Consultancy on Coffee Carbon Footprints

Advice provided to the Sustainable Coffee Challenge Latin America Coffee Carbon Footprint Baseline Study

Extended summary of the final version 1.1

Full version of the final version 1.1 available:

https://agritrop.cirad.fr/617119/

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Date of publication: March 2026

Montpellier, France

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Conservation International (CI) has led the Sustainable Coffee Challenge since 2015, a global coalition bringing together stakeholders across the coffee sector to promote actions and investments aimed at making coffee fully sustainable. As part of this effort, CI is coordinating a study to establish national carbon footprint baselines for coffee production in Latin America. Cirad experts remotely accompanied the study throughout the process to help to ensure the consistency in the applied methods and the relevance of the data collection. Cirad provided continuous feedback to Meo Carbon Solutions, which was the technical implementing partner for the study, through online meetings, email exchanges, and incremented feedback consolidated in a review Excel spreadsheet and a review report, which summarised all discussion points and ongoing recommendations. The incremented review report was first sent after discussions regarding the draft data collection template and the sampling strategy (in February 2025), then after the first data collection phase for Brazil and Colombia (in November 2025). The final version was sent after reviewing Meo Carbon Solutions' draft study report (in January 2026). Overall, Meo Carbon Solutions was reactive and very constructive throughout the collaboration. However, the study's deadlines and constraints related to field data collection did not make it possible to systematically have timely exchanges, notably in terms of raw data analysis, to make sure that all recommendations could be properly applied.

Regarding the data collection, the main review and recommendations consisted of i) ensuring that the enumerators understand the plantation history and the logic driving the farmers' practices, and that they cross-check the data; ii) gathering multi-annual data, including on the immature stage, to allow for a proper modelling of the perennial cropping cycle that accounts for time-averaged data aligned with the full crop cycle length; and iii) detailing organic inputs and the post-harvest processing that are important GHG contributors but too-often poorly described.

Regarding the sampling strategy, the main review and recommendations consisted of i) following a stratified sampling procedure based on an agronomic typology of coffee systems, whose determinants are further detailed in the report; ii) detailing the decision trees for each origin/country accounting for all the typology parameters and indicating the final adjusted sample size; and iii) providing exhaustive and consistent literature background information to ensure the typology consistency and relevance, since mistakes in the first typology was found.

Based on the primary data collection for Brazil and Colombia, the main review and recommendations consisted of i) better harmonising data collected and further investigating key inputs' distributions by farm size category, farming system type, and location to spot potential errors; ii) excluding data points related to farm types that were clearly underrepresented; iii) approaching a proper perennial crop cycle modelling by taking advantage of the age distributions in the samples and compiling age-weighted averages for inputs and coffee outputs; and iv) using collected data to check the Cool Farm Platform baseline assumption that "input levels (fertilisers, pesticides, etc.) are proportionally aligned with the yield curve", which may be a wrong assumption when modelling the perennial crop cycle.

Finally, based on the final draft study report sent on December 19th 2026, the main review and recommendations consisted of i) relying more strictly on ISO norms that define how to present life-cycle based carbon footprints and ensure that the method is fully transparent and results are FAIR; ii) being much more precise, in particular, regarding the objectives of the study, the functional unit, and the system boundaries; iii) clarifying the potential issues with the applied tool (Cool Farm Platform) and further analysis tools; iii) providing disaggregated results and systematic dispersion information; iv) discussing more the links between the results and management levers depending on the farm types; and finally iv) providing more and better figures to illustrate the results.

1 CONTEXT

Conservation International (CI) has led the Sustainable Coffee Challenge since 2015, a global coalition bringing together stakeholders across the coffee sector to promote actions and investments aimed at making coffee fully sustainable. As part of this effort, CI is coordinating the Latin America Coffee Carbon Footprint Baseline Study to establish national carbon footprint baselines for coffee production in five countries: Brazil, Colombia, Honduras, Mexico, and Peru. This initiative builds on a previous study conducted by USAID Green Invest Asia, finalized in 2023, which established national carbon footprint baselines for Robusta coffee production in Vietnam and Indonesia. The objective is to develop industry-accepted and statistically robust carbon footprint baselines for both Arabica coffee in the five targeted origins, as well as Robusta coffee in Brazil.

Meo Carbon Solutions acts as the technical implementing partner, while CI engaged two experts from Cirad—Cécile Chéron-Bessou and Didier Snoeck—to provide an independent and scientifically rigorous review of the study. Chéron-Bessou specializes in life cycle assessment and carbon footprint analysis of perennial crops, particularly in tropical regions, and has contributed to several scientific publications and international projects related to coffee sustainability. Snoeck, a former Cirad researcher with extensive experience in coffee agronomy, farm management, and agroforestry systems, previously worked as a consultant for Nestlé and has been involved in multiple research and decision-support projects for coffee production systems. Their role was to advise the Sustainable Coffee Challenge and Meo Carbon Solutions teams by reviewing methodological approaches, contributing expertise on sampling strategies and data collection design, and helping interpret results to strengthen the credibility, robustness, and transparency of the carbon footprint baselines. Collaboration between the experts, Sustainable Coffee Challenge, and Meo Carbon Solutions began in August 2024 and continued through a series of virtual meetings and document reviews. The experts provided feedback on key aspects of the study, particularly the farmer data collection template and the representative sampling strategy, through written comments, meeting discussions, and iterative document revisions. The final full review report is available online: https://agritrop.cirad.fr/617119/. The full version contents an extended version of the comments and analysis summarised here and an Excel spreadsheet with all Cirad's comments, provided along the whole study, and Meo Carbon Solutions' replies.

Cirad experts' input was advisory; Cirad experts were not responsible for data collection or calculations. While Meo Carbon Solutions considered the experts' recommendations, final methodological and operational decisions remained the responsibility of the implementing partner, meaning that the conclusions presented in the final report do not necessarily reflect the full position of the Cirad experts regarding all methodological or technical choices.

2 REVIEW OF THE DATA COLLECTION TEMPLATE

Exchanges between Meo Carbon Solutions and the Cirad experts began in September 2024 with the review of a data collection template presented as an Excel spreadsheet listing survey questions. Experts were also asked to comment on the links between the survey template and the Cool Farm Platform, which was selected by the study's governance body to conduct the GHG calculations (the analysis of the Cool Farm Platform is provided in the full report version only). Overall, the survey template was considered well-structured and comprehensive from the outset. Most comments therefore aimed to clarify certain questions, simplify data collection, and improve the reliability and consistency of key variables based on practical field experience.

Key recommendations were as follows:

- Enumerators need to take time to grasp the essentials from the plantation history and understand the logics driving the farmers' practices.
- Understanding the systems, cross-checking information and visiting the plantations will help to reduce bias and error risks, notably regarding amount frequencies and units.

- ❖ It is necessary to model the perennial crop cycle and collect input data for at least two stages: the immature and mature stages. For the immature phase, at least one year of data (mainly on inputs) is required. For the mature phase, at least two to three years are required. The perennial modelling of both inputs and outputs should be consistent and reflect the actual crop cycle length and logics.
- ❖ Where questions are supposed to address "averaged practices", it should be clearly stated and dispersion around the mean values should be estimated. Questions about percentages should be avoided as much as possible and converted into practical ratios.
- ❖ More details on organic inputs (beyond coffee crop residues) should be collected.
- ❖ A more detailed accounting for post-harvest processes up to the green coffee beans might be needed in order i) to ensure the mass balance by cross-checking coffee input/output throughput, moisture content, residues amounts and overall losses; ii) to properly quantify emissions related to the post-harvest various processes (dry, wet, semi-wet); and to check for consistency across practices such as irrigation and waste-water treatment and recycling, or organic inputs and crop residues treatment and application.

3 REVIEW OF THE SAMPLING PROCEDURE

Based on experience from the GIA study, the experts recommended avoiding a purely statistical sampling approach based only on production volumes, as this assumes a single average system and overlooks the diversity of coffee farming conditions. Instead, they advised a **stratified sampling strategy** based on a typology of coffee systems reflecting key agronomic factors. After discussions with Meo Carbon Solutions, the final parameters used to capture system heterogeneity included climate and soil conditions, land-use change (LUC) history, fertiliser use, farm size, agroforestry practices, and processing methods.

Soil and climate were considered fundamental drivers of production potential. Experts recommended using detailed environmental datasets (e.g., FAO soil databases) to obtain indicators such as soil pH, organic carbon, cation exchange capacity, and base saturation, which help assess nutrient availability and fertiliser needs. These data should be derived from geographic coordinates rather than collected from farmers. Combining environmental information with survey data would allow comparison between recommended agronomic practices and actual farmer practices, revealing variability across systems.

The typology was considered relevant, but experts suggested clearly defining decision trees for each country to show how parameters determine sampling categories. Particular attention was also recommended for land-use change, as even limited conversion—especially from forests—can strongly affect carbon footprints and soil conditions. Finally, experts emphasised that organic inputs require careful investigation because they are diverse, often poorly quantified, and can significantly influence greenhouse gas emissions.

In summary, key recommendations were as follows:

- ❖ The main recommendation was to follow a stratified sampling procedure based on an agronomic typology of coffee systems taking into account soil and climate constraints, cropping systems main characteristics, and post-harvest processes. Once that was adopted, comments were:
    - o Meo Carbon Solutions' approach that i) classifies the coffee systems based on the agreed critical parameters, and then ii) weights the sample sizes based on these parameters' heterogeneity across origins, seems very relevant.
    - o The background information is rich and important. However, there is a lack of references to actually assess the accuracy of the statements regarding all parameters and their homogeneity degrees (e.g. the initial assumption for agroforestry systems in Brazil was erroneous). There is a critical need to justify the heterogeneity degrees, which are paramount to finalise the sample sizes, based on actual scientific data. A lot of publications are available.

4 REVIEW OF THE DATA COLLECTED

The Cirad experts reviewed the datasets for Brazil (arabica only) and Colombia submitted in October 2025 to assess data consistency and whether the sampling adequately captured the diversity of coffee production systems. Although not all country datasets were available due to time constraints, the review of these two cases was considered indicative for the remaining countries. Roughly 500 farms were surveyed in both countries. We reviewed the various Excel spreadsheets in detail (8 for Brazil and 5 for Colombia), however it was not possible to check each individual entry (~1000). The analysis first examined the geographic distribution of surveyed farms using plot coordinates to evaluate representativeness in terms of soil type and altitude, two key agronomic factors influencing coffee production.

In Brazil, farms were sampled across four states, with a strong concentration in Minas Gerais, the country's main coffee-producing region. While this distribution partly reflects production patterns, some important producing areas such as Paraná (arabica) and Rondônia (robusta, hence not significant for arabica) were not represented, and São Paulo appeared underrepresented. The surveyed farms covered several major FAO soil units, although some soil types, particularly lixisols, were less represented. Soil analysis showed that most farms have acidic soils (pH below 5.5) and low base saturation, conditions that normally require liming and nutrient amendments. However, survey data suggest that lime application is generally insufficient or poorly implemented, indicating a gap in management practices. Many soils also have low nutrient retention capacity, meaning coffee production relies heavily on external inputs. Altitude distribution showed most farms located between 500 and 1000 meters above sea level. Farm size distribution was relatively balanced between small (≤10 ha) and medium (10–100 ha) farms, with few large farms, while unshaded monoculture dominated the production systems. Shaded or polyculture systems were extremely rare in the sample, making some system categories, particularly traditional polyculture, statistically non-representative. Recorded planting densities also appeared lower than expected for modern unshaded systems, so it was recommended to cross-check against input use.

In Colombia, farms were surveyed across nine major producing departments, covering most key production regions. The sample was dominated by small farms, consistent with national production patterns. Soil analysis indicated very acidic soils and low base saturation for most farms, suggesting a strong dependence on fertilisers and soil amendments. However, unlike Brazil, soils generally showed higher cation exchange capacity, indicating better nutrient retention. Coffee systems were mostly monocultures, although many farms still maintained shade trees, with about 38% of farms unshaded. Planting density averaged around 4950 trees per hectare.

Overall, the datasets appeared sufficiently complete to run carbon footprint calculations using the Cool Farm Platform, although some minor inconsistencies and outliers were recommended to be corrected through automated data checks. The experts further recommended modelling perennial crop cycles using groups of farms with similar system characteristics, allowing inputs and outputs to be averaged according to crop development stages before running the calculations. While the sampling covers the main environmental conditions and farming systems, it was noted that a few poorly represented categories may need to be excluded. It was also noted that results should therefore be reported both by farming system category and at a national level, using transparent weighting based on the relative contribution of each system to national production.

Key recommendations were as follows:

- Checking the detailed list of potential issues in the Annex_Review_CIRAD and updating survey Excel spreadsheets.
- Harmonising languages, in order not to mix Spanish, Portuguese, and English within a same column.
- Cross-checking the number of dead trees in one year with the percentage of lost trees over the cycle (x planting density x area) to check for the order of magnitude of the annual loss and the inter-annual variability; this information will be necessary to have a robust estimate of the percentage of dead plants that will also affect the biomass residues.

- ❖ Automating the extraction of nutrient contents across the various compound fertilisers (recorded with different names, languages, and compositions) to sum up inputs for each nutrient per tree and per hectare (ha).
- ❖ Drawing box plots per input type per ha (for each fertiliser nutrient, liming substance, and active substance for pesticides) in order to identify outliers.
- ❖ Further investigating the inputs' distribution by farm size category, farming system type and location (defined as a homogeneous soil-climate area rather than an administrative region) in order to check for the variability intra- and inter-regions and define potential production types to be weighted in order to come up with a representative weighted average per coffee origin. Farming system type is defined by a coffee variety and coffee product type combined with a cultivation type (monoculture or not, ± shaded, as referred in column EN) – irrigation may also be parameterised.
- ❖ Excluding farm types that are clearly underrepresented, e.g., only 1 traditional polyculture system surveyed in Brazil.
- ❖ In order to approach a proper perennial crop cycle modelling, average data for "New plantation" could be used to model an average immature stage for all plantations. The average plantation duration (expected lifecycle) should be modelled per farming system type and location and based on median values per group. Also, plotting coffee outputs depending on the median age of the coffee trees (EP) per type of system would help modelling the production curve depending on the age. The curves can then be used to model the weighted-average yields along the perennial cycle. Finally, plotting yield/ha depending on input levels (i.e., N, then K fertilisers) would be necessary to check the Cool Farm Platform baseline assumption that "input levels (fertilisers, pesticides, etc.) are proportionally aligned with the yield curve" (c.f. section 2.1.2).

5 REVIEW OF THE STUDY RESULTS

The review of the results was based on the first draft PDF final report provided by Meo Carbon Solutions in December 2025. A power point with aggregated greenhouse gas results was also shared, but the report was the only comprehensive source to assess the methodology and results. Overall, it was noted that the report is clearly written, but several methodological aspects require deeper explanation to ensure transparency, consistency, and alignment with established standards. In particular, the analysis should more closely follow international standards for life cycle assessment and carbon footprint studies, such as ISO 14044 and ISO 14067, which emphasise clear definitions, transparency in calculation steps, and reproducibility of results.

A key issue concerns the definition of the study's goal and scope. The report mainly describes the geographical scope but does not sufficiently clarify the broader objectives, the intended uses of the results, or the level of precision required. These elements are essential because they determine how the system should be modelled and how results should be interpreted. The functional unit—the reference unit used to express results—is also introduced too late in the report and remains insufficiently defined. For example, the meaning of the unit "kg GBE" is not clearly explained, nor are important product specifications such as dry matter content, processing stage, or whether beans are ready for export or local use. Similarly, the system boundaries require a clearer description and a visual diagram indicating which processes are included or excluded along the coffee supply chain. This includes clarifying how land-use change is accounted for, defining co-products such as coffee residues, and explaining how these are treated in the calculations.

The methodological section also requires restructuring. After presenting the goal and scope and system boundaries, the report should logically describe the sampling strategy and data collection before explaining the calculation methods. One major point of confusion is the use of two carbon footprint calculators—the Cool Farm Platform and the 4C Carbon Footprint Add-On—without clearly explaining the rationale for using both tools. Their methodological differences, assumptions, and default parameters are only briefly described, making it difficult to understand why results differ between them. If the purpose was to compare tools, this comparison should be explicitly structured and supported with a table summarizing key methodological similarities and differences. More broadly, the report lacks transparency regarding calculation parameters critical to coffee systems, such as residue ratios, crop cycle modelling, and emission factors. A clearer explanation of modelling assumptions—including treatment of carbon pools, biogenic carbon, field emissions, and land-use change—should be provided, with detailed parameter lists included in annexes.

Another concern relates to how missing or inconsistent data were handled. The report briefly mentions the use of proxies or extrapolations when data were missing or implausible but does not quantify their extent or explain the thresholds used to identify problematic values. Although statistical tools such as z-scores were used to detect outliers, the procedure is described later in the report and remains unclear. Greater transparency is needed regarding how data corrections were performed, the proportion of primary versus adjusted data, and the rules applied to replace missing values or remove outliers.

The presentation of results also requires improvement. Some methodological explanations currently placed in the results section should instead appear in the methods section. Comparisons between the two calculation tools are presented but not sufficiently interpreted, which may create confusion. Given that tool comparison was not the primary objective of the study, it would be clearer to present results consistently from a single tool and then discuss tool differences in a dedicated section. More importantly, the results are only presented as national averages, despite the effort invested in developing a typology of coffee farming systems during the sampling phase. Reporting only country-level averages hides the diversity of production systems and limits the ability to identify key emission sources and improvement opportunities for specific farm types. Results should therefore be disaggregated by farming system category and accompanied by dispersion indicators such as standard deviations or coefficients of variation to show the variability within samples.

Finally, the format of the results section needs refinement. Key information—such as whether land-use change is included in the calculations—should be clearly and systematically indicated in tables, figures, and text. More visual representations are needed to make the results easier to interpret, while existing figures require clearer units, consistent number formatting, and inclusion of dispersion indicators to support meaningful comparisons (e.g. error bars). Overall, improving methodological transparency, result disaggregation, and visual clarity would greatly enhance the credibility and usefulness of the study's findings.

6 CONCLUSION

The collaboration between Meo Carbon Solutions and Cirad was smooth and constructive. However, constraints on Meo Carbon Solutions' side due, notably, to issues to access exhaustive field data, while expectations from all involved stakeholders were high, did not make the task easy for Cirad experts, who received the information quite late and had to adjust their agenda. At the end, not all datasets could be reviewed and there was no time to further interact in-between all results' calculation and the final report delivery.

The recommendations were globally considered and particularly fruitful at the beginning through the detailed review of the survey (two rounds) and the co-construction of the stratified sampling strategy (also two rounds). However, in the end, results did not embed all the recommendations. First, the perennial cycle was not properly modelled, or at least, there is no proof in the provided material that input/output data were weighted averaged according to the plantations' ages across the datasets per region or origin in order to properly balance productive and non-productive years (the Cool Farm Platform perennial add-on did not automate this modelling and we advised it should be done apart). Not accounting for the full perennial cycle means that results are highly depending on the plantations' age distribution. This means that i) results across origins will vary depending on the sector development in each country (i.e., more or less developed and old plantations); ii) differences across origins due to sector development will be more or less severe depending on the cropping systems as full-sun monocultures usually have shorter production cycles than agroforestry ones; and iii) depending on the plantation age distribution within a country, the impact of the immature stage will be more or less underestimated. Given the scale of the data collected, including new plantations and plantations at various development stages, it could be possible to conduct a "modular assessment" (as recommended) or even a "spatial assessment" (Bessou et al., 2013). Although the overarching goal was to produce national-level CFT baselines; it should be acknowledged that this goal, in the opinion of the experts, is barely achievable based on statistics-based sampling, given the very high numbers of producers and the high diversity of practices that do mostly not follow normal distributions. Agronomy-based typologies instead make it possible to model the diversity of the systems and their relative contributions to the national impact, while providing more insights on the improvement levers at the practice and practicable levels.

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