SOURCE OR SINK?

The Carbon Footprint of Vietnam Robusta Coffee

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idh the sustainable trade initiative

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Photos: Agri Logic

SUMMARY

Using daily farming records from 300 robusta coffee farms in Vietnam's Dak Lak and Lam Dong provinces spanning a two-year period, we analyzed the carbon footprint of robusta production. We found that the level of diversification is influencing the carbon footprint. Highly diversified farmers who grow more than 30% of non-coffee trees on their farm have higher carbon emissions, but their higher rate of carbon sequestration more than offsets this.

Consequently, such farms can act as carbon sinks, while maintaining high levels of coffee production. Monocrop coffee farms are net sources of carbon, releasing 0.37 metric tons of CO_2e per metric ton of coffee produced. While the period on which this data analysis is based covers only two years, we can draw a tentative conclusion that diversification of monocrop coffee farms in Vietnam's Central Highlands is a viable strategy to transform the coffee sector's contribution to climate change from being a carbon source to a carbon sink. Apart from the effect of diversification, we found that CO_2e emission can also be reduced by optimizing fertilizer management, in particular through reducing the amount of Nitrogen applied through fertilizers into the soil.

Initiative for Sustainable Landscapes (ISLA) Vietnam

IDH's landscape program in Central Highlands addresses three key issues: extreme climate events, particularly recurring droughts; deforestation; and agrochemical overuse. Through the Initiative for Sustainable Landscapes (ISLA), we joined forces with coffee companies and the government in public-private platforms to support coffee farmers to become more climate resilient, cost efficient, to diversify their incomes and reduce their carbon footprint. This includes diversifying agricultural systems, conserving water and soil resource, reducing water and agrochemical overuse, and developing a deforestation-free coffee sourcing area - thus ensuring the landscape is a sustainable sourcing area for coffee and other commodities. We focus on the Lam Dong and Dak Lak provinces, and aim to reach 20,000 farmers by 2020.

1. BACKGROUND

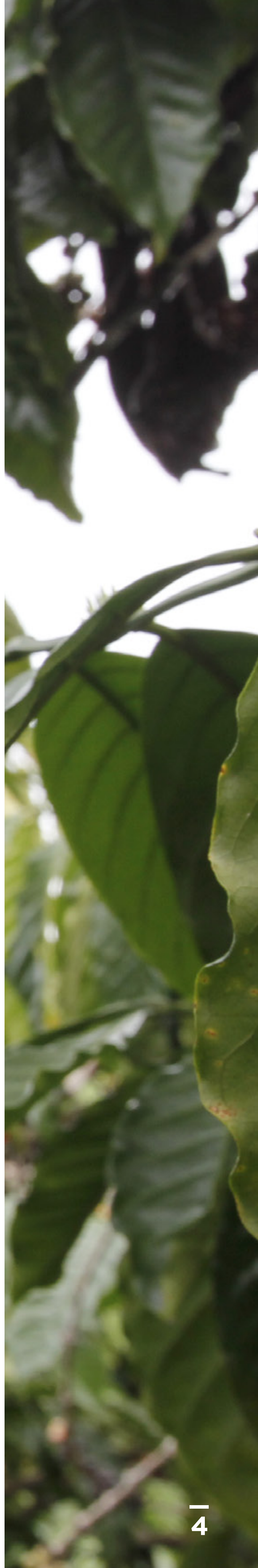
Vietnam is the second largest producer of coffee after Brazil, and the largest exporter of robusta coffee. The Vietnamese coffee sector primarily consists of small-scale farmers who grow coffee on farms ranging from 0.5 to 3.5 hectares. Robusta coffee is mainly produced in the southern provinces of Dak Lak, Lam Dong, Dak Nong and Gia Lai. Within Vietnam, productivity levels vary regionally and from year to year, but typically average 2.5 metric tons per hectare[1]. The sector uses more irrigation water and fertilizer than is required, which leads to high levels of greenhouse gas (GHG) emissions. Climate change is a looming threat that requires rethinking the farming systems in which coffee is produced.

CLIMATE CHANGE IS A LOOMING THREAT THAT REQUIRES RETHINKING THE FARMING SYSTEMS IN WHICH COFFEE IS PRODUCED

IDH, the Sustainable Trade Initiative and coffee roasters JDE and Lavazza fund a number of coffee landscape projects in the Dak Lak and Lam Dong provinces through the Initiative for Sustainable Landscapes (ISLA). The two provinces alone produced around 970,000 metric tons of green robusta coffee per annum in the 2017/18 season, which makes up around 10% of global production. Two of the implementers of ISLA landscape projects are Olam Vietnam Ltd. (Olam) and Atlantic Commodities Vietnam Ltd. (Acom). As part of their respective projects, the two companies implement a data collection method called the Farmer Field Book (FFB), developed by Agri-Logic. A range of questions that flow from the objectives of the landscape facility can be answered by using this data. One of these looks at whether more diversified coffee farming systems in Vietnam can be highly productive and profitable for farmers while acting as carbon sinks.

In this report, we analyze the carbon footprint of robusta production using data from the FFB for the coffee seasons of 2016/17 and 2017/18. We apply the Carbon Footprint Product Category Rules for green coffee (UN CPC 01610[2]), hereafter referred to as PCR.

1. http://gcp-connect.coffee/sites/gcp-connect.org/files/170725_FFB%20report%20 ISLA%20programme.pdf
2 The Product Category Rules for green coffee were valid until November 27, 2016. The SAI Platform coffee working group who made the PCR is no longer active. To date, neither of the two coffee and sustainability alliances, the Global Coffee Platform and the Sustainable Coffee Challenge, has taken up the task of revizing the PCR.



2. METHODS

Sampling

In each province, 150 farmers keep daily FFB records of all activities, inputs used, and outputs produced on their farms. The sample of 300 farmers is stratified, based on the agroforestry class of their farm (Table 1). Much of the diversification comes from the intercropping of coffee with pepper. There is a confounding geographical factor in that most of the monocrop farms are in Lam Dong province, while most of the highly diversified farms are located in Dak Lak.

TABLE 1. AGROFORESTRY CLASSIFICATION USED FOR THIS STUDY IN 2016

Agroforestry class	Description	Definition	Nr Farmers
Monocrop	Nearly fully sun grown	<15% non-coffee trees	156
Medium diversified	Light to moderate shading	15-30% non-coffee trees	35
Highly diversified	Moderate to high shade	>30% non-coffee trees[3]	106

In Lam Dong province, the FBB farms are in the communes of Tan Lam, Tan Chau, Di Linh, Gung Re and Tan Nghia, whereas those of Dak Lak province are located in the communes of Ea Drong, Ea Pok and Ea Tan.

The PCR sampling recommendation is to take the square root of the number of farmers in situations where little variation in production practices is prevalent. While robusta coffee production practices in Vietnam differ between provinces, the variability within provinces is more limited. Based on the PCR guidelines, the samples in the provinces are each representative of 22,500 farmers. Coffee farmer numbers in Dak Lak and Lam Dong are estimated at 170,000 and 123,000[4] respectively. Our sample cannot therefore be considered representative for both provinces. To achieve that, the program would require 413 FFB farmers (square root of 170,000 plus 1 for rounding) in Dak Lak and 351 in Lam Dong. However, this study represents our best estimate to date, and to our knowledge the first attempt in the Vietnam coffee sector to include carbon sequestration as well as greenhouse gas (CO_2e) emissions.

The FFB software contains a module that calculates these CO_2e emissions for each farmer based on the types and volumes of inputs used. The FFB carbon footprint calculation module was largely designed using the guidelines in the PCR, including its recommendation to estimate carbon sequestration as well.

To estimate carbon sequestration, at each of the 300 farms a complete tree stock inventory was made, listing all the species grown, the age of each tree, and the number of trees per species/age-group combination. From this base, changes in the tree stocks are taken into account when farmers plant new trees and stump or uproot existing trees. For each of the species, we attempted to obtain region- and species-specific allometric models. Where these proved unavailable, we relied on field measurements for each species to determine the equation that best describes biomass increases over time. To that end, we measured the diameter at breast height[5] and the overall height of 14 to 35 trees of each species and age group for that species. The prevalence of species on farms determined how many measurements were taken, with more commonly planted species receiving a greater number of measurements.

The measurements were taken across six districts in Dak Lak province. These measurements, in combination with the allometric models, allowed us to model the biomass increase over time for each species. Pairing this with carbon content values per species gave us insight into the above-ground carbon stocks and the rate of carbon sequestration. These biomass models do not take below-ground biomass change into account, as this requires destructive analysis in which trees are completely uprooted to be analyzed, which is beyond the scope of this study. Carbon stock values are adjusted for the number of trees in a species/age group that a farmer uproots or stumps. Pruning waste is not taken into account.

CO_2e emissions from agriculture come from various sources such as land clearing, energy, fertilizers and pesticides. Emissions from energy usage are calculated by multiplying the volume of the energy sources used by the appropriate emission factors for Vietnam[6]. Emissions from electricity usage are calculated by multiplying the amount used by the Vietnam conversion factor for grid electricity[7].

3 Three farmers in the sample had no yields due to large scale renovation of their farms. These are not taken into account in this report as much of the analysis is done on a per Mt coffee basis.

4 IDH (2013): http://www.sustainablecoffeeprogram.com/site/getfile.php?id=203

5 Diameter at Breast Height is the international standard to measure diameter of trees at 4.5 feet or 1.3 meters above the ground

6 IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Vol 1-5

7 Ecometrica (2011). Technical Paper. Electricity-specific emission factors for grid electricity (Matthew Brander et al.) https://ecometrica.com/assets/Electricity-specific-emission-factors-for-grid-electricity.pdf

Emissions from agrochemicals are caused by production, transport and direct and indirect emissions from applications of fertilizer, manure and organic matter, mainly in the form of N_2O[8]. To estimate total emissions from agrochemical use, we therefore first multiply emission factors for fertilizer and pesticide production[9] by the type and volume farmers have applied to cover emissions related to production and transport. Direct and indirect N_2O emissions are estimated based on the type and volume of fertilizer applied, its N content and the type of N contained in it, combined with the N_2O emission factors for the appropriate agro-ecological zone[10]. N_2O emissions from different types of fertilizer that contain nitrogen, compost and manure are then converted to the amount of CO_2e per kilogram of N from each type that was applied to the field.

CO_2e EMISSIONS FROM AGRICULTURE COME FROM VARIOUS SOURCES SUCH AS LAND CLEARING, ENERGY, FERTILIZERS AND PESTICIDES

Methane (CH_4) is an greenhouse gas that is predominantly produced in wetlands (such as paddy rice and marshes) and by ruminants (e.g. cows, sheep). As both wetlands and ruminants almost do not occur in the Vietnamese coffee producing areas, we have left CH_4 out in this paper.

Calculations of carbon emissions are subject to certain boundary conditions set by the PCR. Emissions from land-use change, for example when clearing a forest to plant coffee, need to be taken into account if these changes occurred within the preceding 20 years. Large-scale land clearing took place in the development of the Vietnam coffee sector, but among the farmers in this sample, and indeed for most of the Vietnam coffee sector, the clearing took place more than 20 years ago and is therefore not included in this calculation. Production of durable goods that are expected to be used for more than three years are also not included as per the PCR guidelines.

Aspects of production that individually make up less than 1% of the total emissions are considered insignificant and are not required to be taken into account. These include plastics used for coffee packaging, buckets, and tarpaulins for coffee drying. Emissions from pesticide usage also fall into this category. We have measured them, but they contribute less than 2 kilograms of CO_2e per metric ton of coffee. This effectively leaves us with emissions from fertilizer and energy to be taken into account.

The medium and highly diversified farms grow more crops than coffee alone. The emissions associated with fertilizer must be allocated to the specific crops harvested on a farm, as different crops have different rates of nitrogen uptake and use. To do so, we use the allocation rates for other crops grown from the PCR.

In coffee supply chains where wet processing takes place, significant methane emissions occur from decomposing organic material contained in waste water[11]. Robusta coffee grown on the sample farms is dry processed, which means methane emissions from processing do not play a major role. Should farmers decide to apply composted coffee pulp to their farm, then emissions associated with the composting process are factored into the emissions associated with fertilizer.

Validity

Crop surveys from industry sources estimate the total production from Dak Lak and Lam Dong at 16.2 million 60-kilogram bags of coffee in the 2017/18 season. According to the USDA's PS&D database[12], global coffee production was 159.9 million 60-kilogram bags in the 2017/18 market year, of which 65.9 million bags are robusta. The two provinces are therefore responsible for around 10% of global coffee production and 25% of global robusta production.

The PCR requires averages taken from three years' worth of data to be used in carbon footprint calculations, but in this case only two years of data were available at the time of writing[13]. We focus on the carbon footprint at farm level, whereas the PCR requires GHG emissions to be calculated from farm to port of origin (FOB) or the warehouse of a domestic roaster (CIF).

The carbon stock and sequestration modelling is a first attempt. For several of the species, including robusta coffee, there are no allometric models available. It was beyond the scope of this study to fill those research gaps. We recommend not taking the sequestration rates and stocks as 100% accurate; rather, they provide a starting point from which we expect to introduce increasing levels of refinement as future projects allow for more detailed estimations.

8 Nitrous Oxide (N2O) is a greenhouse gas with a global warming potential of more than 300 times greater than carbon dioxide (CO2). Nitric Oxide (NO) is also emitted from the soil, but is not a greenhouse gas, so is not included in our calculation of emission of greenhouse gasses (http://www.soest.hawaii.edu/mguidry/Unnamed_Site_2/Chapter%202/Chapter2C3.html).

9 Cremaschi, D.G. (2016). Sustainability metrics for agri-food supply chains. PhD thesis, Wageningen University, Wageningen, NL

10 Bouwman, A.F., L.M.J. Boumans and N.H. Batjes (2002). Emissions of N2O and NO from fertilized fields: Summary of available measurement data. GLOBAL BIOGEOCHEMICAL CYCLES, VOL. 16, NO. 4, 1058, doi:10.1029/2001GB001811, 2002

11 Killian, B. et al (2013). Carbon Footprint across the Coffee Supply Chain: The Case of Costa Rican Coffee. Journal of Agricultural Science and Technology B 3 (2013) pp. 151-170

12 https://apps.fas.usda.gov/psdonline/app/index.html#/app/downloads

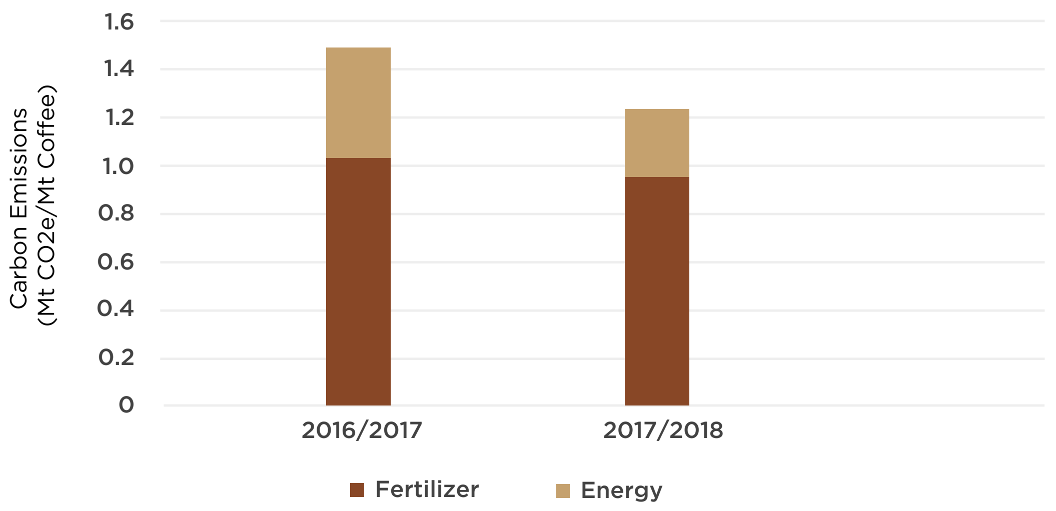
13 As the FFB program in Vietnam will run for at least another season, we expect to be able to update this report with three years of data after the 2018/19 season.

3.
RESULTS

Carbon emissions

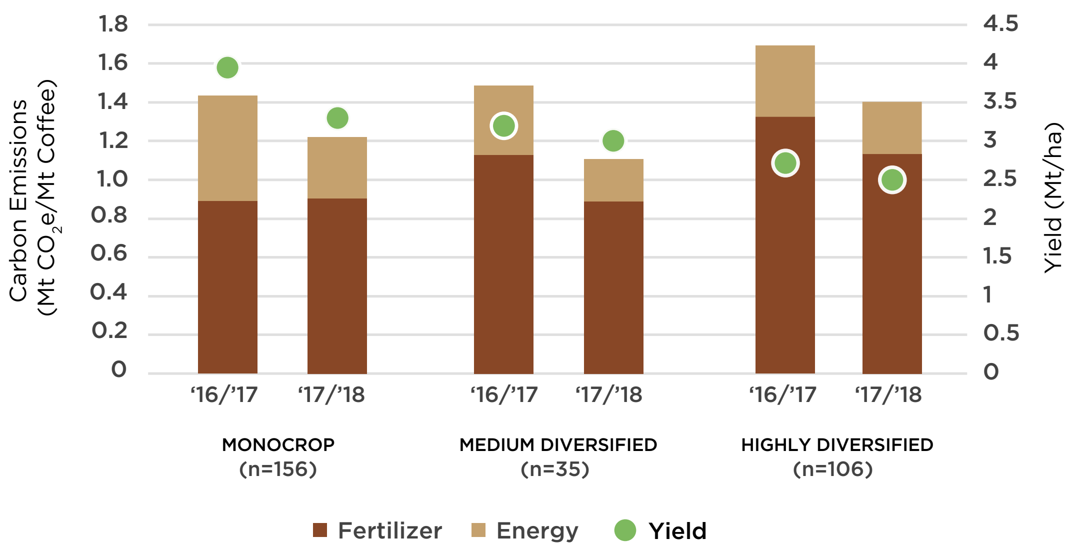
Total emissions of farm-level robusta coffee production were 1.52 metric tons of CO_2e per metric ton of coffee in 2016/17 and 1.26 metric tons of CO_2e per metric ton of coffee in 2017/18, bringing the two-year average to 1.39 metric tons of CO_2e per metric ton of coffee (Figure 1). The two sources of emissions are fertilizer and energy use, as emissions from pesticide usage were found to be less than 2 kilograms CO_2e per metric ton of coffee, and were therefore not taken into account as prescribed by the PCR. On average, 73% of total emissions are from fertilizer use and 27% from energy use.

FIGURE 1. CO_2e EMISSIONS BY SOURCE AND SEASON



In the 2016/17 season, rainfall during the flowering of the coffee was low, which required farmers to irrigate more water than normal. This explains the relatively much higher energy use of 0.47 metric tons of CO_2e for pumping water compared to the 0.29 metric tons of CO_2e in 2017/18. Emissions from fertilizer amounted to around 1 metric ton of CO_2e per metric ton of green bean. The total emissions from fertilizer have not changed significantly, but when broken down by level of diversification of the farm, the picture changes (Figure 2). On diversified farms, the PCR requires allocation of fertilizer emissions to the different crops harvested. During the 2016/17 season, no harvest information was collected for crops other than coffee. We have therefore applied the 2017/18 allocation factors to the 2016/17 data for those farms that grow other crops.

FIGURE 2. CO_2e EMISSIONS BY SOURCE AND YIELD, LEVEL OF DIVERSIFICATION AND SEASON



Yield levels among the monocrop farms went down by 17%, compared to a 7% reduction among the medium diversified and highly diversified farms. The lower absolute yield levels among highly diversified farms are largely explained by location effects as most of them are situated in Dak Lak province, while the majority of monocrop farms are in Lam Dong province. Fertilizer application levels among monocrop farms did not show any statistically significant change between the seasons. This explains the slight increase in emissions associated with fertilizer applications among farms in this group. The project agency that works with most of the highly diversified farms seems to have put more emphasis on optimizing fertilizer applications. We see this reflected in lower application levels per hectare in 2017/18. We cannot reliably allocate part of the emissions to other crops in 2016/17; but given lower fertilizer use in 2017/18 and a relatively small yield decline of 7%, we think it likely that the carbon efficiency of medium diversified and highly diversified farms has improved over time. Nonetheless, the highly diversified farms have statistically significantly higher emissions than the monocrop farms.

Also notable is that emissions from energy use decreased for each agroforestry class as a result of higher rainfall during the coffee flowering period in 2017/18. This resulted in significantly lower volumes of irrigation water being applied, and therefore less energy used for pumping (Figure 3).

FIGURE 3. CHANGE IN CO_2e EMISSIONS AND YIELDS FROM 2016/17 TO 2017/18 BY AGRO-FORESTY TYPE

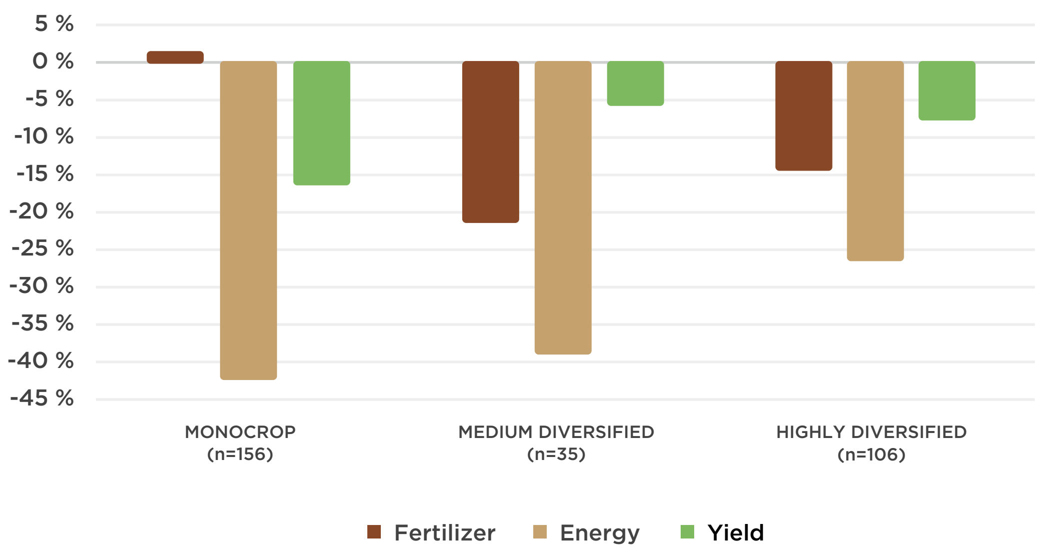
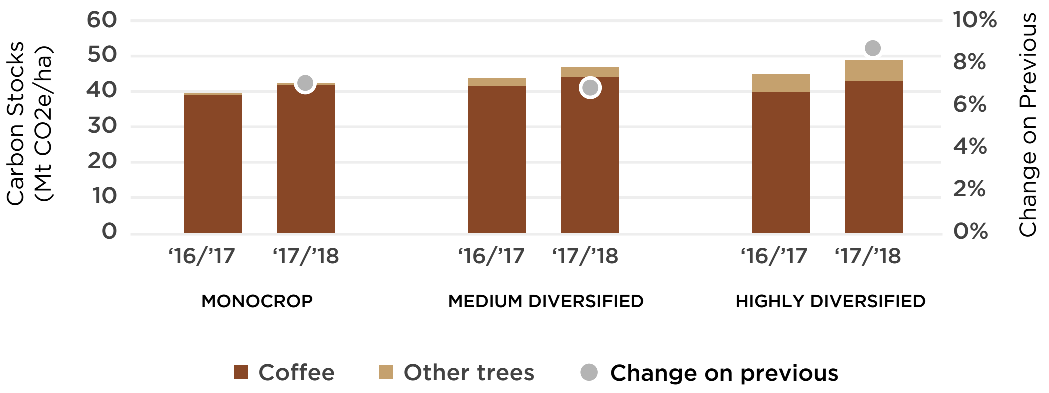


FIGURE 4. CARBON STOCKS PER HA BY AGROFORESTRY TYPE AND SEASON



The secondary Y-axis shows the rate of change in total carbon stocks from 2016/17 to 2017/18

In conclusion, when looking only at emissions per unit of coffee, the three agroforestry classes show an inter-seasonal reduction in emissions. The highly diversified farms are consistently less carbon-efficient per unit of coffee than the monocrop farms. The data period we have so far is not without its limitations, but we do see tentative indications that lower yield change correlates with a higher percentage of non-coffee trees on the farm.

Carbon stocks and sequestration

Estimated average carbon stocks were 42 metric tons of CO_2e per hectare across all farms in the 2016/17 season. This increased to 44.9 metric tons of CO_2e per hectare in the 2017/18 season. The medium diversified and highly diversified farming systems show a slightly better performance, with their carbon stock being 15% and 11% higher respectively than the monocrop farms in the 2017/18 season. The highly diversified farms show a slightly higher rate of carbon stock change from 2016/17 to 2017/18: 8.7% compared to 7.0% and 6.8% respectively for the monocrop and medium diversified farms (green circles related to right hand axis on percentage change; Figure 4).

Irrespective of the agroforestry class, coffee is the largest contributor to the total carbon stocks per hectare. Coffee planting density is slightly lower among the highly diversified farms, but not by much. The contribution of non-coffee trees to the total carbon stock is 11% among the highly diversified farms, compared to 5% on the medium diversified farms and 1% on the monocrop farms. On the highly diversified farms, we expect the contribution of non-coffee trees to increase significantly over the coming five to ten years, as the diversification on these farms is a fairly recent phenomenon and many of the non-coffee trees have not yet matured.

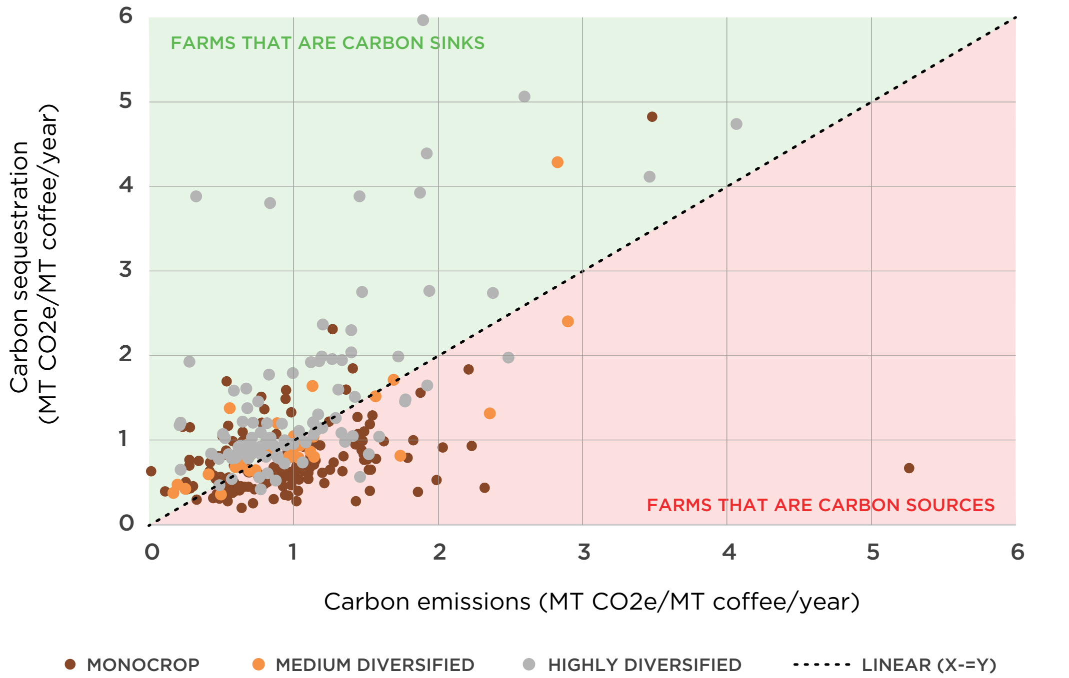
For our purposes, the carbon sequestration is defined as the change in carbon stocks per hectare or metric ton of coffee over a defined period of time, in this case the coffee seasons. Figure 4 shows a larger total carbon stock rate of change on the highly diversified farms. In absolute terms, their carbon sequestration is 3.9 metric tons of CO_2e per hectare per season compared to 2.8 metric tons of CO_2e per hectare per season for the monocrop farms, and 3.0 metric tons of CO_2e per hectare per season for the medium diversified farms.

Carbon footprint

One of the questions posed by the ISLA landscape program is whether an increased level of diversification with other tree crops can offset part of the emissions, or even transform farms from carbon sources into carbon sinks.

The carbon footprint is calculated by subtracting the sequestration from the emissions. A negative carbon footprint therefore means that the farm acts as a carbon sink, removing more carbon from the air than is emitted during production. We found that the majority of the highly diversified farms act as carbon sinks (Figure 5).

FIGURE 5. CO_2e EMISSIONS AND SEQUESTRATION BY FARM AND AGROFORESTRY CLASS FOR 2017/18



The X=Y line indicates where emissions equal sequestration. Farms above the line act as carbon sinks, those below it as carbon sources.

Of the highly diversified farms, 73% are carbon sinks while 27% are sources of carbon (Figure 6). The latter tend to be farms that have quite recently diversified, and we would expect them to start acting as carbon sinks when their non-coffee trees mature. For the monocrop farms, the picture is reversed, with 70% acting as carbon sources. The 30% of monocrop farms that do act as carbon sinks (on a per-metric-ton-of-coffee basis), are those that are both highly productive and highly efficient in terms of fertilizer use. On those farms, the CO_2e volume captured with the biomass increase of coffee trees exceeds the emissions. Combined with the emissions data, we found that highly diversified farms have a negative carbon footprint (Figure 7). On average, these farms remove 0.16 metric tons of CO_2e per season from the atmosphere for every metric ton of coffee they produce. The medium diversified farms and monocrop farms on the other hand emit 0.11 and 0.37 metric tons of CO_2e per metric ton of coffee produced, respectively.

It is arguable that the comparison shown in Figure 7 is not entirely fair given that non-coffee crops are included in the sequestration values, but not in the emissions. Recall that fertilizer-related emissions are allocated to coffee and other crops based on harvest volumes and N uptake rates of each crop. Fertilizer used for other crops is therefore not part of emissions, even though sequestration by non-coffee trees is included.

When we remove the allocation factors from the emissions and assign all fertilizer-related emissions solely to coffee, irrespective of other crops grown on the farm, the footprint of monocrop farms hardly changes. However, the footprint for medium diversified farms changes from 0.11 to 0.13 metric tons of CO_2e per metric ton of coffee per year, while the footprint of highly diversified farms changes from -0.16 to -0.13 metric tons of CO_2e per metric ton of coffee per year. We can therefore conclude that including fertilizer-related emissions from other crops slightly changes the footprint values, but the overall pattern remains the same.

FIGURE 6. SHARE OF FARMERS AND EMISSION-SEQUESTRATION BALANCE BY FARMING SYSTEM

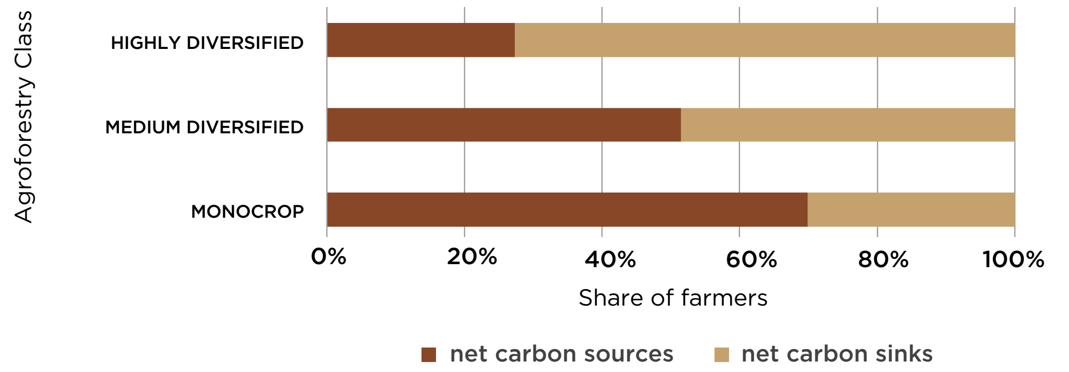
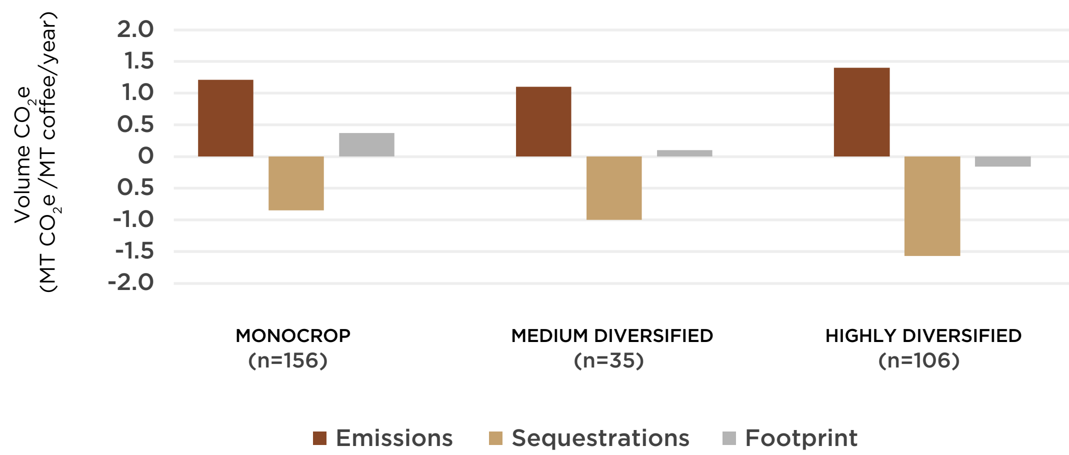


FIGURE 7. CARBON EMISSIONS, SEQUESTRATION AND FOOTPRINT BY AGROFORESTRY CLASS IN 2017/18



4. CONCLUSION

Fertilizer is by far the most important contributor to carbon emissions in Vietnam's coffee production, followed by energy. Fertilizer application levels are fairly stable from one year to the next, but energy use varies with rainfall levels during the coffee flowering period. When rainfall is lower than usual, energy usage goes up as farmers increase the volumes of irrigation water they apply. Other sources of emissions such as pesticides are negligible, contributing around 2 kilograms of CO_2e per metric ton of coffee.

Despite a significant number of highly diversified farms, the majority of carbon stocks are in coffee trees. The rate of sequestration on highly diversified farms is higher than that of farms in the other agroforestry classes. Coupled with the fact that diversification is a more recent phenomenon on a number of farms, this leads us to believe that the role of highly diversified farms in acting as carbon sinks will continue to grow over the coming years.

This report shows that coffee farms in Vietnam can act as carbon sinks without sacrificing yields. Highly diversified farms with more than 30% non-coffee trees on their farm on average act as carbon sinks, and sequester 0.16 metric tons of CO_2e per year for every metric ton of coffee they produce. This is in contrast with monocrop farms, which emit 0.37 metric tons of CO_2e per year for every metric ton of coffee produced.

We also found that 30% of the monocrop farms and 49% of the medium diversified farms are carbon sinks. In these cases, the use of fertilizer tends to be better optimized and more efficient relative to the yields the farms achieve.

While the period on which this analysis is based covers only two years, it appears that diversification of monocrop coffee farms in Vietnam's Central Highlands is a viable strategy to transform the sector's contribution to climate change from carbon source to carbon sink. Another priority is to optimize fertilizer management on those farms that are currently carbon sources.

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