledge gaps on how different feedstocks and pyrolysis protocols affect soil health, crop yields and farmer profitability. Considerable uncertainties exist regarding the required supply chain from biomass collection to production and biochar application as soil amendment to enable a viable business for biochar production and economic use at farmer level.

4.2 Agroforestry

4.2.1 Introduction

Agroforestry is a traditional agricultural practice in many countries, including Vietnam. Examples of traditional agroforestry practices in Vietnam are the forest–garden–fishpond–livestock systems in the lowlands and the home gardens with fruit, timber, or commercial tree-based systems in the uplands. In the past decades forests and agroforestry areas have been significantly reduced and replaced by intensive mono-cropping systems, driven by rapid population growth and increasing demands for food production and economic development. However, across the country, many farmers still adopt and maintain agroforestry as subsistence farming and more intensive commodity cropping systems (Mulia & Nguyen, 2021).

Nowadays, agroforestry has been recognized as an integrated sustainable land-use practice not only for soil conservation and improved resource-use efficiency, but also to adapt to and mitigate climate change thanks to its potentials for carbon sequestration and regulating microclimate. Agroforestry also helps farmers to mitigate market risks, including the price fluctuation and the situation such as Covid-19 pandemic, via diversifying farmer's income and enhancing food security.

There is an estimated >0.83 million ha of existing agroforestry systems in Vietnam storing a total of 1346 ± 92 million ton CO_2 equivalent including above-, belowground, and soil carbon. Over the period of 2021 – 2030, estimates of the potential area agroforestry systems could be expanded to vary from 0.93 to 2.4 million ha. About 10% of this expansion area are highly suitable for production with a sequestration potential of 2.3–44 million ton CO2 equivalent (Mulia et al. 2020).

4.2.2 Policy context

National policies addressing this LMT

Mainstreaming agroforestry will support Vietnam in implementing and achieving its targets of several national policies.

In 2020, Vietnam updated its NDC for the period of 2010 - 2030, including the aims of "developing agroforestry models to enhance carbon stocks and conserve land" (section 2.4.3) as one of the measures under LULUCF sector. Moreover, agroforestry-related targets and activities will likely be incorporated in the national NDC Action Plan which is still under development by the government. However, it is recommended to include agroforestry as a part of the agricultural sector in order to effectively offset sectoral emissions (Mulia et a. 2020). Moreover, Vietnam has committed to the UNFCCC's Koronivia Joint Work on Agriculture (KJWA) to promote and enhance investments for the sectoral adaptation and mitigation measures such as climate-smart agriculture and agroforestry. The National Action Plan of the 2030 Sustainable Development Agenda clearly emphasizes the need for developing a more sustainable agriculture in upland areas, to which agroforestry can provide multiple relevant benefits.

In 2021, the government of Vietnam has issued Decision No. 523/QD-TTg (2021) on approving the Vietnam Forestry Development Strategy in 2021-2030 with a vision to 2050. In which, agroforestry is included as recommended production models for most of the regions across the country, including the northern midland & mountainous regions, north central region, south central region, central highlands, and southeast region.

Several studies mentioned agroforestry as potential direct or indirect targets for carbon finance. However, Vietnam's sectoral forestry policies and related mechanism for carbon credits such as the national REDD+ vision to 2030 have not elaborated agroforestry. In April 2021, the Prime Minister released the Decision No 524/QD-TTg approving the national project "Planting one billion trees in the period of 2021 - 2025", which will be coordinated by the Ministry of Agriculture and Rural Development in collaboration with the Ministry of Environment and Natural Resources and the Ministry of Construction. Likewise, the project focuses on forest plantation and have not included agroforestry.

Actors currently applying the LMT

Agroforestry has been traditionally and widely adopted by rural smallholder farmers in Vietnam. Shade management has been promoted in key agricultural commodities, for example in coffee in the Central Highlands and tea in the North of Vietnam. In the Central Highlands, due to the unfavourable market prices of coffee in recent years, farmers have increasingly intercropped high-value fruit trees such as durian and avocado in their coffee farms. One of the important adoption constraints has been the lack of guidelines for agroforestry development, thus the selection of associated trees relies on farmers' preference and is highly influenced by expectations of economic benefits (Nguyen MP et al. 2020). An ACIAR (Australian Center for International Agricultural Research) funded project led by the World

Agroforestry Centre (ICRAF) in collaboration with the Centre for International Tropical Agriculture (CIAT) and other international and national partners, will contribute to this knowledge gap.

Which funds are available for the LMT implementation

Resolution No. 84/NQ-CP (2021) on Approving the investment policy for the Program on sustainable forestry development for the 2021-2025 period; and the Sustainable Forest management program (Decision No. 809/QD-TTg (2022)) for the period 2021-2025: 78,585 billion VND (3,2 million USD).

4.2.3 Current land use and potential land-use competition

The Spatially Characterized Agroforestry (SCAF) database (http://scafs.worldagroforestry.org/) provides information on distribution, biophysical and socio-economic characteristics of 48 existing agroforestry practices across 42 provinces in Vietnam during 2013–2014. Based on SCAF database, the total area and the potential for carbon sequestration were estimated (Table 6).

Table 6: Total area, carbon sequestration amount and investment cost for expansion of existing agroforestry systems in Vietnam *(adapted from* Mulia et al. 2020)

Agroforestry system	Area (10^3 ha)	Main regions	Total sequestered carbon (mil tCO_2e)	Investment cost (USD ha^{-1} $year^{-1}$)
Melaleuca *(Melaleuca cajuputi)*-based	245.5	Mekong River Delta	482 ± 18.8	
Robusta coffee (Coffea canephora)-based	245.3	Central Highlands, South East	137±29.5	2124 ± 574
Rhizophora (*Rhizophora* spp.)-based	149	Mekong River Delta	617±22.4	
Acacia-based	129.5	North East, Red River Delta, South Central Coast, Mekong River Delta	76.1±15.6	173 ± 4.6
Rubber *(Hevea brasiliensis)*-based	20.5	North West, North Central Coast, Central Highlands	12.0±2.4	
Arabica (*Coffea arabica*)-based	10.5	North West	5.9±1.3	2587
Cashew (*Anacardium occidentale*)-based	10.4	Central Highlands, South East	7.4±1.25	213
Tea (*Camellia sinensis*)-based	9.5	North East, North Central Coast	5.4±1.17	2806
Other systems (*)	79.8	Spread across regions	-	
All systems	**900**		**1343±92.4** (**)	

(*) Other systems: Various fruit- or timber tree-based systems with relatively small areas

(**) Estimates of all eight main agroforestry system; TOC of Other systems were not taken into account

Existing agroforestry systems could be expanded to a total of 0.93–2.4 million hectare, of which approximately 10% is considered highly suitable for production, with a potential to sequester 2.3–44 million ton CO_2 equivalent over the period 2021–2030. For commercial crops, Vietnam's Master Plan on Agricultural Production Development to 2020 with a vision to 2030 prioritizes improvements in in the processing industry rather than area expansion. Agroforestry could be expanded into existing producing regions via gradual conversion of sole crop plantations. There is not sufficient information available for assessing potential land-use competition. Depending on the agroforestry design and management, yields of the main crops might be negatively affected, hence potentially requiring more land than current monocropping systems to maintain total production and increasing demand. By replacing old coffee trees with new high yielding varieties (e.g., TRS1, TR4, TR9 and TR11) off-set potential yield losses (D'haeze 2022). Furthermore, the long-term sustainability of current monocropping systems is questioned (climate and market risks, soil degradation, etc.) and land equivalent ratios (assessing yields of all associated crops) needs to be accounted for. Indirect land-use competition effects have been reported where the expansion of commodity crops have displaced subsistence farming systems of ethnic minorities into forest margens leading to deforestation (Meyfroidt et al. 2013).

No other land use developments are known that compete with the expansion of agroforestry. However, continued low prices of coffee, for example, can lead farmers to abandon coffee and therefore coffee agroforestry switching to other land uses. But, this is more common in coffee monocropping systems, as coffee agroforestry are more profitable and rely less on the coffee price alone due to the diversified income streams from other crops such as pepper, avocado and durian.

4.2.4 Climate risks & sensitivities

Under impacts of climate change, suitable areas for perennial crops such as coffee and tea are projected to be reduced. Mulia et al. (2020) estimated the potential expansion area and impacts of climate change on five major agroforestry systems (robusta-, arabica-, acacia-, tea- and cashew-based) in Vietnam under different climate change scenarios. On average, highly suitable areas for agroforestry expansion are potentially reduced by 34% under RCP 4.5 and 48% under RCP 8.5 by 2050. Arabica and Robusta coffee-agroforestry systems are most affected by impacts of higher temperature with up to 89% and 83% reduction of highly suitable planting areas compared to the baseline under RCP 8.5 in 2050. This value is 30% for tea, while acacia is the most resilient with a projected decrease of 7%.

However, the estimation excluded co-benefits of associated trees in agroforestry systems which can help modify the microclimate within the system thanks to the shade- or ground cover layer keeping the system temperature lower and soil moisture higher. Therefore, prioritizing agroforestry for commodity production is clearly needed to mitigate the strong risks of climate change on such perennial crops, especially coffee.

Currently, drought and water shortages are an increasing challenge for people of the Central Highlands. For example, the 2016 drought reduced the discharge of main rivers by 20-90% (NCHMF

2016, cited in CGAR 2016) with 70% of the cultivation area experiencing severe drought (MARD 2016). Nearly 170,000 ha of crops were affected by the drought, of which 7,100 ha were left fallow and more than 95,00 ha were deficient in irrigation (CGIAR 2016)

4.2.5 Economic implications

According to Escobar et al. (2019), coffee agroforestry systems with fruit trees such as Durian and Avocado are the most cost-effective land use based mitigation measures among the analysed practices, being more profitable compared to monocropping systems. However, investment costs are higher (e.g. 2 times higher) for agroforestry compared to monocropping and profits of agroforestry are higher only once all the trees are mature and bear fruits. In a timber system, returns can take even longer compared to fruit trees. Initial finance mechanisms for transitioning to agroforestry systems might therefore be required.

Mulia et al. (2020) estimated the investment cost for agroforestry expansion in highly suitable areas to range between USD 28 to 2790 million, depending on the agroforestry system. Cashew-based agroforestry and tea-based agroforestry systems have the lowest and highest investments costs, respectively. In terms of carbon sequestration, agroforestry is 1.3–17 times more cost-efficient than sole crop plantations. For example, robusta-based agroforestry can potentially remove 45 mil tCO_2e, equivalent to 41% of total GHG emission of Vietnam's agriculture sector by 2030. It requires an investment cost of USD 6.3 billion for agroforestry expansion, compared to an additional cost of about USD 41 billion for sole plantation to removing the same amount of emissions. Moreover, crop diversification can increase and help farmers reach break-even points earlier, therefore stabilizing their income.

4.2.6 Co-benefits and trade-offs

Through our qualitative risk assessments, co-benefits related to soil (soil protection, nutrients retention, etc) are perceived as most important by researchers and local experts. Stakeholders from the private sector highlighted income diversification and carbon sequestration as most important co-benefits. The improved regulation of the water balance was also mentioned.

a) ***Agricultural production:*** High level of shade and resource competition could limit productivity. Meanwhile, some crops such as coffee benefit from shade trees at their early establishment. The replacement of old varieties with new improved varieties cold mitigate potential negative effects of shade on coffee yield. Both public and private stakeholders are interested in compiling information on trees and crops that grow well together.

b) Landscape: *During drought conditions, there is potential for competition between different water uses, e.g., between water use for electricity and domestic use and the use of irrigation. However, agroforestry can reduce nutrient and sediment loss, thereby reducing the risks of water pollution.*

c) ***Biodiversity:*** Soil biodiversity is expected to improve in agroforestry systems, but there is a lack of scientific studies in the Vietnam agroforestry context. Improved forest quality and increased tree density and diversity in agricultural systems improves biodiversity habitat.

d) ***Nitrogen emissions?:*** *No studies have been found that evidence lower nitrogen emission in agroforestry systems. Although incorporating additional trees is expected to increase nitrogen uptake and thereby potentially reduce nitrogen loss, leguminous trees also add additional nitrogen to the soil through leaf litter. Nitrogen emissions will be more strongly affected by the source, rate, timing and place of application.*

e) ***Water quality:*** Depending on the design of agroforestry systems (tree species and their arrangement), the risk of water pollution by agrochemicals and sediments is reduced.

The main benefit of agroforestry to farmers are the associated products derived in addition to the main crop, such as timber, fruits, fuel wood, etc. Agroforestry systems tend to increase management efficiency, however, implementation costs and time required until benefits (e.g., timber, fruits) are available can be high and limiting the potential uptake.

Trade-offs of the LMT

Risks

Being highly driven by economic benefits, selection of species in agroforestry systems that will enhance ecological benefits is not well considered. Additionally, big timber and native trees are less likely to be selected due to its slow growth rate. Timber-based agroforestry and afforestation, in general, are mostly based on non-native species such as *Acacia mangium* Willd and *Eucalyptus* with an average rotation of about six to seven years, therefore not contributing to biodiversity conservation and related ecosystem services. Fruit-based or commodity-based (coffee, tea) agroforestry are mostly semi-shaded as commercial polyculture or shaded monoculture.

Co-benefits

Besides being a cost-effective practice for carbon sequestration and GHG removal, agroforestry provides multiple co-benefits for agriculture production, soil conservation, improving food security and farmers' income.

Agricultural production

Although competition of resources might affect productivity of each plant component, total production and income generated from the whole system could be higher compared to the sole crop plantations. In addition, thanks to crop diversification, less inputs are required and thus enhancing resource-use efficiency and reducing costs. On the other hand, some studies showed that in several agroforestry systems, interactions among species facilitate common resources and result in higher productivity of each plant component than in sole crop plantations. Agroforestry can also regulate micro-climate and help to mitigate climate risks on crop production.

Soil conservation

Agroforestry reduces water and chemical inputs, so as their impacts on soil, compared to sole crop plantations. Trees, in general, improve soil health thanks to its increasing litters and deep rooting systems which enhance soil organic matter, soil pores, infiltration, water retention and activities of soil organisms. On sloping land, soil erosion and sedimentation can be reduced by arranging agroforestry as crop trips and contour planting.

Biodiversity

Combination of trees, especially with different vegetation layers, regulates micro-climate and conducts favourable conditions on farms for both sun-loving and shade-tolerant species. In addition, trees can increase biodiversity of a system, including through providing a temporary or permanent habitat for wildlife. Agroforestry can reduce the risk of forest encroachment and degradation through providing 'forest products', such as timber and fuelwood as alternative livelihoods and thus help conserve forests and their ecosystem services. Vietnamese agroforestry systems are currently not favouring native tree species within their systems due to a lack of economic incentives. However, if agroforestry can contribute to protect remaining biodiversity, then it can have a positive impact.

Trade-offs

Converting mono-cropping to agroforestry system requires high initial investment and is a long-term process, which can create a huge burden to farmers if sustainable financing mechanisms for the transitioning process are lacking. Some timber and fruit trees also take few years before being able to generate yield and income, thus without any compensation, farmers will lose a part of their income in the first years. Lack of related policies, technical guidelines, extension services and incentives for agroforestry might hinder farmer's motivation to adopt agroforestry.

4.2.7 Risks associated with scaling up

Although the benefits and potentials of agroforestry are well-acknowledged, scaling agroforestry adoption in Vietnam remains challenging. Major constraints including the lack of specific policies needed to enhance institutional support, lack of technical guidelines, quality planting materials, and financial incentives to attract farmers interest and investment efforts. There are different understadings of "agroforestry" from stakeholders of different domains, e.g., forestry and agriculture. A common understanding of definitions, risks and benefits is required for successful scaling. Farmer decision on removing/intercropping some crops is driven by market price. When the market price is too low, farmer will revert to a monocropping system.

4.2.8 Research gaps

A lack of technical guidelines to design and manage locally adapted agroforestry systems have been highlighted as a key constraint for wide scale adoption. Research on the agronomy, ecology and economics of agroforestry is therefore required. The ACIAR funded project running in parallel to Landmarc will contribute to filling this gap, but more resources will be needed.

Agroforestry can vary substantially in the level of complexity. System ages and complexity (simple to complex agroforestry) are critical to be consider for carbon benefits of the system. There is a need to characterize several agroforestry typologies and get baseline data of their benefits as well as trade-off to reach mutual understanding of “agroforestry” by different stakholders/ decision-makers. The potential of sustainable finance for initial investments to incentivize transitioning to agroforestry.

4.3 Biochar

4.3.1 Introduction

Many soils in Vietnam show declining soil organic carbon content due to intensive long-term monoculture with insufficient supply of organic fertilizers and soil protection. This comes at the cost of long-term sustainability related to negative environmental externalities such as N2O emissions due to overuse of nitrogen and reducing crop yields due to unbalanced plant nutrition, reducing soil water holding capacity and increased pest and disease pressure (e.g. Pham et al. 2020, Häring et al. 2014). There is considerable scope for improved soil organic matter management techniques. More than two thirds of the country’s territory is classified as upland soils. Although some studies found higher SOC in agricultural lands than in forested lands (Pham et al. (2018) it is important to note that the latter study did not compare SOC taking into account equivalent soil masses (Wendt & Hauser 2013), therefore questioning the comparability between soils.

There is a lack of field experiments measuring SOC as a function of land management practices in Vietnam in general, and for biochar in particular. Again, the few studies comparing SOC between soils of different management practices did not base their comparisons on equivalent soil masses. Other soil quality aspects such as changes in soil fertility and soil water holding capacity are equally important, yet very scarce.

Policy context

Vietnam has committed to the UNFCCC’s Koronivia Joint Work on Agriculture (KJWA) to promote and enhance investment in climate-smart agriculture (UNFCC 2018). This includes improving soil carbon, soil health, and soil fertility in integrated systems is one of the priorities identified by Vietnam. Soil carbon sequestration is considered within the Vietnamese National Adaptation Strategy to Climate Change. Practices that improve food security with a co-benefit of soil carbon sequestration are prioritized. Therefore, there is a need to clarify soil and plant health benefits of using biochar as a soil amendment.

In 2021, the Vietnamese Government issued Decision 1658/QD-TTg (2021) on approving the National Green Growth Strategy 2021-2030, with a vision to 2050, aiming to contribute to Vietnam’s economic restructuring to achieve economic prosperity, environmental sustainability, and social justice. The goal of the strategy is a green and carbon-neutral economy that positively contributes to limiting global warming. Key Ministries were assigned to formulate and implement specific tasks for an efficient, sustainable, and low-emission agricultural sector towards a circular economy and climate smart agriculture.

In addition, Decision No. 687/QD-TTg (2022) on approving the scheme for circular economy development in Vietnam allocated specific tasks to MARD for developing policies in order to create a legal corridor for the formation and development of a circular economy in agriculture & rural development. MARD was requested to conduct research and propose implementation of one circular economy model (OCOC) in one commune.

A recent workshop (16 September 2022) between MARD and UNIDO revealed a high need for including biochar as a climate resilient solution in the national policy framework to maximize its potential and efficiency.

Actors currently applying the LMT

There is no report that provides a good overview of who applies what type and amount of biochar. However, there was a three-year project called 'Biochar for Sustainable Soils' led by the UN Environment and Global Environment Facility with assistance by the Thai Nguyen University of Sciences. A technology transfer program (www.repic.ch) between Swiss partners and a Vietnamese coffee processing equipment manufacturer (Viet Hien Ltd.), designed a new Pyrolysis Technology to suit the Vietnamese coffee industry. The new technology which uses coffee husks as a feedstock is very efficient, does not produce smoke and meets strict EU emissions standards. In addition to producing biochar, the pyrolysis machine also generates heat, which is used by a coffee cooperative to dry the coffee beans. This technology is managed at the farmer cooperative level.

Next to this highly standardized example, low quality rice husk ash is also produced from rudimentary combustion systems and marketed as biochar with inconsistent quality and lower impact on soil health and yields compared to high quality biochar. This is one of the factors that is distorting the market.

Funds available for the LMT implementation

No good overview of available funds for biochar has been identified. Government investment would likely require clear evidence on soil health, crop yields and farmer benefits before they support the technology at scale. International funding has already been directed to the technology particularly by UNIDO, SECO, GEF and now by ACIAR. Coffee private sector actors are interested to co-invest in the technology and carbon markets could play an important role in 'subsidizing' the technology to overcome the cost restrictions by smallholder farmers. However, the current carbon price is likely still too low.

4.3.2 Current land use and potential land-use competition

There is no information available on how much of the land is treated with biochar. However, the use of biochar does not lead to land use competition if waste products are used as feedstock. Rather, there might be a competition for i) biomass used for producing biochar and ii) use of the produced biochar (e.g. charcoal, active carbon). Competition for biomass is currently not an issue, as there is an increasing amount of bio-wastes that are inefficiently used. Biochar could solve this inefficient use of bio-wastes. For example, coffee and rice husks are often burned for drying the coffee beans and rice, respectively. Due to the intensive agriculture use and resulting high yields there is a high availability of biomass that is available. Agricultural area is not expected to decrease in the coming decades, in the contrary, while soil degradation is increasing, soil amendments such as biochar are increasing in importance.

4.3.3 Climate risks & sensitivities

The climate sensitivities are related to the available area of agricultural land where biochar can potentially be applied and the availability of specific crop waste products used as feedstock. Depending on the specific agroecological zones and specific crops, climate risks and sensitivities will change. For example, coffee in the Central Highlands is expected to being increasingly affected by climate variability and change such as increasing temperatures, more severe and frequent droughts and more frequent flooding. High temperatures and insufficient rainfall during vegetative growth and bean filling can substantially affect crop yield and quality. Salt intrusion due to sea level rise is a problem in the Mekong Delta and can put agricultural production at risk. The Mekong Delta plays a key role in ensuring national food security. In the northern mountainous area, heavy rainfall can increase erosion.

4.3.4 Economic implications

Currently, one of the main concerns and uncertainties of biochar is the potential high costs. Based on a pilot study at a coffee farmer cooperative, two main aspects were identified to be key for the profitability of the system: the price of biochar and the positive impact on the coffee quality. The biochar is used as soil amendment for coffee as well as durian and pepper plantations or it is sold to the local market. The cost for one tonne of biochar on the Vietnamese market, produced with the small-pyrolysis system (the PPV300), is approximately USD 350 to 400 if the capital and operating expenses are entirely accounted to the biochar (Flammini et al. 2020). An average coffee farmer, however, has a monthly income of USD 250-500 and an area of three hectares. On the other hand, the improved drying system using the excess heat from the pyrolysis system can improve the quality of coffee and thereby the received price, which is estimated to be around 10% higher because of fewer price deductions for coffee quality defects. Taking these aspects into account, the payback period for the investment (around 33,000US$) and a production size of at least 36 ha is less than 2 years and becomes very interesting for bigger farmer groups. Current investigations for further improvement on the efficiency and the management of the technology are likely to make the business case even more prominent. On the other hand, the evolution of the market price for biochar is uncertain and must be further evaluated (Zellweger et al. 2018).

The cost of biochar production and market value of biochar has been assessed by Zellweger et al. (2018), however, no information is available on costs of applying biochar and the respective benefits in terms of soil health and related crop yield and final profitability. This information will be collected in parallel to the Landmarc project within the ACIAR funded project led by ICRAF in collaboration with CIAT and other partners.

With the pyrolysis system used for coffee drying, approximately 50% of the heat values of the input are stored in biochar and 50% is turned into a climate positive energy resource. Due to the carbon sequestration, the energy output has a "negative carbon footprint", without any additional negative effects such as N2O emissions. Based on the carbon content of one tonne of biochar / coffee husk, there is a potential of 2.45 / 0.73 tonnes of CO2 that can be sequestered.

4.3.5 Co-benefits and trade-offs

Agricultural production:

Biochar can adsorb nutrients making them unavailable to plants. This can lead to temporary nutrient deficiency. This can be avoided by mixing biochar with another fertilizer. Also, if the pH level becomes too high, nutrient deficiency can occur. However, this would require a huge amount of biochar that is not economically feasible. Furthermore, some of the soil health related benefits have been shown to provide only short-term benefits (e.g., raise in soil pH), and require frequent application of biochar to maintain the required benefits.

Landscape:

Biochar has the potential to increase soil erosion control.

Biodiversity:

Biochar has been found to increase biological activity and biodiversity in the soil. However, this requires further research for the local conditions in Vietnam.

Nitrogen emissions:

Potentially reduced nitrogen emissions due to reduced requirement of nitrogen fertilizers. There is also evidence that biochar can act as a nitrification inhibitor.

Water quality:

Biochar has been identified to reduce soil erosion and nitrate leaching, thereby contributing to improved water quality.

Other risks / co-benefits as part of the LMT implementation:

Heat production, which is currently used for drying coffee beans.

Trade-offs of the LMT

Biochar could also be used as charcoal or active filters, which could lead to increased prices if demand is high. However, this is currently not the case and rather unlikely in the near future. Other trade-offs could result due to negative effects on plant nutrient availability, but this research is still pending.

4.3.6 Risks associated with scaling up

Developing a market and supply chain for biochar is still in its infancy. Hence, creating a market for biochar demand and identifying the right size of biochar production (e.g. cooperative level or industrial level) for competitive prices and carbon markets to facilitate affordability as a soil amendment.

4.3.7 Research gaps

Effect of different feedstocks on biochar quality and soil health, crop yields, GHG reductions (e.g. from reduced need of chemical fertilizers, nitrification inhibition) and overall economic benefit to the farmer (Scheifele & Gattinger 2017). On what soil types and soil constraints biochar can benefit farmers most. Another open question is how long the potential benefit last (e.g. frequency of biochar application needed to maintain specific soil pH level) and an improved understanding of the trade-offs.

4.4 Afforestation/Reforestation

4.4.1 Introduction

Vietnam is one of the few tropical countries where forest areas have been increasing in the last 30 years (Traedal & Angelsen 2020). Tree planting and restoration programs have expanded the country's forest cover from a low point of 9.4 million hectares of forest in 1990 to an estimated 14.8 million ha in 2015 (Keenan et al. 2015). However, the quality of its natural forests has suffered (World Bank 2019). This is a result of major policy reforms and ambitious forest and replanting programs. Total forest cover was 14,415,381 ha in 2017, constituting 41.6 percent of the country and it seems on track to reach the targets set out in the 2016-20 Target Program on Sustainable Forest Development. Nonetheless, deforestation and forest degradation still continue in parts of the country, such as the Central Highlands, and the overall quality of the natural forest continues to decrease. Two thirds of the natural forests are in poor conditions or regenerating, only five percent are rich and closed canopy forests. Most replanted forests are non-native Acacia and Eucalyptus plantations. Climate change further becomes an increasing thread, particularly to the mangroves.

4.4.2 Policy context

Vietnam's commitment to the forest sector is enshrined in the national constitution and has the full support of the Communist Party and the Prime Minister. It has been mainstreamed in national development plans and is manifested through multiple action plans, decisions, and policies of key ministries. Within the updated NDC, Vietnam included managing and developing sustainable forests, enhancing carbon sequestration and environmental services, conservation of biodiversity associated with economic development and increasing income for forest-dependent communities and people as a key measure. The mitigation-related legal documents include the Forestry Law (2017) and as mitigation-related strategies the Vietnam Forestry Development Strategy 2007-2020 (2007).

In the LULUCF sector, Vietnam has actively implemented mitigation measures, especially under the REDD+ programme. In the period 2015-2020, REDD+ programmes and projects have been focusing on improving institutional frameworks and policies, capacity building, developing technical guidelines (reference emission level for REDD+, MRV, benefit sharing mechanism, etc.) and investing in the implementation of REDD+ activities. Several REDD+ programmes have calculated the potential GHG reduction and enhancement of forest carbon stock under specific REDD+ activities. The emission reduction programme in North Central Vietnam is expected to cut 25 million tonnes of CO2eq in the 2018-2025 period.

The national forestry development strategy (period 2021-2023) also highlights a strong focus on promoting afforestation and mobilising state fund for this effort. Some of the specific objectives of this strategy include planting production forest (about 340,000 ha/year in 2030), planting special-use forest using indigenous, precious and rare tree species (on average 4.000-6.000 ha/year), and restoration of production forest, special use forest (on average 15.000 ha/year).

Actors currently applying the LMT

Public and private sector (paper and timber sector), and smallholder farmers.

Fund available for the LMT

Vietnam is one of the world's leading countries in operationalizing a payment for forest environmental services (PFES= system). The PFES program has generated nearly $400 million since 2008. More recent reforestation efforts are led by conservation NGOs such as WWF-Vietnam and PanNature and push mixed plantations rather than monocropped Acacia and Eucalyptus plantations working with small-scale farmers. State budget from the National Forestry Development Strategy (2021-2030) is 78,585 billion VND (3,2 billion USD).

4.4.3 Current land use and potential land-use competition

Main challenges are competing land uses, overexploitation of resources, mounting risks of supply shortages, and insufficient capacity for forest governance and management. The National 5 Million Hectare Reforestation Program 5 (MHRP) that ran from 1998-2010 failed because there was simply not enough land to plant trees. The main driver of deforestation and forest degradation is from competing land uses, particularly agricultural commodities such as rubber and coffee. The area for future plantation expansion is limited; however, there is considerable potential to increase the productivity and economic value of existing plantations. In the future, the available areas for forest are at increasing risks, due to i) direct effects on forest species composition and survival, ii) loss of area due to sea level rise (i.e., mangrove forest ecosystems) and iii) indirect effects due to increased land use competition related to decreased availability of agricultural land area related to sea level rise and shifts in crop suitability. Nevertheless, Vietnam continues to aim at restoring and improving quality of the current 16.2 million hectares of forests.

4.4.4 Climate risks & sensitivities

Increasing temperatures will affect the carbon sink strength of forests. It is difficult to identify a temperature threshold that regulates carbon uptake. Duffy et al. (2021) combined Eddy-covariance flux measurements with applied macromolecular rate theory to identify temperature thresholds where respiration is higher than photosynthesis on a global scale. Changes in temperature and rainfall but as well atmospheric carbon dioxide concentration can change species composition of forests and thereby their carbon storage potential. Natural forests make up only 5% of forested areas and are mainly located in the Central Highlands. Vietnam has a 2,900 km of coastline with the majority facing the East Sea. Sea level rise will directly affect mangrove forest ecosystems. The number of strong to very strong tropical storms and typhoons are expected to increase which could damage forest ecosystems.

4.4.5 Economic implications

Plantation forests can be applied in a competitive way, however, these forest would only provide limited ecosystem services and not contribute to biodiversity conservation. Diverse forests with high percentage of native species can provide positive effects to local communities, particularly ethnic minorities that traditionally rely on non-timber forest resources for their livelihoods. However, this would require substantial public funding and adequate policies and land tenure systems in place.

4.4.6 Co-benefits and trade-offs

Forests play a particular critical role in watershed and coastal protection given the topography of the country. Past reforestation has mainly been achieved by monocropped Acacia and Eucalyptus plantations with low ecosystem value and no biodiversity conservation benefits. Recent developments, however, aim at improving forest quality through mixed species approaches that are adapted to local conditions.

4.4.7 Risks associated with scaling up

There remain highly relevant questions regarding legitimacy of different stakeholders entitled to govern and manage forests. Ethnic minorities are often excluded and negatively impacted by the government's forest protection and development policies.

4.4.8 Research gaps

An improved understanding of how forest governance affects forest dependent ethnic minorities and how their relationship has changed with respect to forest resources for their livelihoods over time.

5. Conclusions

Vietnam has considerable potential and political will for scaling different LMTs. Agricultural productivity is considerably higher compared to other South East Asian countries. On the one hand, this provides a lot of biomass with potential for valorisation and carbon storage (e.g., biochar), while integrated agricultural farming practices can significantly contribute to lowering greenhouse gas emissions. Agroforestry seems to be the most cost-effective LMT that is more easily scaled. There remain, however, various challenges that need to be addressed to close relevant knowledge gaps, enable access to finance and provide other essential enabling conditions. Relevant risks, such as permanence due to changes in crop prices and due to climate change impacts need to be carefully considered and requires that LMT practices increase overall resiliency. Importantly, any incentive for LMTs in the Vietnam context should primarily focus on improving the livelihoods of often vulnerable smallholder farmers and aim for improving biodiversity benefits, which carbon sequestration and reduction of greenhouse gas emissions as co-benefits.

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LANDMARC

ANNEX III

OVERVIEW OF INPUT TABLES FOR SIMULATION MODELLING PER COUNTRY

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11.Vietnam

11.1. Qualitative storylines by identifying measures and actions from interviews for each LMT scenario

Country Vietnam LMT 1: Agroforestry, Central Highlands

	1. Wishes of the future for the LMT: include timing	2. How to achieve the wishes • Who pays? • Who implements?	3. Target/Actions • Policies, strategies, projects
Scenario 1: " All in for agroforestry" **Stakeholder representations:**	• Nearly all monocropping systems are converted into agroforestry/intercropping systems which include at least two woody perennial species	• Value chains and government pay and scale through farmer network. • Farmers implement based on recommendations from extension system.	• Company net zero / sustainability commitments • NDC action plan
Scenario 2: "Half-way through: Area of agroforestry doubled" **Stakeholder representation**s:	• Half of current monocropping systems are converted to agroforestry/intercropping systems which include at least two woody perennial species.	• Value chain and government pay and scale through farmer network. • Farmers implement based on recommendations from extension system.	• Company net zero / sustainability commitment • NDC action plan

Country Vietnam LMT 2: Biochar from coffee husks

	1. What are the wishes of the future for the LMT • include timing	2. How to achieve the wishes • How much does it cost? • Who pays for the cost? • Who implements?	3. Actions • policies, strategies, projects

Scenario 1: "All coffee wastes are converted to biochar and applied back to the soil" **Stakeholder representations:** Farmer cooperatives, local governments, value chain (coffee buyers, traders, processors), NGOs (DSS), UNIDO	• Convert all coffee wastes (coffee husks) to biochar instead of burning (i.e., avoided GHG emissions). • Apply the biochar back to the soil as soil amendment (improve soil health and sequester carbon in soils and potential N_2O inhibition effect).	• Public and private incentive mechanisms to scale biochar production and carbon credits (voluntary) to incentivize farmers applying biochar back to the soil. • Intermediary or hybrid between farmer and coffee processor would produce the biochar. • Farmers apply the biochar as soil amendment.	• National Green Growth Strategy 2021-2030 • Coffee private sector commitments (i.e., net zero; regenerative agriculture) • UNIDO, DSS, ACIAR
Scenario 2: "All coffee wastes are converted to activated carbon and sold on the market" **Stakeholder representations**:	• Convert all coffee wastes (coffee husks) to biochar instead of burning (i.e., avoided GHG emissions). • Biochar is sold on the market as activated carbon.	• Public and private incentive mechanisms to scale biochar production. • Intermediary or hybrid between farmer and coffee processor would produce the biochar. • Activated carbon industry buyers	• National Green Growth Strategy 2021-2030 • Coffee private sector commitments (i.e., net zero; regenerative agriculture) • UNIDO, DSS, ACIAR
Scenario 3: "Half of the biochar is converted to biochar and applied to the soil"	• Convert half of the coffee wastes (coffee husks) to biochar instead of burning (i.e., avoided GHG emissions)	• Public and private incentive mechanisms to scale biochar production and carbon credits (voluntary) to incentive farmers applying biochar back to the soil.	• National Green Growth Strategy 2021-2030 • Coffee private sector commitments (i.e., net zero; regenerative agriculture) • UNIDO, DSS, ACIAR

	• Apply the biochar back to the soil as soil amendment (improve soil health and sequester carbon in soils and potential N2O inhibition effect)	• Intermediary or hybrid between farmer and coffee processor would produce the biochar. • Farmers apply the biochar as amendment.	

11.2. Quantitative storylines: pace of implementation for each LMT

	Current situation (baseline)	**SCEN-"All in…" SH perspective:**		**SCEN-"Half-way through…" SH perspective:**		**SCEN-"Half-way through v2 " SH perspective**	
Year	Now (provide sources)	2030 (change relative to the current situation) (provide sources)	2050 (change relative to the current situation) (provide sources)	2030 (change relative to the current situation) (provide sources)	2050 (change relative to the current situation) (provide sources)	2030 (change relative to the current situation) (provide sources)	2050 (change relative to the current situation) (provide sources)
LMT 1: Agroforestry in Central Highlands	• 66-80% of coffee is currently monocropped	33-40% coffee monocropping	10% coffee monocropping	50-60% coffee monocropping	33-40% coffee monocropping	-	-
LMT 2: Biochar use in Central Highlands	• Very little production of biochar and use as soil amendment	460k -560k tonnes of coffee husks are converted to biochar	1.4 million tonnes of coffee husks are converted to biochar	460k -560k tones of coffee husks are converted to biochar	1.4 million tonnes of coffee husks are converted to biochar	300k -400k tones of coffee husks are converted to biochar	700k tonnes of coffee husks are converted to biochar