GHG emissions of green coffee production

Toward a standard methodology for carbon footprinting

Report
Delft, November 2010

Author(s):
Maartje Sevenster (CE Delft)
Jan Verhagen (Plant Research International)

Publication Data

Bibliographical data:
Maartje Sevenster (CE Delft), Jan Verhagen (Plant Research International)
GHG emissions of green coffee production
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Delft, CE Delft, November 2010

LCA / Greenhouse gasses / Carbon oxide / Measuring / Standards / Environmental pressure
FT : Coffee

Publication number: 10.2284.83

CE-publications are available from www.ce.nl

Commissioned by: Sustainable Agricultural Initiative Platform
Further information on this study can be obtained from the contact person Maartje Sevenster.

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Summary

In this project, the scope for product specific rules for carbon footprinting of (green) coffee is investigated and a proposal is drafted for further work toward actual definition and implementation of such a standard. Overall, the initiative for standardisation aims at two applications:

- Assessing farm management GHG reduction potential.
- Calculating carbon footprint of green coffee for communication in the further value chain (traders, roasters; B2B[1] information).

By investigating current knowledge of GHG emissions associated with the production of coffee, as well as existing standards in the area of carbon footprinting, the main methodological issues and data gaps are identified.

The following main science gaps are identified:

- Net changes in soil organic matter, due to land and crop management, erosion, overirrigation, etc. (variable, unknown).
- Effects of shade trees and intercropping (variable, unknown).
- Direct and indirect emissions due to fertiliser application (uncertain and variable).
- Direct and indirect land use change (variable, hard to quantify and/or attribute).
- Processing: emissions associated with fermentation and treatment of residues.

Some of these issues may be circumvented in a carbon footprinting methodology by using standard emission factors such as the IPCC emission factors for fertiliser application. Variability may be addressed by differentiating such standard emission factors for farming system types. It is recommended to develop a set of standard emission factors that can be implemented easily when certain parameters (farm management, climatic conditions, soil type, etc.) are known.

From a methodological point of view, the following are the main challenges:

- Criteria for the inclusion of inputs and outputs: especially the choice on including or excluding soil and aboveground carbon changes.
- Data quality requirements including coverage, primary data content, precision, completeness: a good balance between representative data and practicable data collection has to be found. This may be the biggest challenge, as was also stated in the consultation round.
- Calculation procedures: define a level of differentiation of farming systems that is both fair and accurate enough and define appropriate emission factors.
- Allocation of flows and releases: define allocations and cut offs (system boundary) that are in line with both PCF and farm management requirements. This applies especially to organic materials going off-farm for further useful application or acquiring organic residues from other farms for on-farm application.

For the next phase of the actual development, an opportunity for funding and broad support could be in widening the scope from only PCR development to linking in with adaptation and sustainable trade partnerships.

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[1] Business to business; for consumer information, the entire coffee life cycle is more relevant.

1 Introduction

1.1 Background

The coffee sector, and particularly the coffee roasters, will likely have to be able to quantify and declare the impact of their activities in terms of GHG emissions at some point in the future. Therefore, the SAI Platform WG coffee wants to work on a non-competitive approach to calculating and reporting on GHG emissions that is accepted by the whole sector and the general public.

In this project, the scope for product specific rules for carbon footprinting of (green) coffee is investigated and a proposal is drafted for further work toward actual definition and implementation of such a standard. By investigating current knowledge of GHG emissions associated with the production of coffee, as well as existing standards in the area of carbon footprinting, CE Delft and Plant Research International identify the main methodological issues and data gaps.

Overall, the initiative for standardisation is in fact aiming at two applications:
- Assessing farm management GHG reduction potential.
- Calculating carbon footprint of green coffee for communication in the further value chain (traders, roasters; B2B[2] information).

The potential differences between those two applications of GHG emission monitoring will be outlined in this report.

1.2 Project goals

The goals of this project are:
- Overview of current knowledge of GHG emissions of green coffee.
- Overview of standards for GHG monitoring.
- Identification of data gaps and methodological issues.
- Proposal for phase II: actual development of coffee 'product category rules for carbon footprinting' as mentioned in ISO 14067 and GHG protocol standards.

The production of green coffee is defined to include the production chain up to and including transport to the nearest (export) harbour.

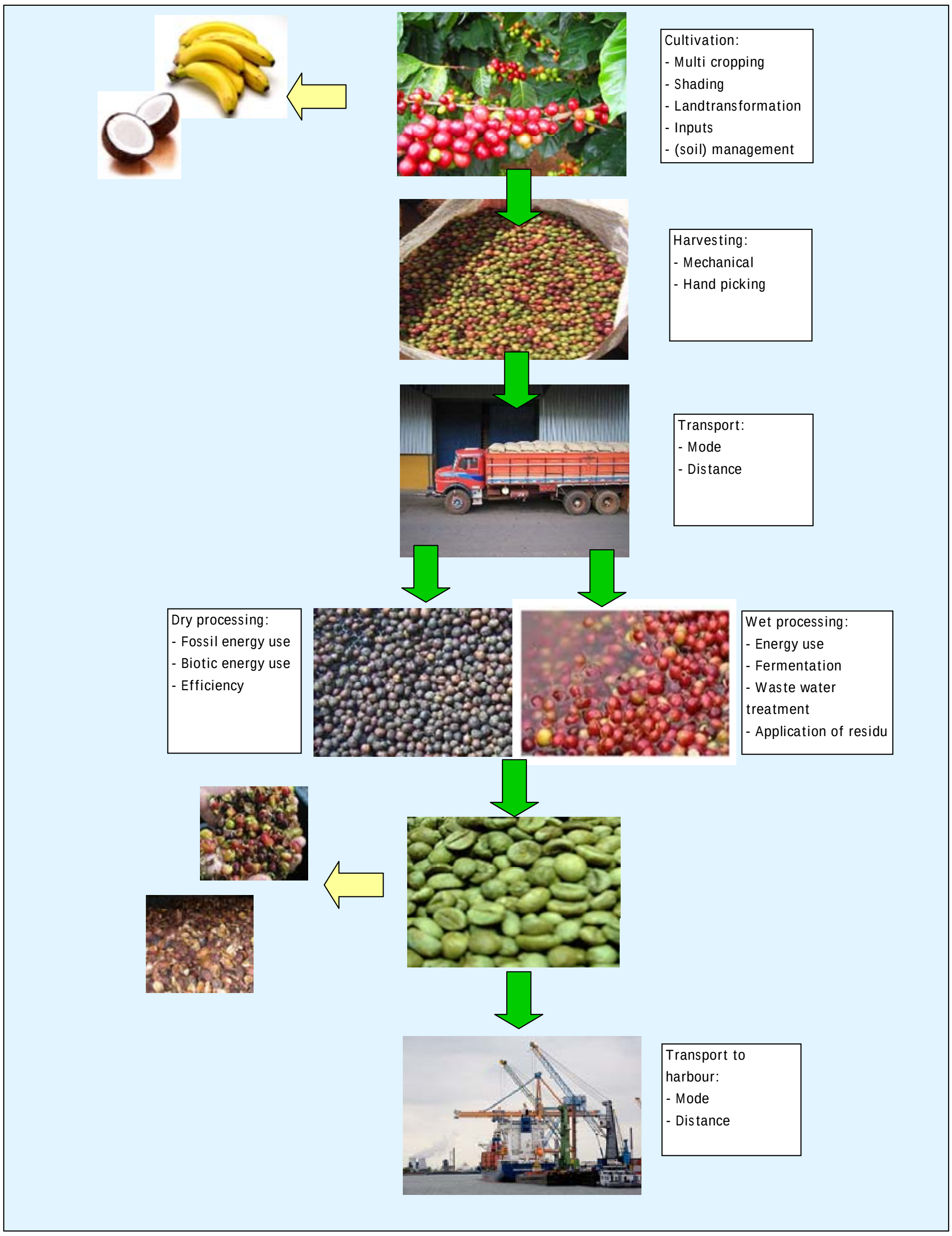
1.3 Green coffee production

In the production of green coffee, roughly the following steps are involved:
- Production of seedlings.
- Cultivation.
- Harvesting.
- Transport.
- Processing (wet or dry).
- Transport to harbour.

[2] Business to business; for consumer information, the entire coffee life cycle is more relevant.

Figure 1 gives a colourful overview, listing issues and potential co-products per life cycle stage.

Figure 1 **Overview of steps in the life cycle of green coffee. Yellow arrows indicate potential (example) co-products**



1.4 Carbon footprinting

According to the draft ISO 14067 standard a carbon footprint is defined as the 'weighted sum of greenhouse gas emissions and greenhouse gas removals of a process, a system of processes or a product system, expressed in CO_2 equivalents'. When applied to a product system, the term product carbon footprint (PCF) is used. In this case, there is always a full or partial life cycle perspective.

Life cycle scores may be used for various purposes. Traditional LCA was targeting relative scores for a range of options to be compared. The outcome of such a study is in principle 'A is better than B within the context of this study'. In order to ensure that such a claim is valid in a general sense, the ISO guidelines prescribe an expert review if the claim is made public.
It is now however increasingly common to use 'footprint' information in B2B customer negotiations or even B2C labeling. Footprints give an absolute score for a certain product within a standard methodology framework, called a Product Category Rule (PCR), in common terminology (ISO 14067, WRI and WBCSD, 2010). Measurement and monitoring of GHG emissions has developed into one of the main topics of sustainable production and consumption over the last years. Several standards exist or are on their way to harmonise monitoring and calculation methods. The following applications may be distinguished (e.g. GHG protocol[3]):
- Organisation level (monitoring and reporting).
- Project level (quantifying mitigation efforts).
- Product level (carbon footprinting).

Next to those different applications, different 'scopes' for investigation exist. The scope can range from only those GHG emissions occurring at the actual location (scope 1 in GHG protocol) to all GHG emissions associated with energy use, energy production, materials purchased, etc. (scope 3 in GHG protocol).

Based on this, we can identify the following applications when specifically looking at the production of green coffee:
- Organisation = farm (monitoring).
- Project = on-farm management options (management).
- Product = green coffee at harbour (PCF).

Strict monitoring and reporting is not amongst the aims of the initiative (see Section 1.1) so the organisation level will not be explicitly discussed in this report. Assessing on-farm management options is one of the aims, so project level is part of the assessment. The challenge will be to shape the footprinting standard in such a way as to integrate both goals.

One of the main differences between product- and projectlevel assessments lies in the fact that one typically addresses a status quo and the other addresses change. In LCA terminology (e.g. ILCD Handbook, JRC, 2010) this distinction is called attributional versus consequential approach. The different approaches may be characterised as follows:
- Attributional approach: aims at describing the environmental effects associated to a product life cycle, describes the status quo in average terms.
- Consequential approach: aims at describing the total effects (also outside the system) of changes in a life cycle, describes total changes in marginal terms.

A consequential approach may be applied to products, but in that case the result should be interpreted as the 'effect of drinking one extra cup of coffee on top of current consumption' whereas in attributional approach, the results should be interpreted as the 'average effect of drinking a cup of coffee'. In a consequential approach, the net emissions associated with a product may in fact be negative. In an attributional approach this can never be the case unless through long-term carbon sequestration.

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3 www.ghgprotocol.org.

1.5 This report

This report provides an assessment of issues that will play a role in the development of a PCR and recommends an approach for the actual phase of developing those (Phase 2). The draft report was presented to a group of experts for consultation. Input was received from:

- ISEAL.
- ECOM.
- 4C.
- GTZ.
- Hanns R. Neumann Stiftung.
- Rainforest alliance.

The input was used to shape the final version of the report. Some comments were relevant to actual PCR choices and they were not incorporated in this report as yet.

In Chapter 2, the sources of emission in the cradle-to-harbour life cycle of green coffee will be described, along with the current scientific knowledge on quantification of those emissions. At the end of this chapter the most important gaps in scientific knowledge will be discussed.

In Chapter 3, carbon footprinting and accounting standards will be described. This includes a list of items that need to be part of a PCR. Chapter 4 will give an overview of the main conclusions and a recommendation for Phase 2 of the project.

Abbreviations used in this report are:

- EPD: environmental product declaration.
- PCR: product category rules (EPD).
- PCF: product carbon footprint.
- CF-PCR: product category rules for carbon footprinting[4].
- LULUC: land use and land use change (GHG emissions thereof).

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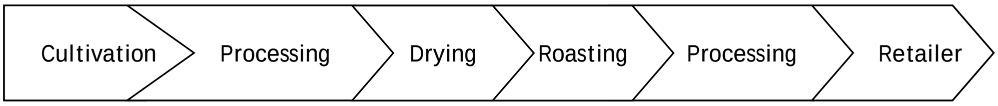
4 This term was adopted from the ISO 14067 draft of March 9th, 2010. Recently, the use of the term PCR was dropped to avoid confusion with ISO 14025. The current term is Product Group Specifications. For the purpose of this report, the two terms are interchangeable.

2 GHG emissions: science

2.1 Introduction

In general terms the coffee value chain is not different from other agricultural commodities and can be described in sections starting from the cultivation and ending at the consumer (Figure 2). The material or product flow is towards the consumer whereas the flow of demands and rewards is in the opposite direction.

Figure 2 **Steps in the complete coffee life cycle (drying may take place at several points)**



In this chapter, we will look at the demands related to GHG emissions and focus on the first two components: cultivation and processing. We will identify critical factors that determine the GHG emission profile of the coffee value chain.

2.2 Coffee cultivation

In agriculture the effects of management are co-determined by natural factors (soil, climate) and the technologies used and skills of the farm manager. This holds for production levels but also for the environmental impacts. So also GHG emissions. Extreme events that have the potential to dramatically reduce the carbon stock (e.g. fire, drought, storms, erosion, pest and diseases) are addressed briefly. This section focuses on regular farm management.

The Intergovernmental Panel on Climate Change (IPCC) produced accounting guidelines for GHG emissions. It is a tiered approach using default emission factors to estimate the GHG emissions related to different field and farm level activities in the first tier. The second and third tier include more location and system specific information. The detail of the measurements and modelling determine the difference between the last two tiers.

A full emission accounting includes all significant GHGs. For agriculture these are: carbon dioxide, methane and nitrous oxide. Carbon dioxide in agricultural systems is linked to land conversion, soil management and energy use, nitrous oxide is mainly related to the use of fertilisers whereas methane is strongly linked to livestock husbandry via enteric fermentation and manure storage. In this paragraph we will focus on carbon dioxide and nitrous oxide emissions at the farm level. Methane emissions are relevant during processing and waste management of the product (Section 2.3).

Issues related to adopt GHG reducing measure in agriculture are partly GHG specific. For both carbon dioxide and nitrous oxide the variability and uncertainty of the processes determining the emissions is relatively high. Monitoring and verification of the emissions reduction is therefore a difficult task. Research has already contributed to increasing the understanding and quantification the processes and associated emission reductions. It is however clear that the most important driver of the emissions management is not uniform within fields or farms and between farmers. As management is also related to the age of the crop and weather conditions the impact of management will also differ over time.

Agriculture is a main source for nitrous oxide in the atmosphere. This emission is mainly determined by the nitrogen input (i.e. organic and inorganic fertiliser) to the soil. Managing nitrous oxide emissions can be done via fertiliser management but these emissions are highly variable in space and time making monitoring difficult. Reductions in nitrous oxide emission are effective as these are non-reversible.

The carbon related to the use of fossil fuel for the production of inorganic fertiliser and machines can be relatively easy allocated to the agricultural production process. Changes in terrestrial carbon are equally important. Land conversion and preparation to establish nurseries and farmland are important sources of carbon emissions. The magnitude of these emissions depends largely on the carbon stored in the initial land cover. A conversion of pristine forest will have a large negative impact whereas the conversion of degraded agricultural land could also have a positive impact.

An established coffee farm will also store carbon. Maintaining this carbon in the soil and above ground biomass is an important strategy. Increasing the carbon levels in the systems via soil and crop management (e.g. tillage, pruning and waste management) is also possible. Carbon sequestration is viable option, but it should be kept in mind that:

- The amount that can be stored is limited, the saturation level is mainly determined by the biophysical environment.
- The stored carbon is non-permanent[5]. Changes in management, pests and diseases can decimate the carbon sequestered. This process can be much faster than the actual sequestration process.
- The actual amount sequestered needs to be assessed for a fix period relative to a reference period.
- Activities to manage emissions or sequester carbon in one site could lead to changes in emissions outside that region. Tracing all possible interactions pathways is very difficult.
- Aboveground biomass can be measured fairly well and remote sensing is a useful tool to monitor above ground changes. Measuring soil carbon and especially changes in soil bulk density are still difficult.

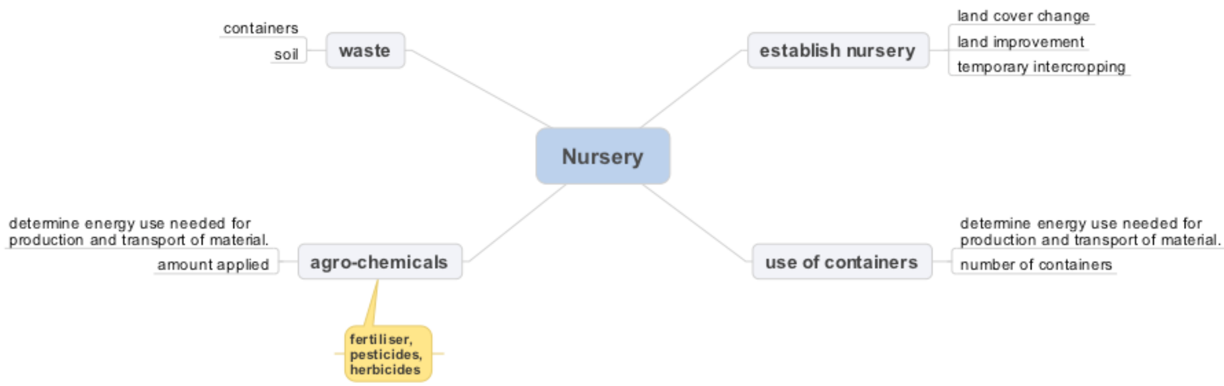
2.2.1 Coffee cultivation and GHG emissions

When accounting emissions the systems should be consistent, transparent, accurate and verifiable. This section deals with the components that need to be addressed to arrive at a consistent and transparent system. Accuracy and verifiability are beyond the scope of the assignment.

The cultivation of coffee starts with the seedlings in the nursery. Propagation with seeds directly in the field is also done but is more risky. In Figure 3 the relevant processes are displayed.

[5] Note, however, that there can be some net flux into deeper layers so some storage can be considered permanent (> several 100 years).

Figure 3 Representation of relevant processes in nursery stage



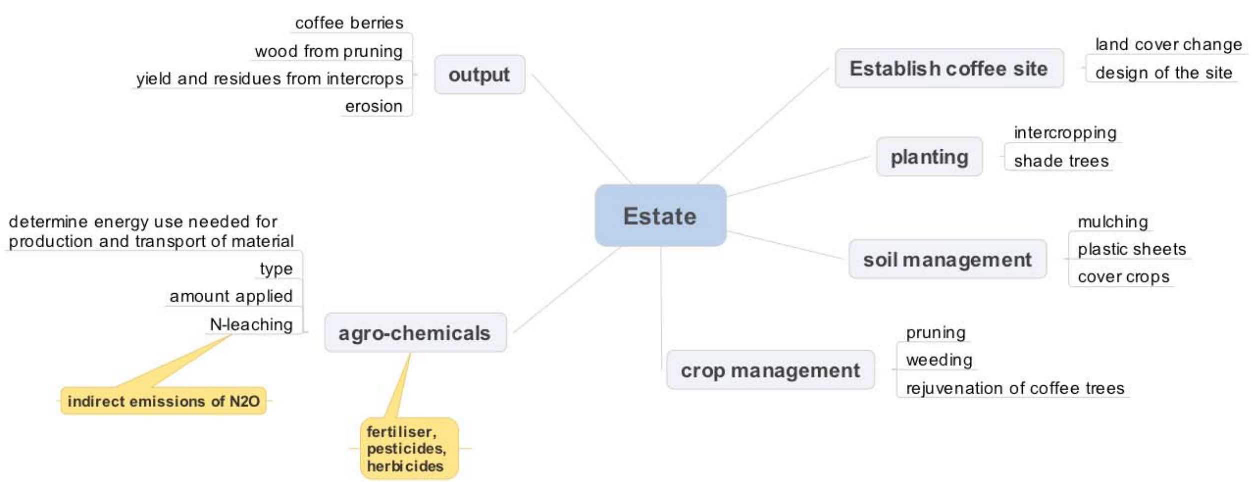
A large variety of production systems exist. The two ends of the spectrum are forest coffee and estate grown coffee. The first relates to a natural forest system with coffee trees of which the berries are collected without further interventions. In large-scale unshaded estate grown coffee management (fertiliser, pruning, chemical pest control) is an essential component.

Beyond the natural factors (i.e. soil, climate) management is the key factor that determines the differences in GHG emissions between coffee production systems. This inventory will therefore focus on the impact of management on GHG emissions. The actual order of magnitude will however also be determined by the biophysical setting of the production system.

It takes about three to four years before coffee plants become productive during this period intercropping is and option to still have some income generated from the land. In any case establishing a coffee estate is a large investment and depending on the size of the plot planning is needed develop the site.
A growing plant accumulates carbon until it reaches maturity and may contribute to the accumulation of carbon in the soil.

In Figure 4 the management option that influence GHG emissions are presented. Not all production systems will include all options, also differences in the frequency of the interventions (e.g. fertiliser application, pruning) will differ.

Figure 4 Representation of relevant processes at the estate



In Table 1 the various activities and potential sources of carbon and nitrous dioxide linked to the cultivation of coffee are summarised. The unit of measurement will vary per activity. But when area and productivity are know the emissions can be allocated to either a yield (kilogram product per hectare), the product (kilogram end product) or area (hectare). The time scale of activities and effects will depend on the age of the site (nursery and estate, coffee estates can have a lifespan from 7 up to 50 years), the reference period or baseline and the reporting period. The latter two are part of negotiations, but when clear are relatively easy to establish. The detail and accuracy however will in general be lower when not data is available.

Table 1 Activities and associated GHG emissions and uncertainty

Estate	Type	Description	Carbon/ Nitrous oxide	Uncertainty/ range*	Remarks	
Establish site	Land cover change	This includes deforestation, land clearance and rehabilitation of degraded land	Difference in above and below ground carbon	High/high	Above ground carbon is relatively easy to measure (e.g. with remote sensing). Below ground carbon is more difficult to quantify	
	Design of the site	This includes the inclusion of windbreaks and erosion control measures with non-coffee species	Difference in above ground carbon	Low/ medium	Above ground biomass is relatively easy to measure	Effect of erosion measures is included in the output section

Estate	Type	Description	Carbon/ Nitrous oxide	Uncertainty/ range*	Remarks
Planting	Intercropping	Crop type and management related to this crop		High/high	
	Shade trees	Choice of shade tree and associated management		Medium/ medium	Note that inter-cropping and shade trees can be combined
Soil management	Mulching	Organic material added	Amount and carbon content of added material	High/ medium	The origin of the material should be taken into account If carbon is moved from outside the coffee system the carbon stock is depleted in the place of origin
	Plastic sheets		Energy needed for production and transport	Low/ medium	Life time of the material should be taken into account
	Cover crops	Reduction of leaching of fertilisers, erosion and added organic material to the soil depending on management of cover crop	Effects are difficult to quantify	High/ medium	
Crop management	Pruning and rejuvenation	Regrowth and yield	Relatively easy to assess frequency and material removed	Low/ medium	Effect on yield and management of material is included in the output section
	Weeding	Remove competition	For mechanical weeding energy needs should be taken into account	Medium/ medium	If material is removed, carbon is also removed

Estate	Type	Description	Carbon/ Nitrous oxide	Uncertainty/ range*	Remarks	
Irrigation		Active irrigation	Energy for pumping	Low/low	Overirrigation may lead to excess leaching of N (irrigation). This is currently outside scientific scope	
Agro-chemicals	Fertiliser	Supply nutrients that are essential for crop growth. Aim is to increase yields	More biomass means more carbon. Type and amount used are important	High/high	For inorganic fertiliser the production and transportation costs should be included	For inorganic fertiliser the origin of the material should be taken into account (see Section 2.3.).
			Fertiliser is a main source of nitrous oxide. Type and amount are important	High/high	Leaching of N may result in indirect emission	
	Urea, lime		CO_2 emissions from application	Medium/ medium		
	Herbicides, pesticides	Combat competing plants and insects that reduce production	For mechanical application energy needs should be taken into account	Low/ medium	For inorganic herbicides/pesticides production and transportation costs should be included	
Output	Outputs from the system	Coffee berries	Main output is removed from the system: removal of carbon	Low/low		
		Residues e.g.: wood from pruning or other crops	Removal of carbon if removed from the system	High/ medium		

Estate	Type	Description	Carbon/ Nitrous oxide	Uncertainty/ range*	Remarks
		Yields from other crops	Removal of carbon	Low/high	
		Erosion	Loss of topsoil is loss of carbon	Medium/ high	

* Uncertainty/range. Both are estimated and qualified high, medium and low. A high range in uncertainty means that for some of the issues mentioned, uncertainty may be high, for others low. Also, the uncertainty may be higher or lower in different circumstances.

2.2.2 Farming systems

While management in production is typically done at the field level, decision making and integration is done at the farm level. By using a whole farm approach, spatial and temporal interactions between the C and N cycle are considered properly allowing for an accurate benchmarking between production systems.

A farming system is defined as a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate. Depending on the scale of the analysis, a farming system can encompass a landscape or only a small area. The delineation in farming systems offers a framework in which different development strategies, innovation and management options can be quantified and explored.

In general, diverse and integrated systems like the smallholder system can reach higher efficiencies in material (carbon) flows. This however requires management skills and insight in the interaction with soil processes and crop responses that are not always available at the local level.

Farming systems will vary in size, intensity, specialisation and objectives per region, agro-ecological and socio-cultural environment. Most distinct is the difference between smallholder farmers and the large estates, but also regional and continental differences in the shade provision from banana plants to trees, soil management are important.

The effectiveness and efficiency of interventions (presented in Table 1) will not only depend on the agro-ecological setting but also depend strongly on trade-off and synergies within farming system. Placing the interventions within the farming system (e.g. shade versus non-shade in Africa and Asia; highland farming in Africa, South America and Asia, soil management for different soils and farming systems, mixed versus mono systems) will allow for a complete and fair calculation of the GHG balance and targeted research and extension.

It is possible to define standard farming systems based on some of the following parameters (indicative):
- Agro-ecological zone (high land/lowland, wet/dry).
- Mixed – mono cultures.
- Size/specialisation/objectives.
- Intensity (use of inputs, management).
- Soil.
- Possibly socio-economic setting (access to markets, infrastructure).

Emission factors for some of the emission sources, such as direct and indirect emissions of N_2O from fertilisation, could then be defined per farming system. This will require considerable effort, however. Farm categories are already utilised by Rainforest Alliance in pilot projects, on the other hand, so there may be practical examples to start from.

A model the farming system can be used to identify pools and flows of carbon, and can serve as a framework to identify mitigation options related to these pools in the context of the whole farm. For specialised estates the picture is less complex than for a smallholder systems with a large variety of activities.

Figure 5 Simplified model of a specialised estate

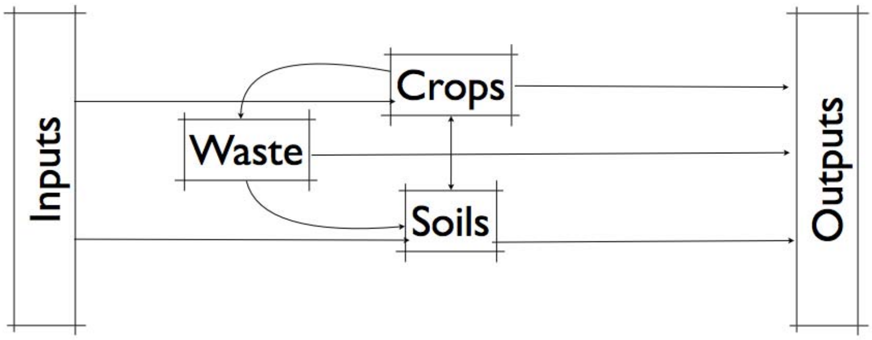
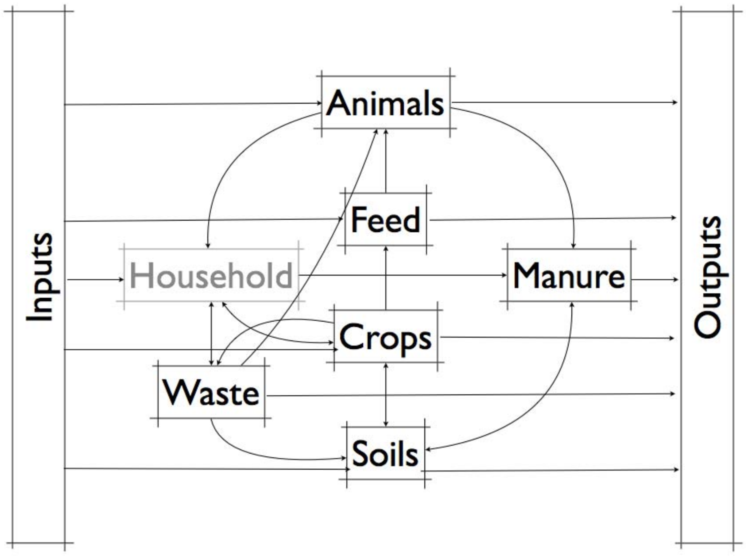


Figure 6 Simplified model of a smallholder system



Management will affect the different pools depict in Figure 5 and Figure 6 (i.e. soil and crop management, for the list of the relevant management options see Table 1) the arrows indicate the flows of carbon and greenhouse gasses. Differences in climate, soils and terrain also partly dictate the management options and the effectiveness on yields and greenhouse gas emissions.

Not all farming systems will use or be able to use the same management options or have identical input levels. Smallholder systems in general will have lower input (i.e. fertiliser, irrigation use of agro-chemicals) whereas large estates will have higher inputs of agro-chemicals and energy.

The effects of management on the GHG balance can be derived from plot, field, on-farm data obtained via experiments and or interviews combined with expert knowledge and models.

Diverse and integrated systems like the smallholder system can reach higher efficiencies in material (carbon) flows. This however requires management skills and insight in the interaction with soil processes and crop responses that are not always available at the local level. Low producing systems will in general be less efficient and have higher emissions per unit product and area than high producing systems.

To establish a GHG balance differences in use of fossil fuel, agro-chemicals and soil and crop management are the most important factors to address.

2.3 Coffee processing

Once ready for harvesting, the following processes need to be performed in order to produce green coffee:
- Picking/harvesting.
- Transport.
- Sorting.
- Processing.
  - Dry: drying (natural/forced).
  - Wet: (de-)pulping, fermentation, mucilage removal, drying (natural/forced).
- Storage.
- Hulling.
- Grading and sorting.
- Transport of green coffee to harbour.

GHG emissions arise on the one hand due to energy use at the various processing and transport steps. The type of energy carrier is crucial in determining the GHG emissions per unit of energy applied. For transport, the type of vehicle used is also of importance. Transport between farm and processing location may be done with tractors and/or relatively small vehicles that have a high fuel consumption per ton-kilometre of transport. Also transport to harbour is typically not possible with large and efficient lorries.

In some systems, coffee drying is done actively (i.e. not just using direct solar energy) with fire wood or fossil fuels. The emissions of CO_2 from combustion of the wood may be disregarded, as they are short-cycle emissions (uptake from the atmosphere and re-release within 100 years). However, some net emissions do arise and there may be an issue with deforestation or emissions from forestry. This depends very much on local conditions. In the case of use of fossil fuels, all emissions of combustion and production of the fuel are part of the system. This is true for all energy use for treatment, processing and transports for the particular system under study. When there is on-farm processing, the transport (distances, modality, loading) will be different from a system with centralised processing. A drying step may occur at several points in the production chain.

Overall, we can say that emissions associated with combustion and pre-combustion (production) of energy carriers are typically well known and well defined. For the use of fuels, it is not necessary to know the detailed combustion process in order to determine the GHG emissions (contrary to e.g. air pollution). The amount of fuel actually used may be translated into GHG emissions using standard IPCC factors.

The mass balance of the processing has to be taken into account. Loss of cherries in the sorting leads to ratio of green coffee to inputs and thus to higher foot print per ton of green coffee.

A potentially large source of GHG emissions is related to the treatment (disposal) of residues and waste water of processing. Residue consists of the outer skin (pericarp/exocarp), the pulp (mesocarp) and the hull (endocarp) as well as some of the silver skin. Waste water is high in organic content, causing oxygen demand in surface waters, and is fairly acid. Treatment options and associated GHG emissions are discussed in more detail below.

2.3.1 Wet processing

The wet processing method is considerably more complex than the dry processing method and involves two steps – pulping and fermentation – that yield wet residues and waste water that may lead to considerable climate impacts depending on treatment. Also the de-hulling, after drying, results in a residual flow that has different possible applications.

Emissions of concern are methane and nitrous oxide (N_2O). If any CO_2 emissions were to occur, e.g. in incineration of residue, they would be biogenic and may thus be disregarded from a climate change perspective.

Amongst others, waste water with biogenic components arises from the pulping and the fermentation steps. The ongoing digestion of these polluted streams causes decrease in oxygen content in water ways and emissions of methane and N_2O. Although treatment methods are also important for reduction of water pollution we will focus here on the climate effects.

Table 2 gives an overview.

Table 2 Residual flows in wet processing

Processing steps for wet processing	Nature of the rest streams	Possible uses/treatment
1. Pulping: Removal of skin and some of the pulp by pressing the fruit by machine in water through a screen	Polluted water	– Direct emission to surface water or soil – Filtering and recirculation: washing/pulping waste water – Series of ponds – Lagoon: fermentation waste water – UASB: biogas recovery
2. Ferment-and-wash or machine assisted wet processing (mechanical demucilaging): removal of rest of pulp and mucilage (slimy substance surrounding the parchment (hull))	Wet residue of pulp and mucilage	– Direct application on plantation as fertiliser – Composting and application on or off farm – Cattle feed, biofuel, energy recovery, growing mushrooms, citric acid production, gasification, ethanol production (pretreatment needed in most cases)
3. Hulling: the parchment layer (hull) is removed by dehulling machine	Hulls (the coffee bean endocarp contains 54% cellulose, 27% pentosans and 19% lignin)	Biofuel, energy recovery, gasification, cattle feed[6], growing mushrooms[7], producing a molded article from coffee bean hulls[8]

Both in direct emission to surface water and in treatment in lagoons, CH_4 and N_2O emissions will arise. If released to the atmosphere, those emissions have to be fully counted toward the product system. In treatment options with biogas recovery, the methane becomes a co-product that may be applied as an energy source, either within the system or externally. In this situation, it may be considered to replace fossil methane (natural gas) and thus to lead to a significant reduction in emission of fossil CO_2. Depending on methodology choices, a 'carbon credit' may be given to the product system, even if the methane is used outside the system. The same is true for direct use of (dry) residues for energy purposes. Such choices regarding allocation and system boundaries are discussed in Chapter 3 (especially the textbox in Section 3.3.4, 'System expansion' on page 31). Note that even after methane capture, there may be residual emissions of greenhouse gases to the atmosphere related to the waste water, which need to be included.

When the residues are used as organic fertiliser on the farm(system) itself, all actual emissions are part of the system. In external applications, also as feed or substrate, again some allocation will have to be applied in order to determine farm/product overall foot print (see Section 4.3). Energy use and

6 http://www.scielo.br/scielo.php?pid=S0102-09352009000600015&script=sci_arttext.

7 http://scialert.net/fulltext/?doi=rjes.2008.145.150&org=10.

8 http://www.freepatentsonline.com/3686384.html.

non-energy GHG emissions of all pre-treatment and transports of such residue application options should obviously not be overlooked, but not necessarily be allocated to the green coffee (see Section 4.3).

2.3.2 Dry processing

In dry processing, skin, pulp and hull are all removed simultaneously, resulting in a relatively dry residue. The applications are essentially the same as for the dry residue (hull only) in wet processing. Main difference with wet residue is the inability to apply dry residue as fertiliser or compost. It can be applied as mulch.

Table 3 gives an overview.

Table 3 Residual flows in dry processing

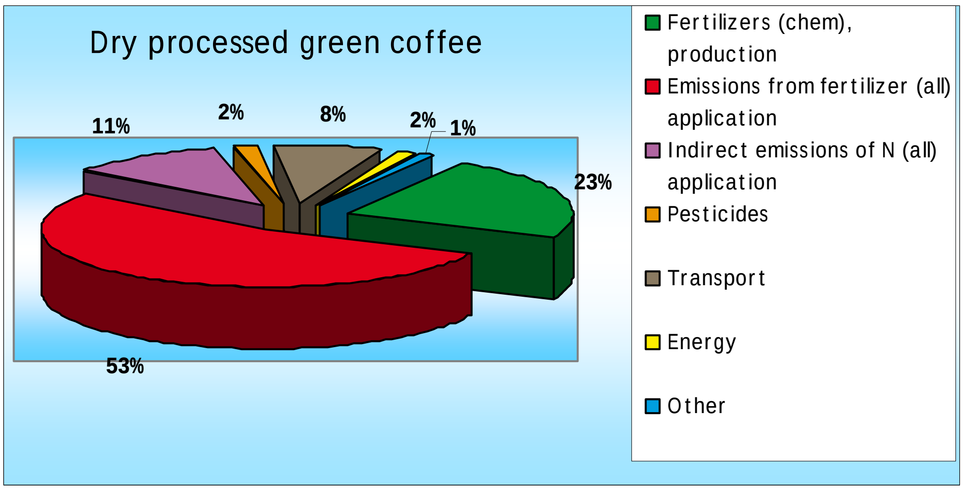
Processing steps for dry processing	Nature of the rest stream	Uses
1. The bean is dried for several weeks	NA	NA
2. The skin, pulp and parchment (hull) are removed in one step	Dry residue	Biofuel, energy recovery, growing mushrooms, citric acid production, gasification, ethanol production (pre-treatment needed in most cases)

2.4 Existing studies

In Figure 7 and Figure 8, detailed footprints are given for dry and wet processed green coffee at harbour to give an impression of contributions of various emission sources.

Typically, the relative contribution of transport to the cradle-to-harbour emissions of green coffee are of the order of 5 to 10%. The energy used in processing contributes typically less than 2% but may be higher in some specific cases.

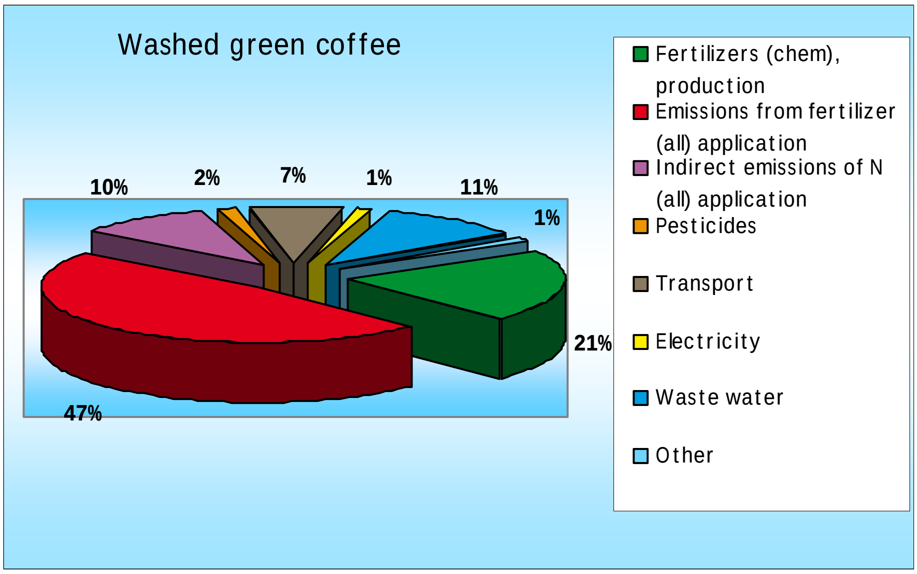
Figure 7 Example of contributions toward footprint: dry processed green coffee at harbour



Source: SaraLee.

For washed green coffee, the emissions associated with waste water disposal may contribute 10-20% to the total (11% in this example, Figure 8).

Figure 8 **Example of contributions toward footprint: wet processed green coffee at harbour**



Source: SaraLee.

This leaves cultivation as the main factor (70-85%). Most of that is associated with fertilisation, both from the production of chemical fertilisers and from emissions due to N-fertilisation and the application of lime and urea. In these examples, approximately 50% of the green coffee footprint thus results from volatilisation and leaching of nitrogen, as well as CO_2 emission of lime and urea, from fertilising. This is based on average IPCC factors, but the emissions will in practice depend crucially on various parameters, as discussed in Section 2.2. In lower input systems, of course the contribution of fertilisers will be lower. Also for organic fertilisation emissions of volatilisation and leaching occur, however.

2.5 Science gaps

2.5.1 Cultivation

The following main science gaps are identified:

– Net changes in soil organic matter, due to land and crop management, erosion, overirrigation, etc. (variable, unknown).
– Effects of shade trees and intercropping (variable, unknown).
– Direct and indirect emissions due to fertiliser application (uncertain and variable).
– Direct and indirect land use change (variable, hard to quantify and/or attribute).

Some of these issues may be circumvented in a carbon footprinting methodology by using standard emission factors such as the IPCC emission factors for fertiliser application. Variability can be addressed to some extent by differentiating such standard emission factors for farming system types, as suggested in Section 2.2.

Such an approach could be used for shadow trees, e.g. distinguishing N-fixing, C-fixing and wood yield in standard categories.

The effect of local soil condition and characteristics is large. A good balance has to be found between fair product comparison and optimal farm management. On the one hand, a farmer should not necessarily be ‘punished’ for working on less favourable soil. On the other hand, the drivers to improve should be geared to local conditions as much as possible.

The consequences of attribution and choice of system boundaries for GHG accounting and management in diverse and integrated farming systems and landscapes are not well studied.

In short, default emission values are lacking or do not always accurately reflect the local situation. There is a clear need to develop management and farming system-specific emission factors in the given biophysical context.

At the local and regional level, various studies describe in detail the production process at the farm level, including the effects of different management options on yield and yield quality. A global overview however is lacking. To be able to benchmark different systems and assess the impacts of interventions on the GHG balance such a comprehensive overview is needed.

Adaption and mitigation effects

From a farm management perspective, it is important to realise that mitigation options associated with soil carbon stocks also have important adaptation potential. Coffee production systems are directly affected by climate change. Besides soil and topography, temperature, water and wind are important criteria by the selection of production sites. A few months with relative low rainfall is needed to induce flowering. A small rise in temperature or changes in rainfall regime could have a large impact on production potential or even render areas unsuitable for coffee production. In mountainous production areas the temperature effect will be clearest as production system are forced uphill. Temperature increases can also result in changes in occurrence and pressure of pests and diseases, creating extra challenges for management.

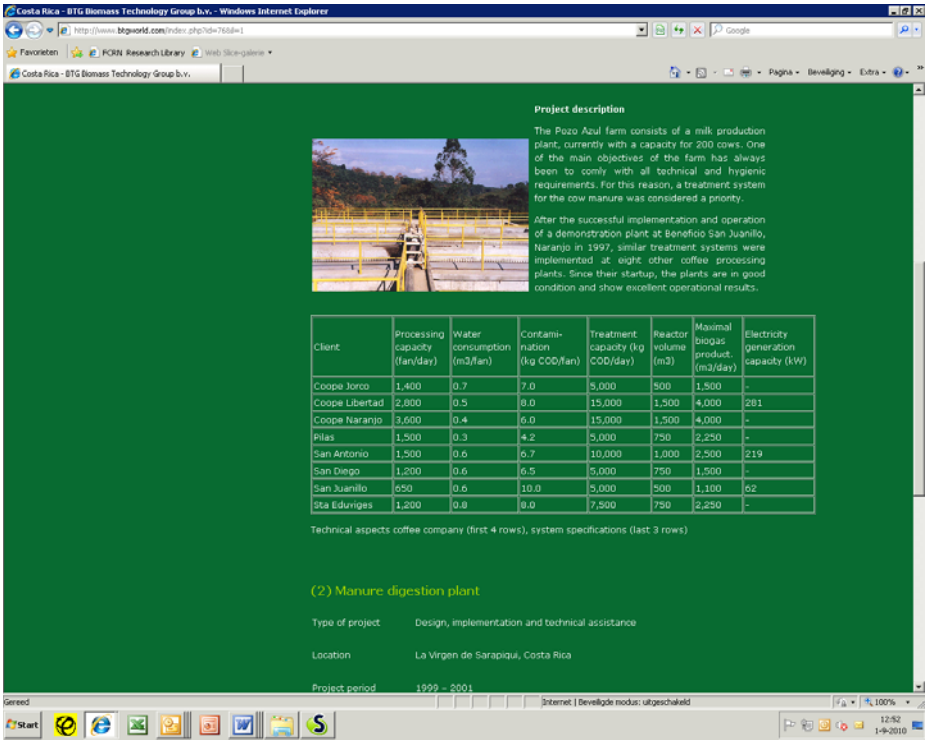
Finding measures that both contribute to a climate friendly, lower GHG emissions, and climate safe, adapted to climate change, production systems will be the challenge for the sector in the coming years. Stabilising production via choice of variety and improved management will no doubt contribute to achieving these goals. To better understand the adaptation and mitigation options requires more empirical monitoring of on farm activities and the effects on production and GHG emissions. Although adaptation potential can not really part of a carbon footprinting PCR, more knowledge on this is very valuable for sustainable coffee farming.

2.5.2 Processing

The main gaps for processing are the emissions associated with fermentation and treatment of residues. Methane and N_2O emissions in fermentation processes are complex and depend very much on local circumstances. Amongst others, the amount of waste water per ton of cherries also varies considerably, with huge ranges in efficiency of water use. Whether this makes a difference with respect to the amount of GHG emissions per ton of processed coffee is not clear. Ultimately, the amount of biotic material is the same; the effect of higher concentration in anaerobic processes in lagoons or otherwise is unclear. Other factors are temperature, oxygen levels in the surface water, etc.

An estimate of the potential methane emission from waste water is 1 cubic metre of methane per m^3 of water (Jan von Enden, GTZ PPP project). This is probably a high value as methane production and capture was actually the goal. This value translates to approximately 0.7 kg of methane per m^3 of water.
The Biomass Technology Group works on UASB reactors and gives a saving of approximately 25 ton CH_4 per year per reactor module of 250 m^3 capacity. Details for specific projects are given on their website (see Figure 9). Specifications differ considerably and deriving emissions factors may not be straightforward.

Figure 9 Listing of project parameters for UASB



Project description

The Pozo Azul farm consists of a milk production plant, currently with a capacity for 200 cows. One of the main objectives of the farm has always been to comly with all technical and hygienic requirements. For this reason, a treatment system for the cow manure was considered a priority.

After the successful implementation and operation of a demonstration plant at Beneficio San Juanillo, Naranjo in 1997, similar treatment systems were implemented at eight other coffee processing plants. Since their startup, the plants are in good condition and show excellent operational results.

Client	Processing capacity (fan/day)	Water consumption (m3/fan)	Contami-nation (kg COD/fan)	Treatment capacity (kg COD/day)	Reactor volume (m3)	Maximal biogas product. (m3/day)	Electricity generation capacity (kW)
Coope Jorco	1,400	0.7	7.0	5,000	500	1,500	-
Coope Libertad	2,800	0.5	8.0	15,000	1,500	4,000	281
Coope Naranjo	3,600	0.4	6.0	15,000	1,500	4,000	-
Pilas	1,500	0.3	4.2	5,000	750	2,250	-
San Antonio	1,500	0.6	6.7	10,000	1,000	2,500	219
San Diego	1,200	0.6	6.5	5,000	750	1,500	-
San Juanillo	650	0.6	10.0	5,000	500	1,100	62
Sta Eduviges	1,200	0.8	8.0	7,500	750	2,250	-

Technical aspects coffee company (first 4 rows), system specifications (last 3 rows)

(2) Manure digestion plant

Type of project Design, implementation and technical assistance

Location La Virgen de Sarapiqui, Costa Rica

Project period 1999 - 2001

Source: www.btgworld.com.

For treatment of solid wet residue, the emissions are equally variable.

3 GHG emissions: standards

3.1 Introduction

In this chapter we will summarise the content of standards concerning GHG emissions, focussing on issues that are of relevance for the development of a standard PCR for green coffee.

As discussed in Section 1.4, an important parameter of GHG emission quantification is whether an attributional or consequential approach is used. In relation to this, the choice of allocation of emissions between co-products, is important. We will start to list the main parameters that need to be defined in a PCR. Some of the individual standards provide such lists as well.

In the textbox below, the definition of CF-PCR according the ISO 14067 (draft) is given.

Carbon footprint product category rules
CF-PCR
Set of specific rules, requirements and guidelines for developing carbon footprint declarations for one or more product categories (ISO 14067).

3.2 Main methodological issues

In any life cycle study, be it full LCA or other, the main choices to be made by the practitioner are the following:

- System boundaries: which steps in the life cycle are included, cradle-to-grave, time coverage to smooth out variations and initial conditions, cradle-to-gate, own processes only?
- Emissions sources: for those steps, which emissions sources are included, combustion, soil carbon changes, refrigerant leaking, deforestation,..?
- Impact categories and indicators: which effects are calculated?
- Allocation:
  - Handling of co-products (multi-output processes).
  - Handling of wastes (multi-input processes).
  - Handling of recovery of materials or energy.
- Data representativeness and quality: can general values be used or are specific measurements necessary?
- Functional unit: the foot prints needs to be related to a unit, such as one ton of green coffee packaged for transport.

If all of those have been unequivocally pre-defined, one may talk of a clear ‘standard’ or PCR. Within any study, the standard always needs to be defined and applied to all systems part of it, to allow for fair comparison. When talking about product carbon footprinting, a standard PCR needs to be applied across studies, to allow for fair comparison between studies and easy interpretation of results in B2B communication. ISO 14067 quite explicitly links PCR to ‘declarations’ (see textbox above, ‘Carbon footprint product category rules’).

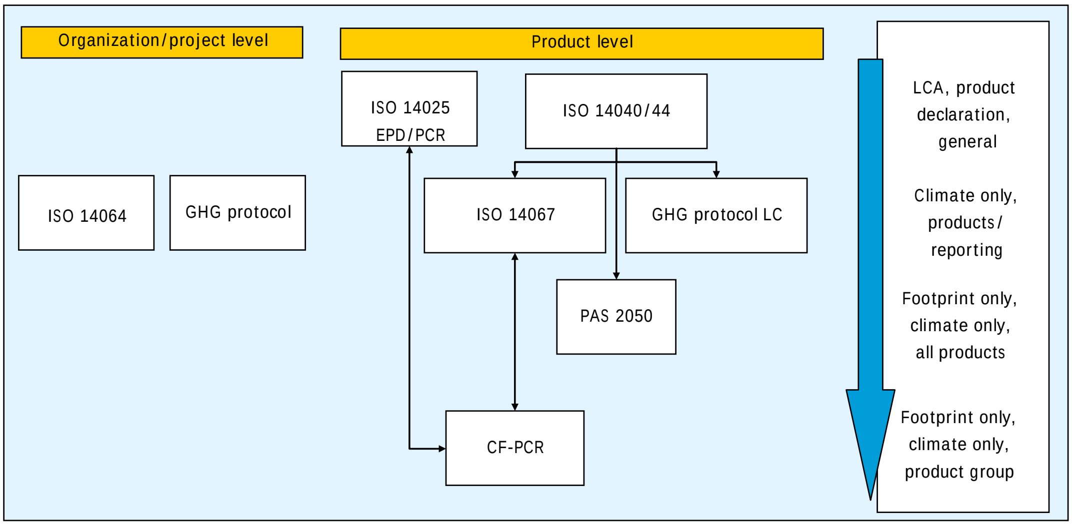
3.3 Relevant standards

Existing carbon footprinting standards are typically at a higher level than a PCR. They rather address all the criteria that a PCR should adhere to.
A number of standards are in existence or under development, that address the assessment of GHG emissions of products. In order of increasing specificity, those are:

- ISO 14040/44 standard for life cycle assessment in general.
- ISO 14067 and GHG protocol for product life cycles, standards for only greenhouse-gas emissions measured over the life cycle.
- PAS 2050, standard for greenhouse-gas emissions of products with a specific aim toward footprints, not management.

The current SAI initiatives is part of the ongoing effort to develop CF-PCR, with potential to address also project level emissions (see Section 1.4). This means that ISO 14064[9] and the GHG project protocol (2005) may also be relevant. They are not discussed separately, however.

Figure 10 Overview of relevant standards and terminology



Below, each of the product standards is briefly described. Only issues that are relevant for the SAI coffee carbon footprint initiative are described in order to keep the discussion concise.

3.3.1 ISO 14040/44

The set of ISO guidelines referred to as ISO 14040 covers life cycle assessment in general. They describe criteria that a study should meet, including transparent reporting. One of the central points is that methodological choices must be made in the context of the goal and scope that are defined at the start of a study. The guidelines do not prescribe what those choices are, however. The most explicit rule concerns the handling of co-products.

[9] ISO 14064-2:2006 specifies principles and requirements and provides guidance at the project level for quantification, monitoring and reporting of activities intended to cause greenhouse gas (GHG) emission reductions or removal enhancements. It includes requirements for planning a GHG project, identifying and selecting GHG sources, sinks and reservoirs relevant to the project and baseline scenario, monitoring, quantifying, documenting and reporting GHG project performance and managing data quality.

Although limiting the environmental categories to climate change only is probably not true to the 'spirit' of ISO 14040, against a defined goal of measuring a carbon footprint it is strictly speaking ISO conform.

Over all, these ISO guidelines are too generic to turn to for guidance in standardisation issues.

3.3.2 ISO 14067

The ISO 14067 standard for carbon footprint of products is in development stage. Anything discussed here may therefore be subject to change. The final standards are expected toward the end of 2011. There is a clear link to the ISO standard on environmental (product) declarations. The preliminary standard is essentially an adaptation of ISO 14040/44 to specific climate change issues. That means that issues relating to changes in soil organic matter, aboveground biomass, carbon storage in products and livestock emissions are addressed explicitly. The IPCC methodology is followed. Unintended emissions that are the consequence of changes in land use, caused by competition between commodities (*indirect* land use change) are not included.

There is no explicit choice with respect to attributional or consequential approach nor with respect to allocation.

Part 2 of this ISO standard deals with communication of the PCF. It draws heavily on ISO 14021/25 for self-declared environmental claims and environmental product declarations. In accordance with the latter, it defines special CF-PCR[10]: product category rules for carbon footprinting. Without the use of a CF-PCR, carbon footprints cannot be compared. Therefore, when a carbon footprint communication is intended for business to consumer, a CF-PCR has to be used. Any CF-PCR shall include, as a minimum, the following:

- Identification of intended audiences and their information needs.
- Instructions on the content and format(s) of the carbon footprint communication.
- Information on which stages are covered and which are not, if the communication is not based on a life cycle assessment (LCA) covering all life cycle stages.
- Product category definition and description (e.g. function, technical performance and use).
- Limitations of the CFP approach.
- Goal and scope definition for the LCA of the product, according to the ISO 14040 series, including:
  - Functional unit.
  - System boundary.
  - Description of data.
  - Criteria for the inclusion of inputs and outputs.
  - Data quality requirements including coverage, primary data content, precision, completeness.
  - Representativeness, consistency, reproducibility, sources, uncertainty, and units.
- Inventory analysis, including:
  - Data collection.
  - Calculation procedures. And
  - Allocation of flows and releases.

[10] This term was adopted from the ISO 14067 draft of March 9th, 2010. Recently, the use of the term PCR was dropped to avoid confusion with ISO 14025. The current term is Product Group Specifications. For the purpose of this report, the two terms are interchangeable.

– Impact category is climate change.
– Period of validity.

Additional requirements are defined when B2C communication is the aim.

Furthermore, ISO 14047 identifies the possible establishment of a **CFP programme**: a voluntary or mandatory international, national or sub-national system or scheme that registers, accounts or manages GHG emissions, removals, emission reductions or removal enhancements outside the organisation or greenhouse gas project. The **programme operator** is the body or bodies that conduct a CFP programme. A programme operator can be a company or a group of companies, industrial sector or trade association, public authorities or agencies, or an independent scientific body or other organisation.

3.3.3 GHG protocol WRI/WBCSD product life cycle

The GHG protocol (www.ghgprotocol.org) is road testing a standard for product life cycle assessment. The final version is expected toward the end of 2010. The standard is explicitly adopting an attributional approach:

"*Companies shall use an attributional approach to assign life cycle GHG emissions to an individual product system for the purpose of public reporting, unless existing sector-specific or program guidance stipulate the need to address indirect or consequential emissions sources. An attributional approach to GHG emissions accounting in products provides information about the GHG emitted directly by a product and its life cycle.*"

From the attributional approach, a direct conclusion is drawn that substitution ('indirect system expansion') as a means of dealing with co-products is not acceptable (see also textbox in Section 3.3.4, 'System expansion' on page 31). Only direct system expansion is allowed. As this leads to undesirable functional units (e.g. 'one kg of green coffee plus 2 litres of methane plus 100 grams of mushrooms'), the approach of system expansion does not have a place in product carbon footprinting (see also textbox 'System Expansion' on page 31).

Also in this protocol, PCR are identified as providing important guidance. It is even explicitly stated that if a PCR exists that prescribes a consequential approach then this should be followed.

Emissions due to land use and land use change (LULUC) are included.

GHG product protocol

GHG emissions due to land use and land use change include:

– CO_2 emissions and removals resulting from a carbon stock change.
– CO_2, NO_2 and CH_4 emissions resulting from the removal of biomass (logging, mowing, burning.
– Preparation of the soil (tilling, disking, subsoiling) and the application and impacts of inputs such as liming and fertiliser applications.
– CO_2, N_20 and CH_4 emissions and removals of CO_2 from managed land practices (managed soil emissions, rice cultivation, manure management, livestock rearing, peat extractions).

The emissions are only considered in a product level GHG inventory if the land use and/or land use change is directly attributable to the studied product; guidance is provided to help a company determine what impact are attributable.

The GHG protocol further states:
"*Processes that are not directly attributable to the function of a product include facility operations, corporate activities, and capital goods. These are referred to as background processes throughout this standard.*
- *Capital goods shall be included in the product system if deemed significant for the studied product or product sector.*
- *Facility operations and corporate activities should be included in the product system where relevant.*

The following emission sources should not be included in the quantification of emissions:
- *Emission credits due to the storage of carbon in a product.*
- *Biogenic carbon emissions due to the combustion of renewable bio-based materials.*
- *Purchased Offsets.*
- *Avoided emissions due to consequential modelling assumptions.*
- *Allocation of emissions due to recycling that cannot be justified or proved (i.e. assuming a product may be recycled when no recycling data exists)".*

3.3.4 PAS 2050

PAS 2050 is a very specific standard for product carbon footprinting. It does not have any international status, as it is developed by the British Standards Institution (BSI) and thus in a specifically British context. However, the PAS 2050 provides interesting leads for the choices to be made in a CF-PCR and currently is the only finalised standard internationally available. It is therefore included in this assessment.

Like the GHG protocol, adopts an attributional approach. Moreover, allocation issues are more specifically dealt with. PAS 2050 does allow substitution in cases where it can be demonstrated that a co-product displaces an 'average' existing alternative. In other cases economic allocation should be applied. In some well-defined cases, a cut-off to the life cycle is required.

Emissions associated with capital goods should be excluded. Operation of premises should be included. Emissions associated with direct land use change should be included, but emissions of land management (changes in soil carbon content) are excluded.

Offsetting may not be included in the footprint.

System expansion
System expansion is a way to deal with co-products in life cycle assessment. If two or more co-products arise from a life cycle, then it is not intrinsically clear which emissions arise due to which of those products. A solution for this ambiguity is to 'expand the system' and use a multi-functional unit. In coffee processing, this could be 'one kg of green coffee plus 2 litres of methane plus 100 grams of mushrooms'.

In practice, system expansion is often used in the form of substitution. This is also called 'indirect system expansion' (GHG protocol) or 'subtractive system expansion' (ILCD Handbook). In this approach, the foot prints of 100 grams of mushrooms (from average cultivation) and 2 litres of methane (from natural gas extraction) are subtracted from the expanded system. This is a way to keep the functional unit to 'one kg of green coffee'.

Substitution is in practice very often used to deal with end-of-life treatment options such as energy recovery (incineration) or recycling.

Different standards – and practitioners – take different points of view on these approaches, although most agree on the fact that direct system expansion has no role in attributional modelling. This is further discussed in Section 3.6.

3.3.5 Existing CF product category rules

The Carbon Trust, one of the institutions behind PAS 2050, is implementing this standard for a range of product groups, thus making specific choices for each of them. The exact content of those 'PCR' are not publically available.

An initiative similar to the current project was initiated by the International Dairy Federation in collaboration with the SAI working group on dairy. The draft CF-PCR was released in June 2010. Standards were laid down with respect to:

- The functional unit for raw milk production as well as final products.
- The way to deal with LULUC emissions:
  - Direct land use change included.
  - Soil organic matter (changes) excluded.
- The allocation to be used in the production of oil seed cakes (feed).
- The allocation to be used between milk and beef (cattle).
- The allocation to be used for co-products in dairy processing (cream, whey, etc.).
- System boundaries.
- Reporting of emissions, distinguishing between biogenic, fossil and land-use-change related.

This standard was drafted by a group of LCA experts both from within the dairy industry and from universities and consultancy, by means of iterative writing via e-mails and teleconferences. A wider group of stakeholders was consulted at irregular intervals.

Several PCR's are listed on the websites www.gednet.org and www.environdec.com, in the context of the Environmental product declaration (ISO 14025) and other initiatives. The status of these PCR is not always clear, however; e.g. there are PCR on dairy products that are not in line with the abovementioned IDF standard that has international industry support. This is exactly why Gednet is targeting international harmonisation of PCR, ultimately leading to one PCR for a product (group) used around the globe. The coffee PCR initiative could seek advise from e.g. the SAI dairy working group on how to proceed.

3.4 Other initiatives

3.4.1 SAN climate module

The Sustainable Agriculture Network has recently launched a climate module (draft). It lists adaptation and mitigation criteria and is a supplement to the already existing Sustainable Agriculture Standards (SAN 2010).

New criteria in the SAS targeting mitigation are:

- Decrease emissions of processing.
- Conduct a GHG emission inventory.
- Take steps to lower emissions and increase sequestration.

Soil and aboveground carbon stocks play an explicit role.

The SAN Climate Module strives for:

- Implementing programs and procedures for adaptation to and mitigation of climate change.
- Taking measures to diminish the main contributing sources of GHG emissions and monitoring changes.
- Analyzing and considering actions for addressing potential climate change risks and improving farm's resilience.
- Fostering regeneration of native vegetation on sites that are degraded or vulnerable to extreme weather events.
- Working with local institutions and associations to enhance the community's climate change adaptive capacity.
- Providing worker housing facilities that minimise and reduce GHG emissions, encouraging the use of renewable energy.
- Maintaining or increasing soil carbon stocks.
- Reducing the use of nitrogen fertilisers.
- Preferring wastewater treatment options that minimise methane emissions.
- Managing agricultural biomass residues to generate energy or by-products.

There are no absolute targets for reduction; the module focuses on monitoring and management. There is no guidance on quantification of emissions; the farm or group must e.g. develop their own method for monitoring carbon sequestration (soil, tree and crop biomass).

3.4.2 Global Agricultural Climate Assessment

The GACA initiative of the Sustainable Food Lab, Unilever and SAI platform aims at farmer empowerment with respect to mitigation and adaptation issues. Farming systems around the globe will be inventoried to yield data on local management options but also on global emissions and reduction potential in agriculture. The GACA thus has an explicitly quantitative goal.

To this end, strict definitions of goal and scope parameters are maintained. The approach gives interesting pointers for the SAI coffee PCR as system boundaries, allocation, etc., have also been defined with both farm management and product foot printing (e.g. PAS 2050) in mind.
Some examples:

- All LULUC emissions are included, but reported separately to allow for foot printing applications that exclude (some of) those sources.
- Organic residues that will be applied as fertilisers outside the system cross the system boundaries without any associated burden.
- Emissions of e.g. composting are allocated entirely to the system, to give incentive for current system to 'choose' optimal treatment method.

Standard emissions factors for typical composting are provided in the corresponding calculation tool called the Cool Farm Tool [11], to facilitate the farmer. This initiative may provide a good starting point for further development of a coffee PCR. Perennial crops are part of tool, but this is not very well developed yet.

3.4.3 COSA, 4C

The IISD performed an assessment of sustainability initiatives in the coffee sector in 2008 (IISD, 2008). A method for measuring the actual sustainability effects (economic, social, environmental) of certification schemes and other sustainability approaches was developed and applied.

[11] http://www.growingforthefuture.com/content/Cool+Farm+Tool.

Although energy management, carbon sequestration and pollution management (fertilisers and other) are some of the indicators, there is no translation to actual GHG emissions/uptake or climate impacts.

The Common Code for the Coffee Community (4C, www.4c-coffee association.org) project was conducted as a public-private partnership initiated by the German Federal Ministry for Economic Cooperation and Development (BMZ) and implemented by the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH and the German Coffee Association (DKV) in 2002. In 2004 SECO, the Swiss State Secretariat for Economic Affairs joined the BMZ as public partner in financing the project, while the European Coffee Federation replaced the DKV as the private partner. During the development process, more than 70 representatives from over 20 countries actively participated in the design of the concept, the majority of them coffee producers. Various international organisations have been involved in the development and implementation of 4C, such as the UN-affiliated International Coffee Organisation (ICO), the World Bank, the International Labour Organisation (ILO), plus several regional development banks.

The 4C code of conduct has several items that are related to carbon management on farm, but not explicitly target mitigation:
- Protection of biodiversity.
- Minimised use of pesticides.
- Soil conservation.
- Nutrient and organic matter management.
- Waste water management.
- Use of renewable energy.
- Saving energy.

Many other codes and certification schemes are targeting similar management parameters. They may become a good source of monitoring data, but do not directly provide leads for definition of CF-PCR.

4 Harmonisation

4.1 Introduction

In this Chapter, we summarise the findings of Chapter 3 and outline some of the steps that will need to be taken in the standardisation and harmonisation process.

4.2 Scope definition

4.2.1 Foot printing

With respect to scope issues for carbon footprinting, PAS 2050, ISO and GHG protocol largely agree. There are some deviations though, and the three standards leave different levels of freedom of choice. A PCR should make those choices to leave no or little freedom for the practitioner.

All allow for cradle-to-grave (full) or cradle-to-gate (partial) foot printing. The latter is only to be used in B2B communications. The functional unit depends on the type of product. While double functional units are acceptable in LCA (ISO 14040/44) and even preferred in some cases, for foot printing this is impractical (see also allocation).

Emissions sources to be included overlap, with the exception of changes in soil and dead organic matter. The latter is excluded in PAS 2050, but included in GHG protocol and ISO. Capital goods are excluded in PAS 2050, but included in GHG protocol (if relevant).

Offsetting is typically excluded, as the resulting emission reductions are not part of the direct life cycle of the product system.

In terms of approach, both PAS 2050 and the GHG protocol explicitly take the attributional approach. This means, in the words of the GHG protocol, that only processes in the actual supply chain are contributing toward the foot print and that the current, realistic emissions are counted.

Emission factors in all cases are to be the GWP100 as advised in the latest available IPCC assessment (currently 2007). Short-cycle carbon emissions are excluded from foot printing in most standards, except when the carbon is stored in a product for longer time periods. For food, this is typically not considered the case. An issue of debate is the emission for methane of biogenic origin, such as fermentation of organic residues. As this methane derives from carbon that was recently sequestered from the atmosphere in the form of (short-cycle) CO_2, a lower factor than for fossil methane is due. The difference between biogenic and fossil GWP100 should in all cases be 2.75. However, some experts prefer to use 25 and 22.25, respectively, 25 being the most recent IPCC GWP100 for methane; this is prescribed in PAS 2050. Others prefer 27.75 and 25, respectively, claiming that the IPCC factor does not include some of the indirect effects of methane. This is correct, but this indirect effect is certainly lower than 2.75 and uncertain. This issue needs to be specifically addressed in a CF-PCR.

4.2.2 Farm management

For farm management options, ISO 14064 and GHG project protocol may provide guidance. There is no reason to use different system boundaries in this context, possibly with the exception of offsetting. For farm management, measures such as installing on-farm wind mills that export energy, may be an option (although not likely in case of coffee plantations). In that case, the wind energy will very clearly be part of other product systems and -foot prints, but the generation of wind energy might be considered a farm management option albeit a 'peripheral' one.

In terms of emission sources, inclusion of soil and dead organic matter in the scope may be considered essential in the farm management context, whereas a CF-PCR may exclude these emissions sources (as does PAS 2050 and the IDF dairy standard). If a consequential approach is followed, issues such as indirect land use change might become relevant.

4.3 Allocation

4.3.1 Foot printing

Allocation is one of the major issues that should be addressed in a CF-PCR. In principle, all standards follow the same system of 'preferential' allocation, but there are subtle differences. The preferential order in dealing with co-products is:

- Subdivision of processes so that co-products are no longer co-products.
- System expansion to include co-products in the functional unit.
- Allocation based on physical (causal) relations.
- Allocation based on other factors, such as economic value, mass, etc.

The first step is in principle obvious; if you can subdivide processes so that allocation is no longer necessary this of course has preference. The second step is system expansion (see textbox 'System Expansion' on page 31).

ISO does not differentiate direct and indirect system expansion explicitly, which is to say that substitution is not mentioned in the ISO standards discussed. However, it is likely that the original intention of ISO 14040/44 was to interpret system expansion only in the direct sense. The GHG protocol (WRI and WBCSD, 2010) explicitly ranks substitution between physical allocation and allocation by economic value. In other words, while system expansion in the direct sense is still a way to avoid allocation, substitution is regarded here as a true allocation method.

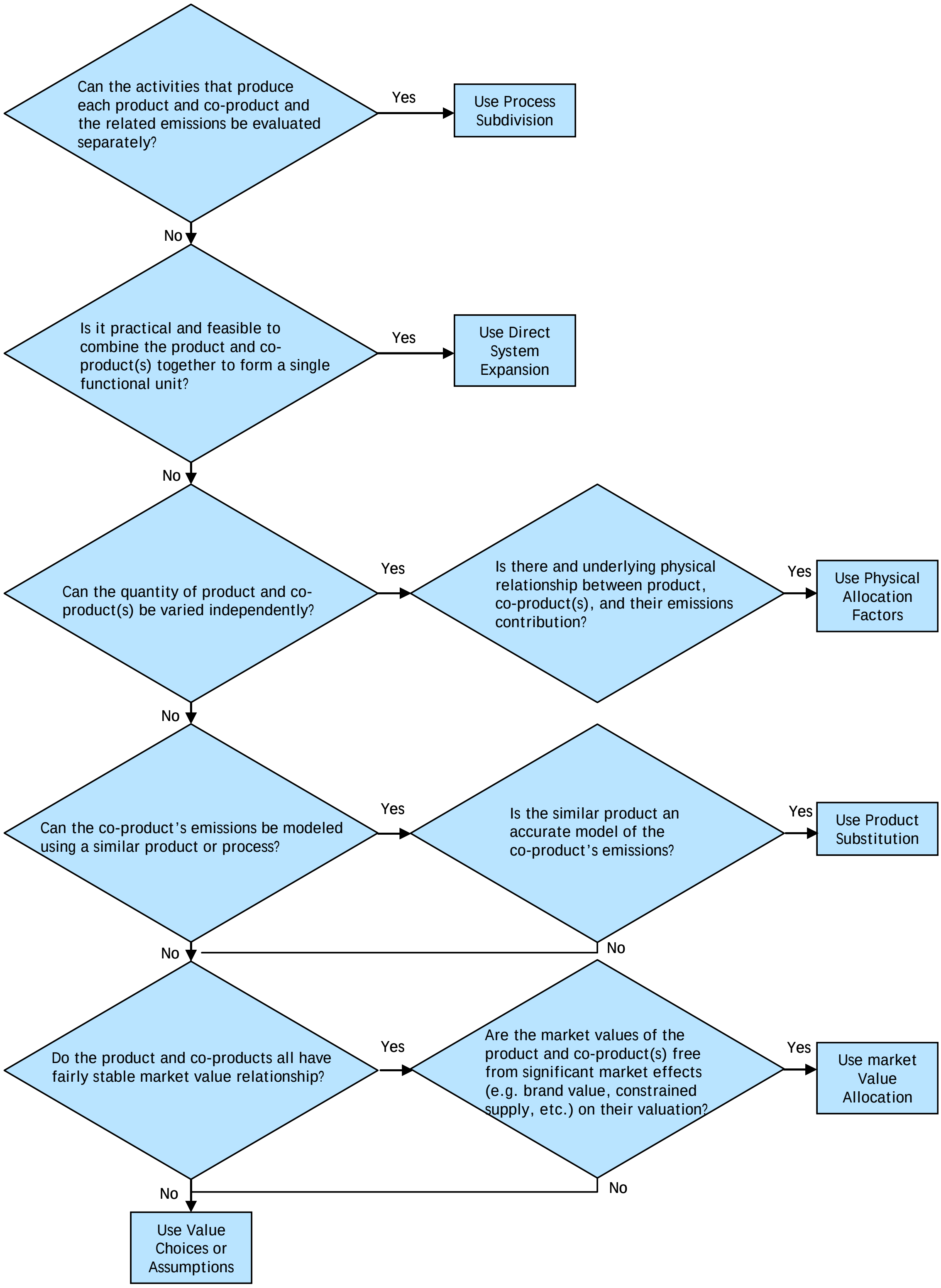
To what extent substitution has a place in the attributional approach is a matter of debate. In principal none of the standards, nor the ILCD Handbook, exclude it. However, substitution does lead to inclusion of (avoided) emissions from outside the direct supply chain and thus contradicts the definition as used in the GHG protocol (see Section 3.5.1). Also, a potential disadvantage of substitution is that in theory a net negative foot print could arise for the main product (see e.g. ILCD Handbook), although this is more likely in a consequential approach[12]. In any application of substitution in attributional approach, it should be beyond doubt that the co-products do replace *average* products (see example); this requirement is explicitly made in e.g. PAS 2050.

[12] As is the case in e.g. the Danish LCAFOOD database.

Example co-products
In dairy production, beef is a co-product, amongst others from dairy cows that are slaughtered after their productive years. This beef is considered to be of low quality and applied in mince and snacks. This means that we cannot apply substitution with beef from beef herds to do the allocation in this case.

Within the last step (allocation based on other factors), both PAS 2050 and GHG protocol have a preference for economic value as a basis for allocation. In fact, the allocation decision tree of the GHG protocol may provide good guidance in determining preferred allocation in a green coffee PCR (see Figure 11).

Figure 11 Allocation decision tree according to GHG protocol



Source: WRI and WBCSD, 2010.

4.3.2 Farm management

For farm management, all effects of a change, both direct and indirect should be taken into account. This may mean a consequential approach may be favoured but is not strictly necessary. A sectoral standard should in this case provide guidance on how to deal with co-products that are ultimately applied in external product systems, such as will be the case for residues of the coffee processing. In the GACA methodology (see Section 3.4.2) a choice was made for 'system cut off' for the useful application of organic residues, rather than full system expansion or substitution. In that case a co-product leaves the 'system' without any associated burdens. The definition of the system boundary can then be defined in such a way as to designate the sphere of influence of the farmer, e.g. including off-farm composting processes but not further transport and application of the compost itself.

4.3.3 Shading and polyculture

An allocation issue quite specific for coffee as a perennial crop is the variety of farm systems with regard to the use of shade trees and to polyculture. If soil carbon and aboveground biomass stocks are included in the scope (system boundary/emissions sources), the allocation to green coffee is complex. The aboveground biomass stocks in trees can in fact be directly traced to co-products (wood from shade trees, fruits from other trees, …) and thus strictly speaking it would be preferred to do this, thus avoided allocation. The differences between shade/unshaded and mono/polyculture would then be reflected in the green coffee carbon footprint primarily via soil carbon stock changes and yield. The soil carbon stock changes could be allocated by area occupied, but this would require establishing the 'area' occupied by each individual tree. Allocation by economic value is probably the most viable option.

4.4 Data quality

In all standards, data quality, with a view of being representative of the product system, plays a major role. In practice, this brings about very complicated data collection issues and these rules are probably most frequently compromised in practical foot printing.

Time variability in agriculture leads to large interannual variations in actual emissions. In theory, long-term averages would have to be used that can be shown to represent the 'true' average (e.g. PAS 2050). This complicates data collection, however, especially in the case of farm management measures. On the other hand, to establish the real effects of mitigation efforts, long term monitoring may well be the only option. After all, it is quite possible that the results in the first year(s) after implementation are show now improvement or even deterioration due to e.g. unfavourable weather patterns.

Also, the sampling of farms is an issue. In order to establish the carbon emissions associated with green coffee from a certain farming system (cooperation, region), it has to be shown that the sample of farms that were included in the emission inventory gives a representative average for the whole system. In practice, inter-farm variability may also be large, leading to a need for large samples.

If dealing with the carbon footprint of green coffee from one particular farm, the demands on data could require very high level of specificity. Local soil type, climatic conditions, environment, etc., would all play a role in actual emissions. Typically, foot print standards do not require such detailed data but opt for IPCC calculation standards.

An issue specific for coffee cultivation is the fact that for a productive life time of some 20 years, an start up period of two to five years is needed before the bushes are producing at near full capacity. Thus, an 'allocation' over time is necessary. Emissions occurring in those first years, including the nursery stage (see Section 2.2) need to be distributed over the 20 years of harvested crop. By considering only the emissions in the year of production, this would be overlooked.

4.5 Data gaps

Data that would be missing in order to properly implement a foot printing standard obviously depends partly on the PCR definition. Here we address the main likely points.

It is useful to distinguish foreground and background data. Foreground data concern actual processes on the estate and at processing such as described in Chapter 2. Background data are e.g. the GHG emissions associated with electricity use. For e.g. pulping, one would just measure the amount of electricity in kWh per ton of green coffee (foreground data). The amount of kg CO_2 equivalent per kWh is background data and typically taken from standard databases.

4.5.1 Missing foreground data

Actual annual data for longer time series to provide real averages are missing. Many of the sustainability and certification schemes did not collect quantitative data initially but are starting to that from now on (e.g. Utz).

Emissions associated with land use change (deforestation) are very rough assessments with worst-case scenario if specifics are unknown. True LUC emissions in a specific case require intricate data on local conditions. The same is true for land management, but IPCC standards are well accepted.

Good knowledge of N content of processing residues if applied as organic fertiliser is required.

Emissions associated with residue and waste water treatment are hard to quantify. Database of standard emissions for common treatment methods could be part of PCR (thus essentially turning these emissions into background data). Unit need to be more specific than just litre of waste water and kg of residue, and include actual organic load.

4.5.2 Missing background data

Electricity mixes may not be known with standard emissions factors for many of the countries concerned in coffee production. This may be developed relatively easily by LCA practitioners based on energy information for those countries.

4.6 Main challenges in CF-PCR development

Taking the list of requirement of PCR from the ISO 14067 draft standard as a starting point, we identify the following issues as the main challenges:

- Criteria for the inclusion of inputs and outputs: especially the choice on including or excluding soil and aboveground carbon changes.
- Data quality requirements including coverage, primary data content, precision, completeness: a good balance between representative data and practicable data collection has to be found. This may be the biggest challenge, as was also stated in the consultation round.
- Calculation procedures: define a level of differentiation of farming systems that is both fair and accurate enough and define appropriate emission factors.
- Allocation of flows and releases: define allocations and cut offs (system boundary) that are in line with both PCF and farm management requirements. This applies especially to organic materials going off-farm for further useful application or acquiring organic residues from other farms for on-farm application.

A good farm-system based set of emissions factors specifically for coffee cultivation would make assessments both considerably easier and more accurate. Currently, IPCC methodology is used in footprinting. This is quite time consuming and typically not very accurate. As yet, such a system or set does not exist as a well established model. Development can be based on existing information, however, and Rainforest Alliance is applying farm categories in pilot projects (private communication Rainforest Alliance).

An option for implementing this could also be to define key parameters for operational modules that make up a farming system. For each module such as land preparation (mechanised, manual labor, combined or not with burning), fertilisation (high, medium, low, no chemical fertiliser input yes/not in combination with high, medium, low, no input of organic matter) and so on, standard GHG emissions could be formulated, for a range of external factors (e.g. climate, altitude, slope, soil type, etc.).

5 Work in progress

5.1 Conclusions

All PCF standards discussed in Chapter 3 assign a prominent role to the development and use of Product Category Rules (PCR). The ISO 14067 may be used as the primary guide on the content of a PCR, but as this standard is still expected to undergo significant changes this is an uncertain basis at the moment. Nevertheless, the current draft standard does provide a very good minimum number of issues as listed in Section 3.3.2, that a CF-PCR should address. For the case of green coffee, in addition to the demand for identifying 'criteria for the inclusion of inputs and outputs', it is recommended that inputs and outputs to be included are actually partly explicitly defined, especially when concerning soil carbon and aboveground biomass stock changes. This may e.g. be in the form of standard emission factors for a range of uncertain emission sources (see Chapter 2).

Emission sources related to soil processes, aboveground biomass and waste water and processing residues are the main aspects of the green coffee life cycle for which exact quantification is complex or even impossible. These constitute the main science gaps. The scientific community is working on filling these gaps, as they are common for many product life cycles. Land use change, both direct and indirect, are topics of ongoing scientific discussion.

Data gaps necessarily exist for the same issues (foreground). In addition, some relatively easily filled (background) data gaps exist such as country electricity mixes for some (many) coffee producing countries. In practice, whether data gaps need to be solved will partly depend on the actual definition of the CF-PCR. If e.g. soil carbon is excluded from the scope, then the data gap for this topic is not important in an immediate sense. In the consultation round, a general preference was expressed to include issues using standard emission factors rather than leaving them out for lack of precise emission factors. The establishment of 'key parameters' and emission factors per farm system type could provide a good balanced approach. All footprinting standards take the better safe than sorry approach on land use change, stating that it is better to include it in rough approximation or worst case scenario than to leave it out.

The differences in perspective between product carbon footprinting for 'declaration' purposes and assessment of farm management options have been discussed elaborately. It may well be possible to design a CF-PCR that integrates both, by e.g. defining adequate cut-off criteria. Preferably, improvements in the farming system should be reflected in a lower foot print of green coffee, but this may not be possible in all cases.

Main points of disagreement between standards are soil carbon, capital goods and preferential order for allocation. Argument in favour of including capital goods, which typically do not contribute significantly to the overall footpring, would that it distinguishes between mechanised and less mechanised systems. Consideration of the trade off between data requirement and added information should be made when drafting a PCR.

One should realise that a (CF-)PCR is never a finished document, however. There will always be the need for updates when existing scientific or methodological issues are solved. An example of this is indirect land use change, that is mentioned in all standards as a potentially important issue but excluded until further notice due to lack of scientific agreement. Such an approach is also advised for a coffee foot printing standard. Pragmatic choices should be made and revised regularly to keep up to date with scientific progress.

5.2 Activities in Phase 2

The activities in Phase 2 are in principle aiming at developing and testing a PCR for carbon footprinting of green coffee. The most important function of a PCR is to provide unambiguous choices for all issues concerning goal and scope definition (see e.g. Section 3.3.2). Which choices are actually made is less important to some extent. For the SAI coffee initiative, crucial considerations are expected to come from the fact that farm management (changes) need to be combined with product foot printing (status quo). The GACA initiative (known by most through the Cool Farm Tool, see Section 3.4.2) could provide good leads for this. The approach taken there is to combine foot printing (which requires common approach and well defined system boundaries to allow for comparison) with farm management relevance: definition of the system boundary in such a way as to designate the sphere of influence of the farmer, which may involve some off-farm processes (e.g. residue treatment).

In parallel and in support of the PCR, it would be very relevant to create an overview of global coffee production systems, based on a farming systems approach. Establishing key parameters influencing the carbon balance, one could then develop management and farming system-specific emission factors in the various biophysical contexts reflecting the global diversity of coffee production. A first 'order of magnitude' screening would aid in establishing the main (large) contributors and deciding which are the variables that matter.

Note that such as system is not essential for a PCR, as IPCC emission factors could be defined as the standard. These are less accurate and time consuming in practice, however.

5.3 Recommendations

Participants in the process

In the drafting of the PCR, experts on both GHG emissions of coffee cultivation and processing and life cycle methodology should be involved. In addition, to ensure that the developed PCR is supported by – in the ideal case – the entire sector, a good representation of all stages in the life cycle is necessary. As the coffee life cycle is fairly fragmented, with respect to sectors like e.g. dairy that preceded in establishing a PCR, in terms of vertical organisation and thus in terms of geographic location of e.g. primary producers and roasters, this is a somewhat daunting task.

In principle, it would be preferred to involve representatives of international sector organisations at the highest level of aggregation. This ensures maximum supporting membership per person involved the PCR programme group and involvement of a wide range of stakeholders. However, if those organisations do not carry enough weight with all members or cover only a small fraction of their sector this may be counter productive. In the consultation round, there was a clear preference for broad stakeholder involvement.

Another route would be to start the PCR without explicit support and consultation of the entire community. This is not a necessary requirement from the point of view of e.g. ISO standards. If there is critical mass behind it, the standard will inevitably spread further. A good balance between critical mass and a 'lean and efficient' approach needs to be found.

An approach to follow would be the ISEAL Standard Setting Code, which includes stakeholder mapping. This ensures high quality of the process and involvement of relevant parties.

SAI could take the lead in the process and also assume 'ownership' in terms of responsibility for updates. Typically, minor updates may be done every two years or so, at the same time assessing whether there is need for a major update. The standard should be publicly available in order to be successful however.

Legal aspects

As carbon footprinting is a voluntary instrument, legal aspects are limited. Frequent updating and adherence to ISO and other standards will help in maintaining the credibility and therefore the applicability of the PCR. It also provides a background for reviewing and/or certification.

Funding

Generally, carbon footprinting and associated PCR development is considered an issue for private partners as long as foot printing is voluntary self-regulation. In other sectors, the development of PCR is typically taken on by industry itself.

However, because coffee is also grown by a large number of small holders, the crop is important for local and regional economies. The synergy of climate mitigation and adaptation means that foot printing in this sector is relevant from a development perspective. Linking to development money (direct investments and development aid) or to the climate mitigation and adaptation funds are options worth exploring. Synergies with on going initiatives such as executed by GTZ; international collaboration funds from the Netherlands with partner countries such as Guatemala, Vietnam can be sought. When linking to adaptation, also rural development funds in producing countries might be available.

Another player in the field of public-private partnerships is the Dutch 'Sustainable Trade Initiative'. This multi-stakeholder platform[13] targets several agricultural sectors, amongst which cocoa and tea. Coffee could well be added to the list if there is interest from industry in doing so.

It is interesting to investigate the possibilities of the GACA initiative of Sustainable Food Lab (Section 3.4.2). Participant from the coffee sector in the GACA is currently Starbucks; farming systems in Kenya are part of the data collection exercise[14]. This can be extended. An effort to collect data to establish key parameters for farm emission factors might be aligned with GACA although it is possible that more detail is needed than Cool Farm Tool

[13] www.duurzamehandel.com.

[14] www.sustainablefoodlab.org/farmsystems.

provides. Funding is however provided almost entirely by 'downstream' food industry, i.e. roasters, and the project would be much larger than PCR development.

PCR development alone will probably generally be viewed as industry business. In that case, the most likely funding structure would be contribution by roasters directly. Other stakeholders would participate in the consultation and iteration process, contributing only their own time in return for being able to influence the final standard. It should be noted that such as process will be time consuming, but is not necessarily very costly. More research budget would be needed for development of farming system key parameters and emission factors, but in that case more funding sources are probably available.

Literature

BSI, 2008
PAS 2050 Specification for the assessment of the life cycle greenhouse gas emissions of goods and services.
London : British Standards Institution (BSI), 2008

IISD, 2008
Daniele Giovannucci and Jason Potts with B. Killian, C.Wunderlich, G. Soto, S. Schuller, F. Pinard, K. Schroeder, I. Vagneron.
Seeking Sustainability : COSA Preliminary Analysis of Sustainability Initiatives in the Coffee Sector.
Winnipeg (CA) : International Institute for Sustainable Development (IISD), Committee on Sustainability Assessment, 2008

ITC, 2010
Climate change and the coffee industry
Geneva : International Trade Centre (ITC), 2010

ISO 14067, 2010 (DRAFT)
Carbon footprint of products, part 1 and 2, draft version, March 9, 2010
S.l. : S.n., 2010

JRC, 2010
International Reference Life Cycle Data System (ILCD) Handbook
Ispra : European Platform on Life Cycle Assessment European Commission, Joint Research Centre (JRC),Institute for Environment and Sustainability (IES), 2010

SAN, 2010 (DRAFT)
SAN Climate module : Criteria for Climate Change Adaptation and Mitigation
Washington DC : Sustainable Agricultural Network (SAN), Rainforest alliance, 2010

WRI and WBCSD, 2005
The GHG Protocol for Project Accounting
S.l. : World Resources Institute (WRI) ; World Business Council for Sustainable Development (WBCSD), 2005

WRI and WBCSD, 2010
Product Life Cycle Accounting and Reporting Standard, Draft for Road Testing January 2010.
S.l. : World Resources Institute (WRI) ; World Business Council for Sustainable Development WBCSD), 2010